Report to Council

District of Lake Country

To:	Mayor and Council	**Meeting Date**:	March 17, 2026
From:	Paul Gipps, CAO	**Meeting Type**:	**Regular Council Meeting**

Prepared by: **Matthew Salmon, Infrastructure & Development Engineering Director**
Department: **Infrastructure & Development Engineering**

Title: Phased Development Agreement | ASP00005 | Lakestone
Description: Phased Development Agreement (Lakestone) Bylaw 1318, 2026

RECOMMENDATION

THAT Phased Development Agreement (Lakestone) Bylaw 1318, 2026 be read a first and second time;
AND THAT Phased Development Agreement (Lakestone) Bylaw 1318, 2026 be forwarded to a public hearing.

EXECUTIVE SUMMARY

The Phased Development Agreement (PDA) for the Lakestone area establishes a clear, comprehensive framework to guide long‑term development while ensuring alignment with District objectives for infrastructure, environmental protection, housing diversity, and public safety.

Staff are recommending Council consider replacing the 2012 Lakestone Master Plan with a new Phased Development Agreement (PDA). The 2012 Master Plan is outdated and does not provide sufficient detail to support current and future development decisions. The 2012 Lakestone Master Plan can be accessed through the District's website via this path: Home > Government > Document Library > LakeStone Master Plan or via this link: 2012 Lakestone Master Plan

By adopting the PDA, the District gains stronger regulatory tools, improved clarity, and enhanced certainty for both the community and the developer.

The PDA is structured around a front‑end agreement supported by eleven technical schedules that govern critical aspects such as zoning, environmental policies, phasing, infrastructure requirements, servicing standards, amenities, and parks. This structure provides a modernized, enforceable approach to managing growth over the life of the Lakestone development.

The PDA's provisions and standards were created in consultation with all pertinent District departments and have received approval from the responsible department heads. In addition to the PDA framework, all subsequent development phases will continue to require the necessary regulatory approvals: the District's Approving Officer must authorize all subdivisions, Building Permits are required for all buildings, and the District Engineer must approve all public infrastructure prior to construction activities.

Development to date—including Waterside, Benchlands, and ongoing work in Highlands North and the Summit Phase—has advanced with new reservoir capacity, emergency access improvements, and ongoing wildfire mitigation.

To provide time to complete the remaining phases as contemplated in the PDA, the suggested term of the PDA is **20 years.** The PDA outlines the next phases of build‑out: Highlands East, Central, West, South, and the Glenmore Residential area. These future phases will introduce a mix of single‑family homes, town homes, and low‑rise

multifamily housing, increasing housing diversity and affordability while integrating parks, trails, and strong environmental stewardship.

Key land use changes within the CD3 zone include removal of outdated industrial designations, addition of the 9850 Chase Road parcel, and new allowances for home-based businesses. All CD3 zone entitlements will be locked in for the duration of the PDA, providing stability and predictability. The District's Zoning Bylaw can be accessed through the District's website via this path: Home > Government > Bylaws or via this link: Zoning Bylaw

The plan incorporates a coherent servicing and mobility strategy, including permanent and emergency access points, upgrades to water, sewer, and stormwater systems, and road and pathway standards consistent with District policy. The Districts Subdivision and Development Servicing (SDDS) Bylaw can be accessed through the District's website via this path: Home > Government > Bylaws or via this link: SDDS Bylaw

More than half of the land base—51%—will remain dedicated to open space, trails, and parks. Comprehensive environmental monitoring, wildfire mitigation, and FireSmart design principles ensure public safety is prioritized throughout development.

Retaining wall requirements reflect the steep terrain and are governed by clear design parameters, supporting consistency and reducing staff workload for routine approvals.

Overall, the PDA reinforces the District's commitment to responsible, safe, environmentally conscious development. It ensures that future growth aligns with infrastructure capacity, community expectations, and long‑term resiliency while providing clarity and certainty for both the District and development partners.



Figure 1. Timeline of the 2012 Lakestone Master Plan and the 2026 PDA

DISCUSSION/ANALYSIS

1. **Purpose of the PDA.** A Phased Development Agreement (PDA) is a regulatory tool that provides long-term development certainty for both the municipality and the developer. It outlines the development framework, infrastructure expectations, environmental requirements, and zoning provisions that will apply for the duration of the agreement.

2. **Why a PDA?** PDAs (authorized under B.C. Reg. 190/2007 and Local Government Act, ss. 515–522) provide regulatory certainty for complex, long-term developments. A PDA is being introduced to replace the 2012 Master Plan due to several issues:
    - The 2012 plan lacked clarity in multiple key areas.
    - The term "Master Plan" is not recognized in the Local Government Act.
    - The document is outdated and no longer reflects current policies, servicing needs, or environmental requirements.
    - The PDA includes a road reservation agreement registered on title to secure land for future roads. The draft PDA document clearly defines the intended outcomes and the strategic approach for development.
3. **Difference Between the Master Plan and the PDA.** The PDA replaces the former Lakestone Master Plan and introduces clearer, enforceable expectations supported by structured technical schedules (Figure 2 & Table 1).

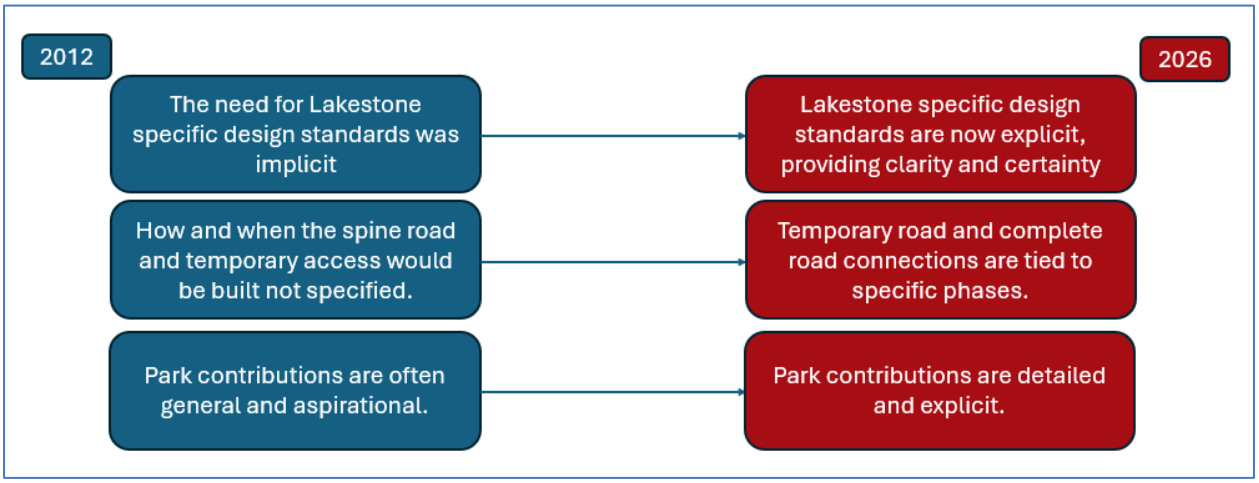


Figure 2. The key differences between the 2012 Lakestone Master Plan and the 2026 PDA

Item	2012	2026
Total units	1365	1380
Length of trails	24 km	29 km (13.5km remaining)
Industrial land	Attached to Glenmore residential phase	Removed from PDA
Total park dedication	51% of total area	51% of total area
Improved parks	Three	Four
Variances	Implicit	Explicit and specifically detailed
Home-based business (in zoning)	Not allowed	Allowed
Offsites and spine road connection	Listed but timing not prescribed	Obligations detailed and tied to specific phases

Table 1 . Comparison of the 2012 Lakestone Master Plan and the 2026 PDA

4. **Summary of Completed Masterplan Phases.** The Master Plan included a number of phases (Figure 3). A summary of all units provided is shown in Table 2. The following phases have been completed or are proceeding under the original Master Plan:
    - Phases 1–2: Waterside
    - Phase 3: Benchlands
    - Phase 4: Highlands North & Phase 5: Summit Phase (construction began in August 2024 with completion expected by the end of 2026)

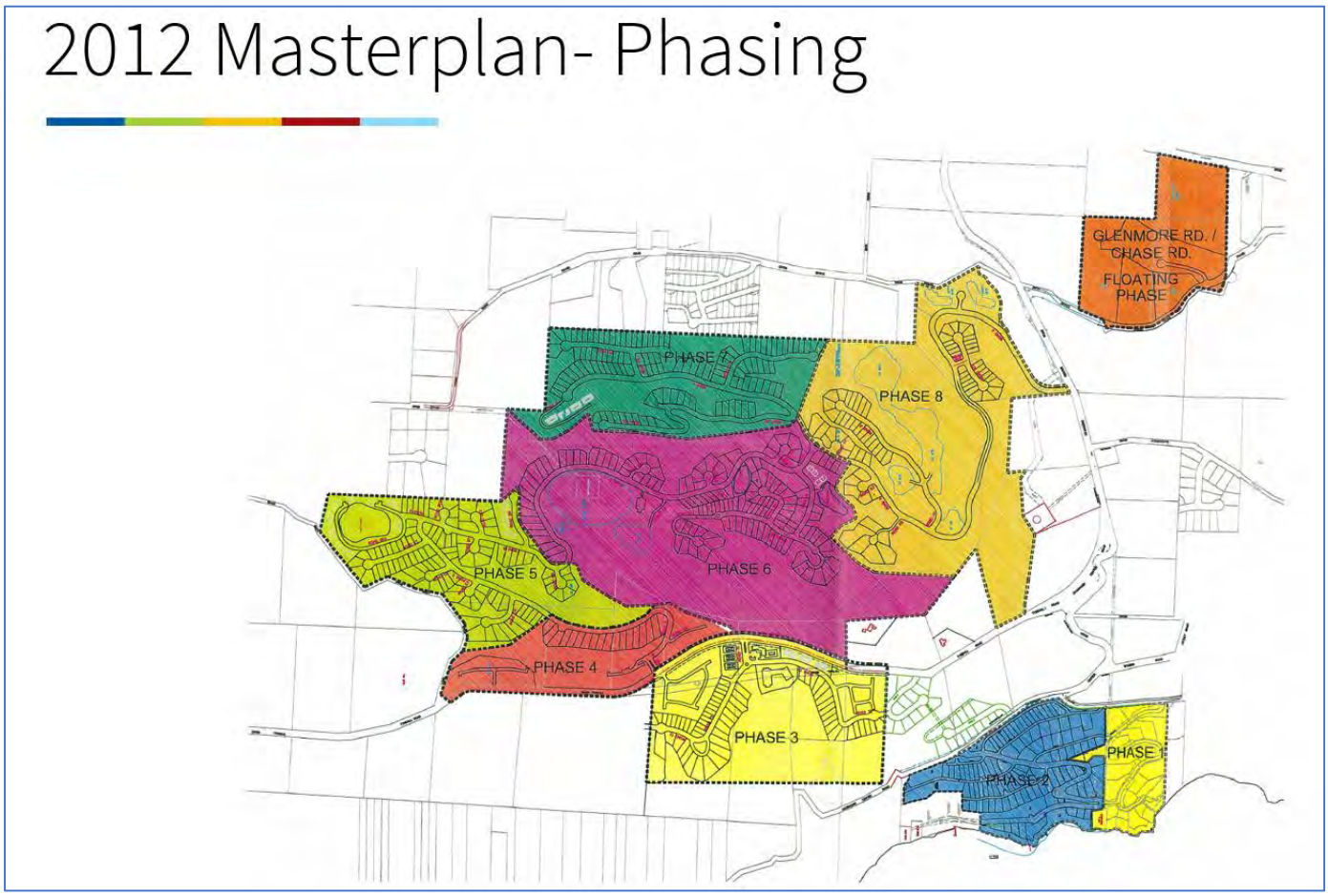


Figure 3. The 2012 Lakestone Master Plan Phases

DENSITY ALLOCATION

Phase (PDA)	**Density**	**Notes**
Highlands East Highlands Central Highlands South Highlands West	Single family: 229 Multi family: 329 Total: 558	
Glenmore Residential	Single family: 59 Multifamily: 265 Total: 324	Previously referred to as the "floating phase"
Sub-Total	**Single family: 288** **Multi family: 594** **882**	

Phase (Master Plan)	**Density**	**Notes**
Developed to date	Single family: 319 Multi family: 114 Total: 433	Waterside, Benchlands and Highlands North
Pending Development: Summit subdivision Lot 80 EPP86639	Single family: 57 Multi family: 8 Total: 65	Currently approved for construction
Sub-Total	**Single family: 376** **Multi family: 122** **Total: 498**	

Lakestone (complete area)	**Density**	**Notes**
Residential Units: Master Plan Sub-Total PDA Sub-Total **Total**	 498 882 1380	
Commercial Floor Area: Master Plan Sub-Total Remaining **Total**	 641.8m^2 7,310.7m^2 7,952.5m^2	6 CRU at The Zara

Table 2 . Summary table of housing units and types in the 2012 Lakestone Master Plan and the 2026 PDA

5. **PDA Structure.** The PDA includes multiple technical schedules summarizing zoning, infrastructure, environmental requirements, and long‑term servicing expectations. The PDA includes the following technical schedules:
    - Lakestone Phased Development Agreement – 20 Year term
    - How to Use this PDA
    - Phasing Plan
    - Zoning Bylaw Provisions CD3 as of 03-03-2026
    - Environmental, Wildfire, Geotechnical, and Safety Policy
    - Interim Access and Egress Conditions
    - Subdivision and Development Servicing Bylaw
    - Civil Infrastructure Standards
    - Lakestone-Specific Standards
    - Amenities and Parks Requirements
    - Servicing Capacity Ownership

6. **Future Development Phases Under the PDA.** Each area has unique housing forms, infrastructure sequencing, and access requirements**.** A summary of all units to be provided is shown in Table 2. Future phases (Figure 4) include:
    - Highlands East
    - Highlands Central
    - Highlands South
    - Highlands West
    - Glenmore Residential

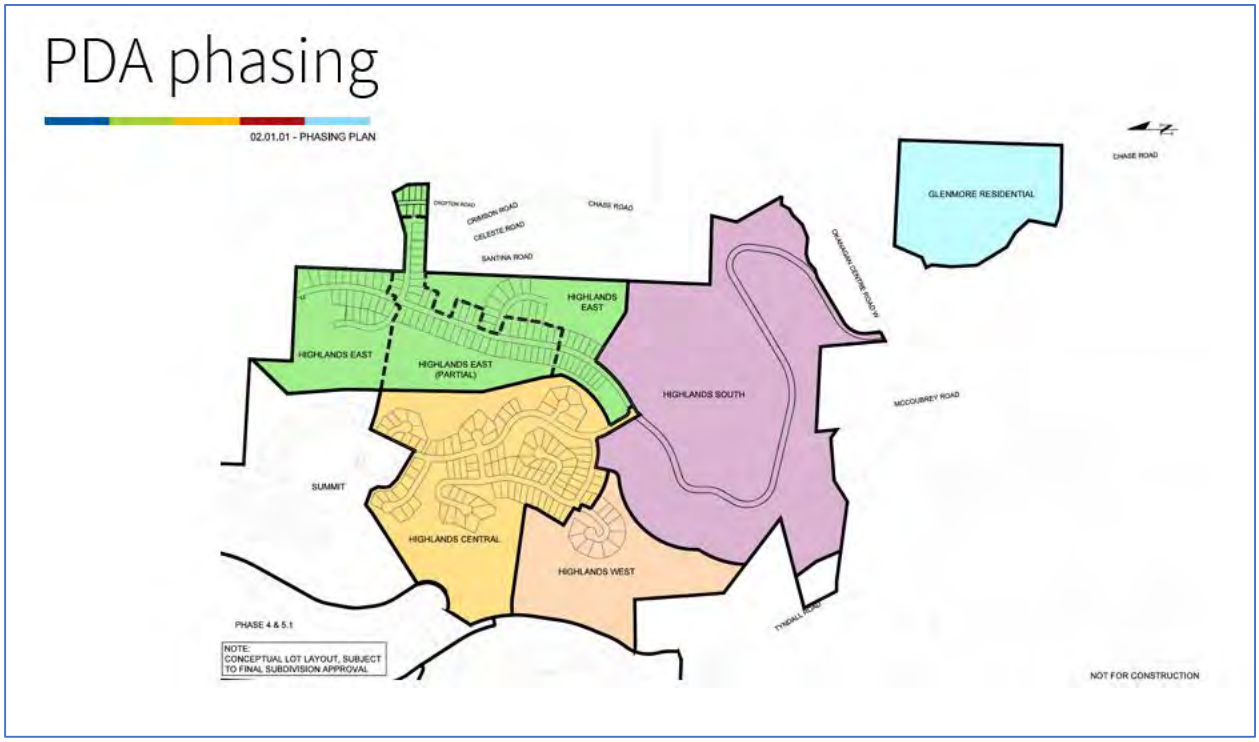


Figure 4. The 2026 PDA Phases

a. Highlands East (Partial) (Figure 5)

- Designed for mid-level housing with lower-priced lots.
- Limited to 50 dwellings due to traffic constraints.
- Developer must install and maintain a controlled-access gate for residents.
- Construction traffic will use a private haul road connected directly to Chase Road.
- An emergency access route will be equipped with locked bollards.
- The remaining sections of Highlands East would be contingent on the completion of the Spine Road connection to Okanagan Centre Road West.

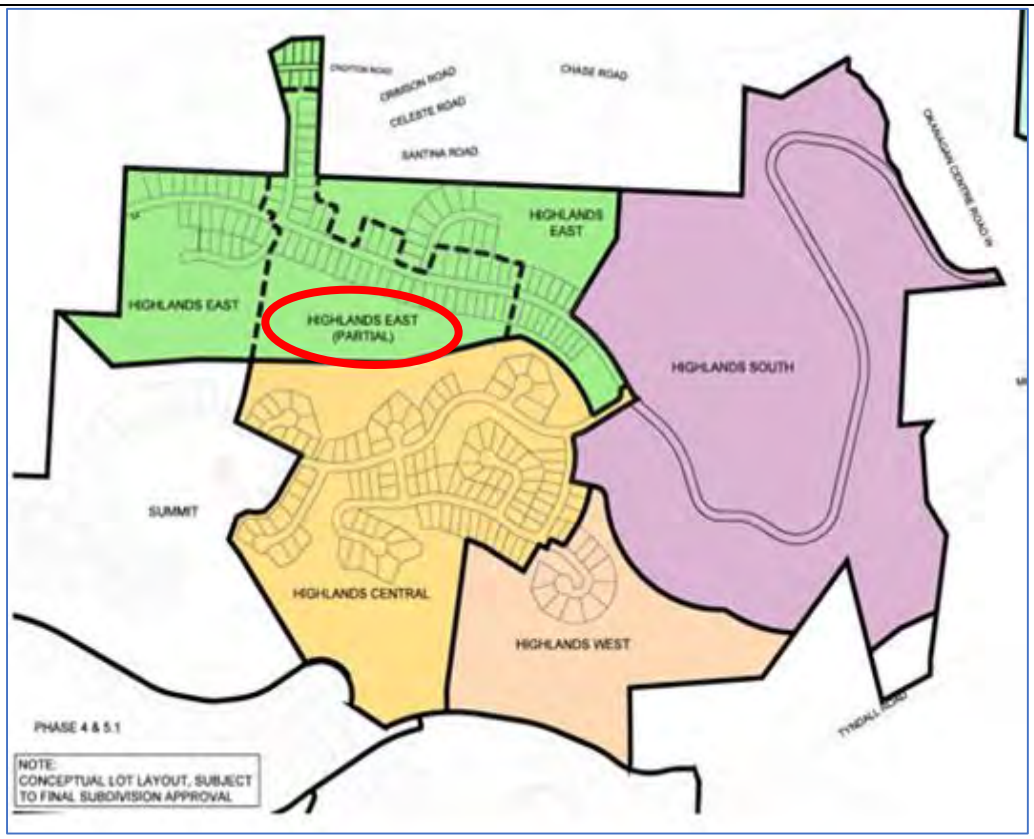


Figure 5. The 2026 PDA - Highlands East (Partial) Phase

b. Highlands Central (Figure 6)

- Predominantly single-family homes.
- Accessed via Beacon Hill Drive.
- Egress available via Beacon Hill Drive or a temporary emergency access road.
- Includes community parks, wetland areas, and new trail connections.

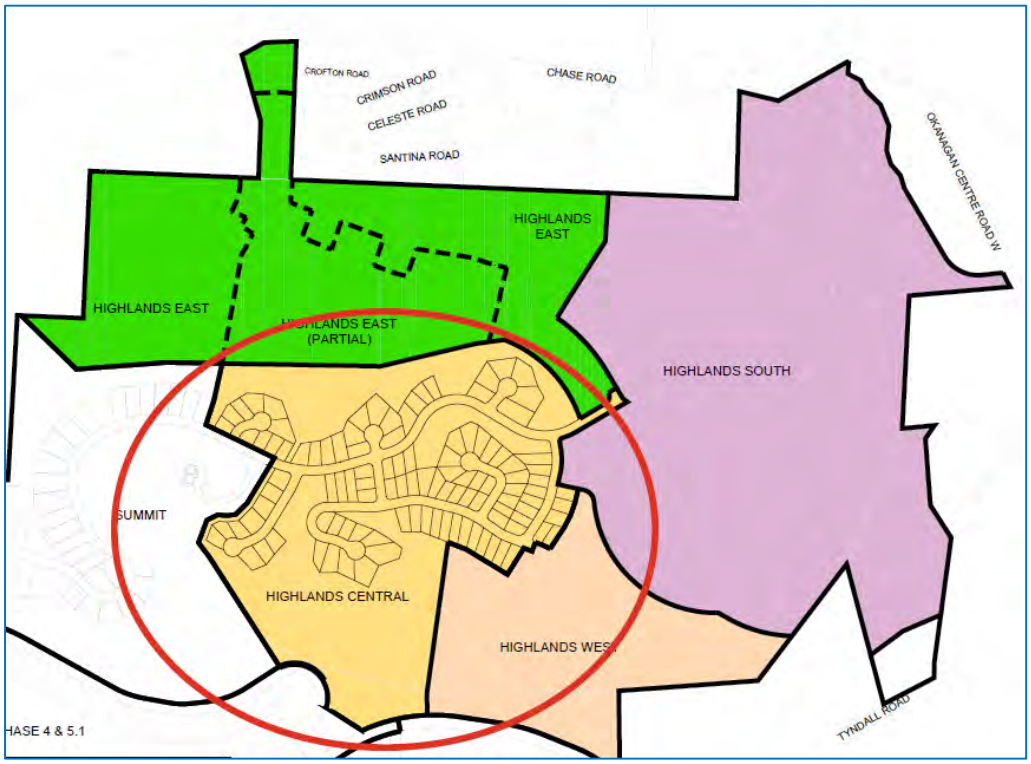


Figure 6. The 2026 PDA - Highlands Central Phase

c. Highlands West (Figure 7)

- The smallest of the phases (reduced to meet cul-de-sac length limits).
- Development is contingent on the completion of the Spine Road connection to Okanagan Centre Road West.

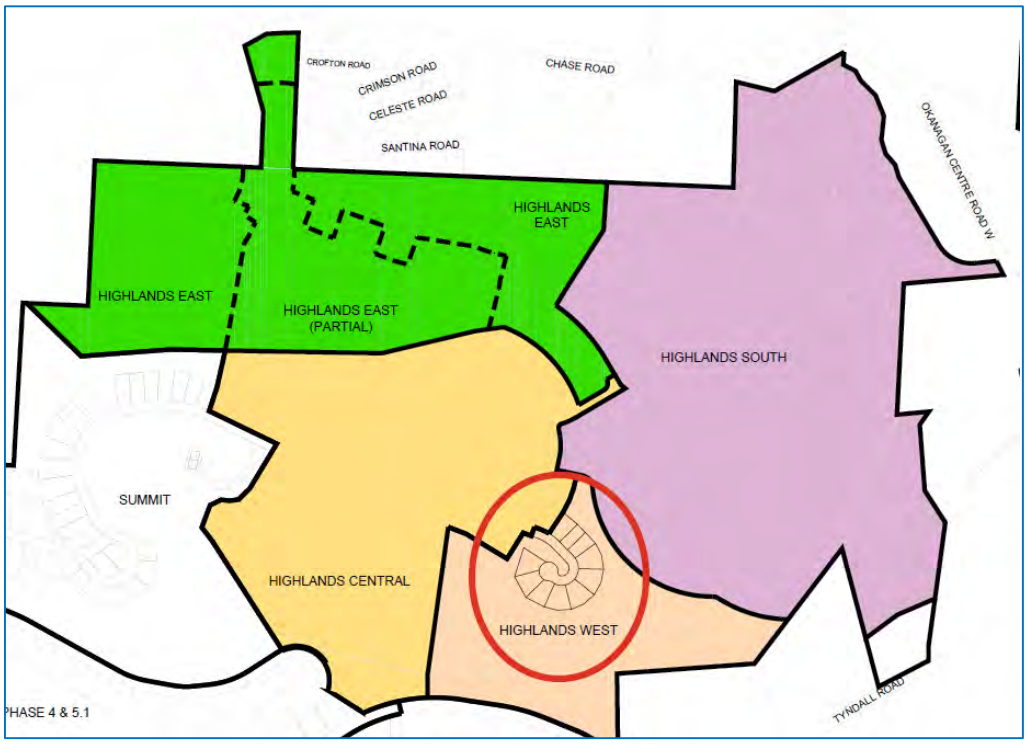


Figure 7. The 2026 PDA - Highlands West Phase

d. Highlands South (Figure 8)

- Access provided by the new Spine Road.
- Multiple nodes of town home and low-rise multifamily housing.
- Each node will require a Development Permit.

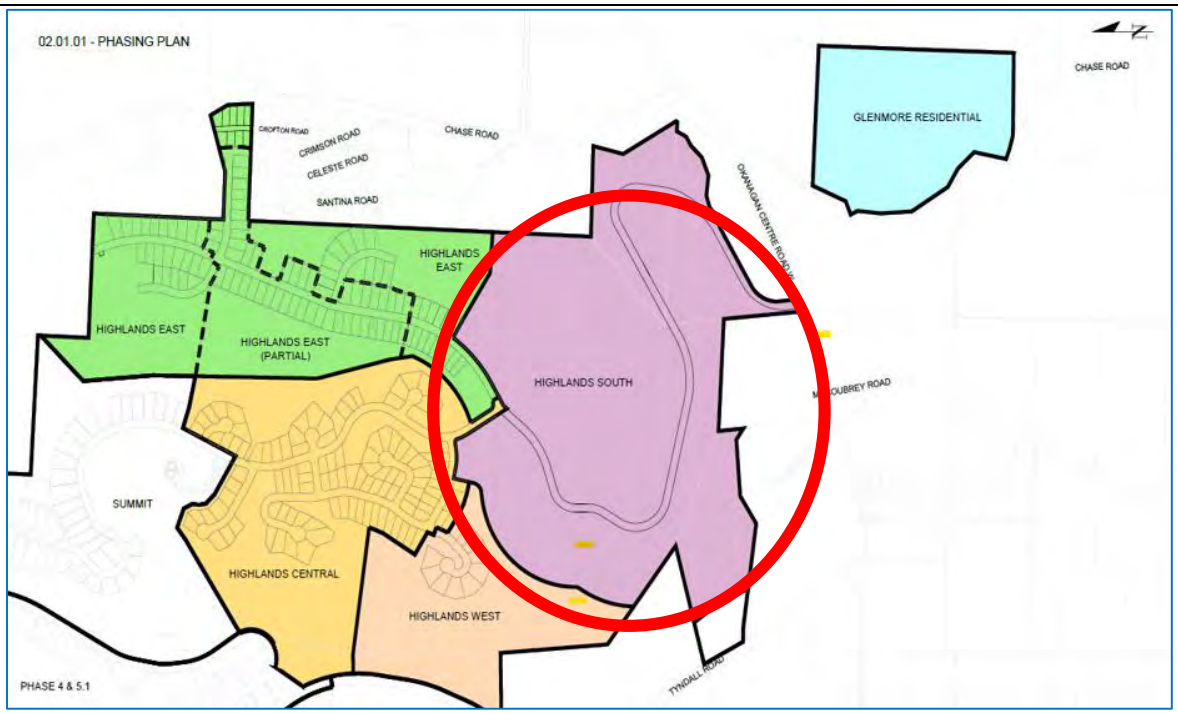


Figure 8. The 2026 PDA - Highlands South Phase

e. Glenmore Residential (Figure 9)

- Intended for entry-level single-family homes, duplexes, and town homes.
- All multifamily buildings require Development Permits.
- Benefits from proximity to the future Lake Country Business Park.
- Includes upgrades to Chase Road and new road connections.

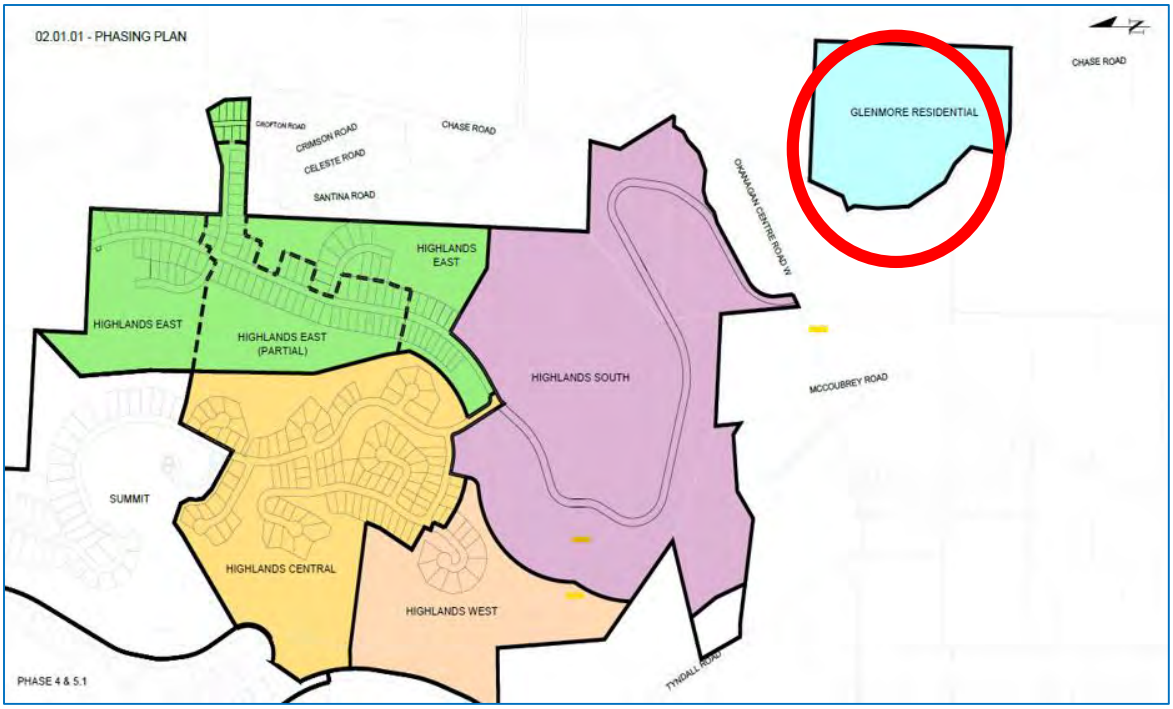


Figure 9. The 2026 PDA - Glenmore Residential Phase

7. **Zoning Changes.** Key land use amendments include removing the industrial portion, adding the Chase Road parcel, and allowing home‑based businesses. The CD3 – Lakestone Zone would be included in the PDA, thereby freezing the zoning entitlements for these lands for the duration of the PDA.

8. **Servicing & Infrastructure**. The PDA identifies the permanent and emergency access points, servicing requirements, and the maximum allowable development thresholds prior to completion of the southern access infrastructure. These provisions ensure that safe, reliable, and adequate access is maintained throughout all stages of development for the remaining phases. A summary of the access provisions is provided in Figure 10 below:

   - **2 permanent access points**:
     - Tyndall Road (west)
     - Okanagan Centre Road West (south)
   - **2 emergency egresses:**
     - Chase Road (east)
     - Long Road (north)
   - Potential future full-access connection to Chase Road from the north/east, dependent on development of adjacent lands.

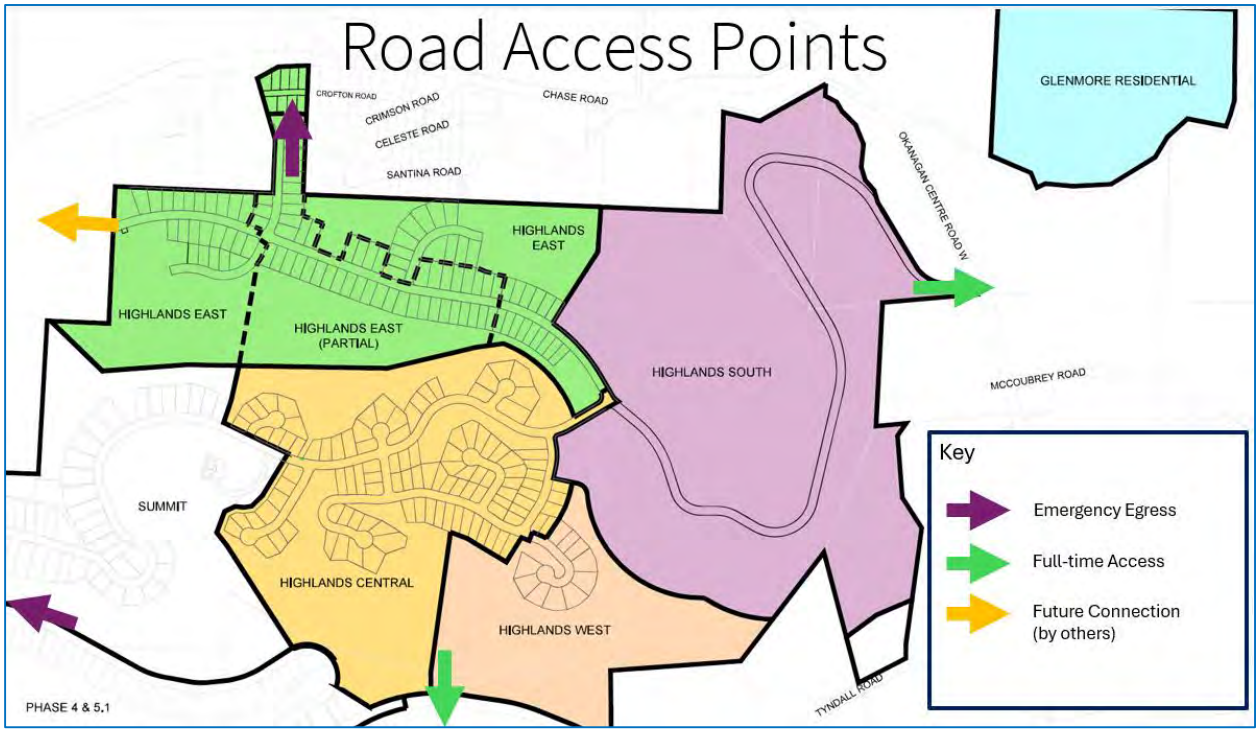


Figure 10. The 2026 PDA – Access Points

9. **Mobility & Transportation.** The PDA incorporates updated Lakestone design standards for road cross‑sections, pathway integration, and emergency access standards to support efficient mobility and safety throughout the development area (Figures 11-13 & 15). A defined limit controls how much development can occur before the southern access is constructed, as shown by the white property outlines in Figure 14 below.

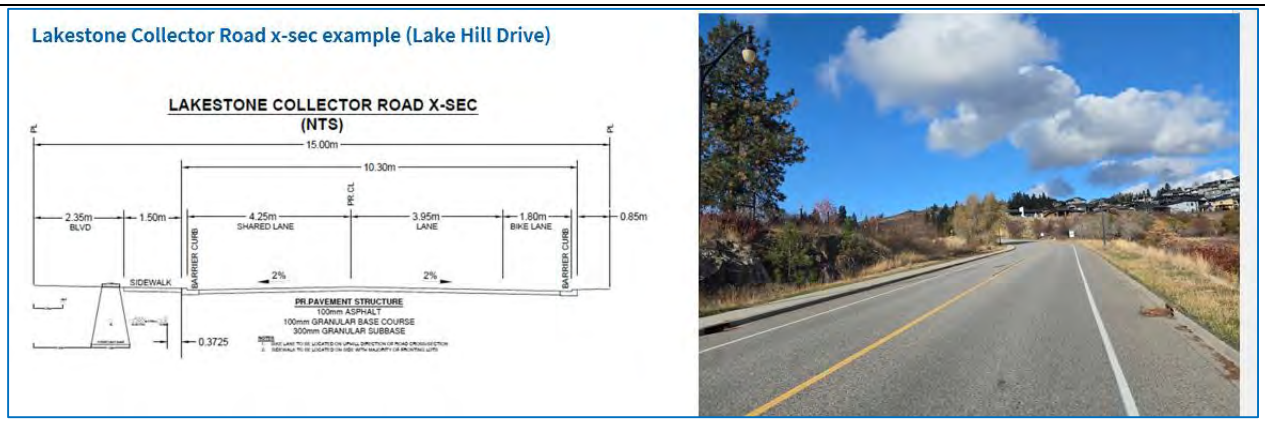


Figure 11. The 2026 PDA – Typical collector road standard

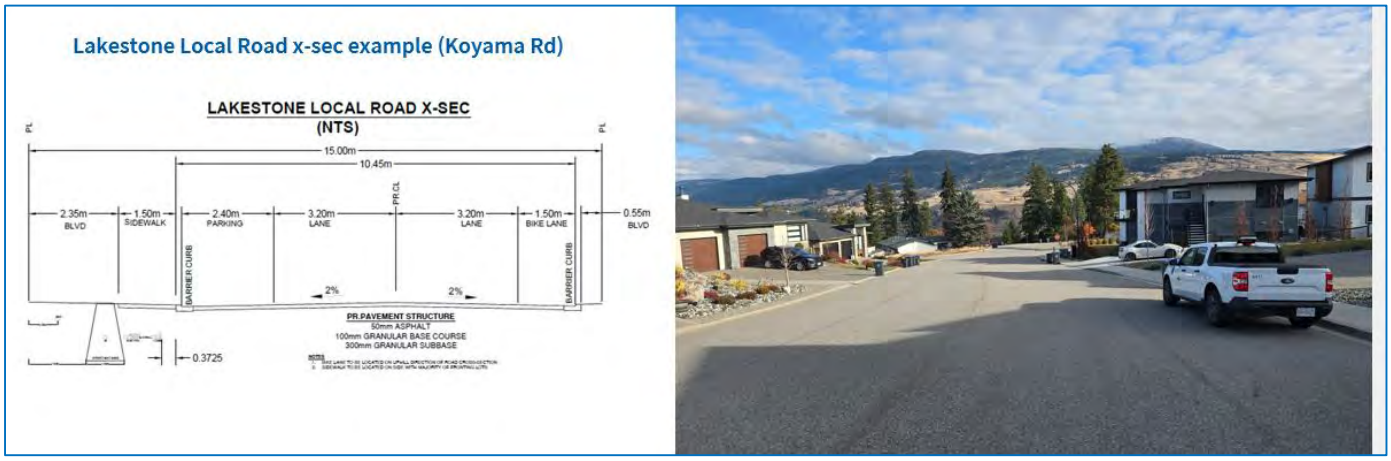


Figure 12. The 2026 PDA – Typical local road standard



Figure 13. The 2026 PDA – Future OK Centre Rd West road standard



Figure 14. The 2026 PDA – The maximum development before the southern access is constructed

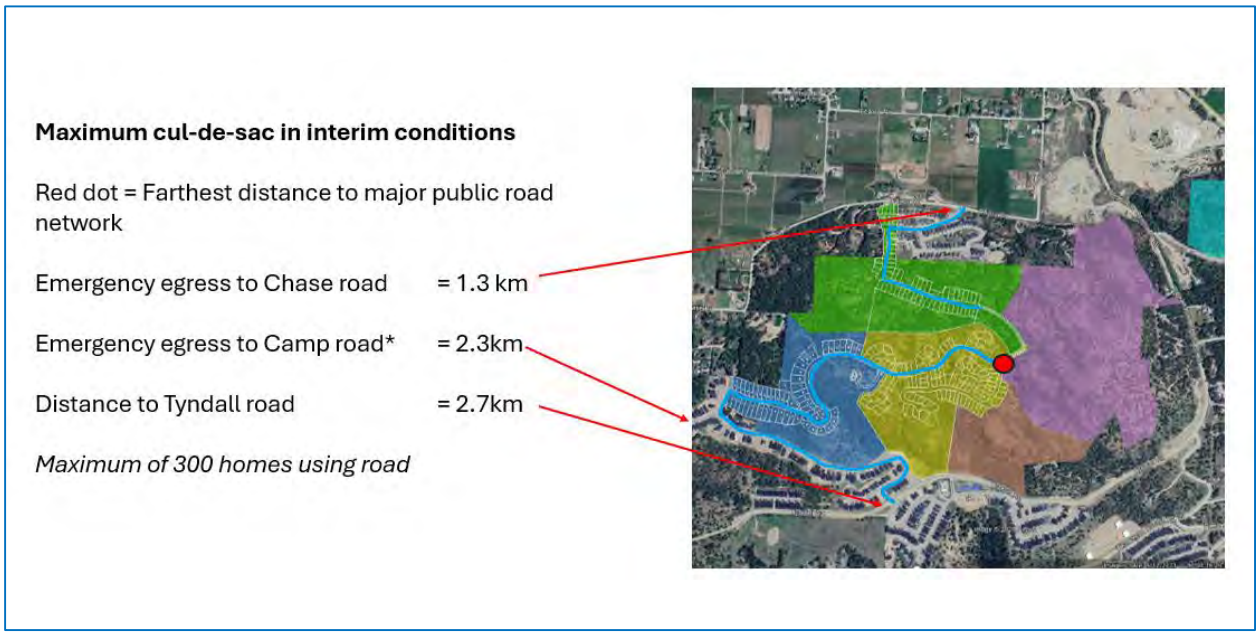


Figure 15. The 2026 PDA – Maximum cul-de-sac lengths

10. **Utilities.** The PDA outlines phased expansion of water, sanitary sewer, and stormwater systems consistent with Lakestone‑specific servicing standards, such as:

    a. **Water Supply.** A new reservoir and expanded water infrastructure support build-out and fire protection.
    b. **Sanitary Sewer.** Phased extension and capacity allocation are outlined in Schedule 7.
    c. **Stormwater.** Stormwater systems will follow Lakestone-specific standards, with on-site management and environmental protections.

11. **Parks, Trails, and Natural Environment.**

- Requirements are detailed in Schedules 4 and 9.
- Each subdivision phase requires:
    - Environmental monitoring
    - Impact assessments
    - Mitigation plans
- An additional community park has been added.
- Ongoing tree replacement and fire mitigation due to 2023 wildfire and pine beetle impacts.
- 51% of the entire development area is protected as open space, parks, or trails.
- Trail construction will continue with each phase and includes pocket parks and larger community parks (Figure 16 & 17).
- Highlands East park will expand and improve existing Santina Park.

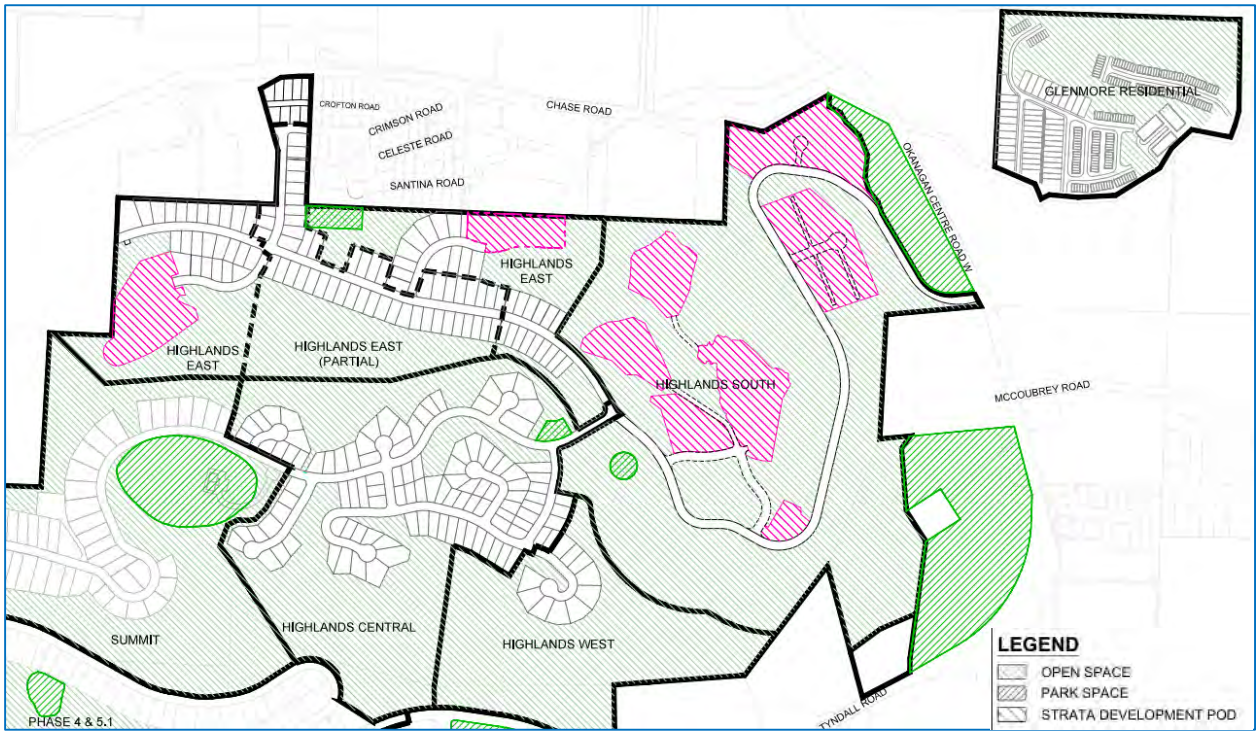


Figure 16. The 2026 PDA – Parks and greenspace overview

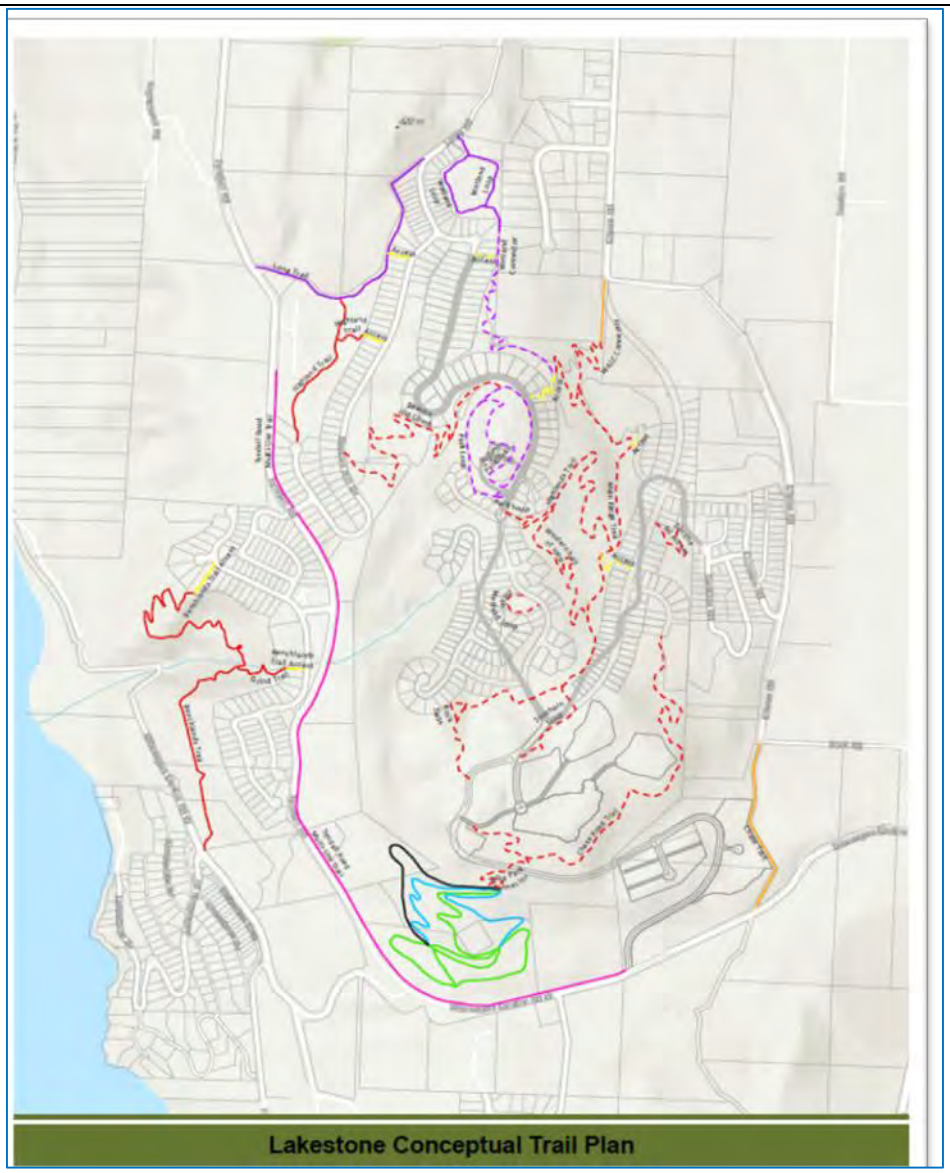


Figure 17. The 2026 PDA – Conceptual trail plan

12. **Retaining Walls.** Due to steep terrain, public walls may be up to 15 metres in height on the Southern Spine Road and 10.3m elsewhere within the development, while private walls up to 2 metres do not require a Development Variance Permit but still require building permits.

13. **Fire & Public Safety.** The PDA integrates FireSmart principles, improved water supply capacity, emergency access networks, and wildfire mitigation measures informed by the 2023 wildfire event, as such:

    - Wildfire mitigation will be completed **before subdivision approval**.
    - Lakestone Design Guidelines integrate **FireSmart principles**.
    - Trail networks provide access for firefighting.
    - A new reservoir, hydrants, and staging areas increase fire response capability.
    - Lakestone's 2023 wildfire performance demonstrates effective fire management.
    - Distances to the fire hall remain under the **8 km threshold** required by the Canadian Fire Underwriters Survey.

14. **Subsequent Steps.** The next stages in the process to formalise the PDA after 1st & 2nd readings are:
    a. Public Hearing

b. Forward to the Inspector of Municipalities for approval, this is required for any PDA with a term of more than 10 years.
c. 4th reading/adoption and rescinding of the Lakestone Master Plan

COMMUNICATION
Below is a summary of questions from the previous Committee of the Whole meetings.

Council Comments	Proposed Changes
Concerned that Lakestone's private wall height exemption would be greater than the one being considered for District wide.	**Private wall variance changed to 2m (had been 3m).** The proposed change to the District-wide regulation for retaining walls would provide flexibility equal to or greater than what is allowed under the Lakestone variance. The Lakestone variance was still required, however, to avoid the need for processing many individual Development Variance Permits that would have otherwise been required.
Councillors asked for clarity on where the 15m retaining wall height variance was applicable.	**Wording in Schedule 8.1 and 8.4 was updated** to make clear that the variance was based on the schedule, specific for each phase and not a 15m blanket right. The 15m height only applies to the Spine Road.
Councillors had concerns about the location and quantity of street trees	**Wording was improved in Schedule 8.1 and 7.1.1** to provide specific responsibility and location.
Councillors expressed concerns about the retaining wall styles	At the Committee of the Whole (CoW) meeting, these wall styles were reviewed, and it was emphasized that for developer-constructed walls, the style will remain consistent with what has already been used—both for aesthetic continuity and, more importantly, to ensure geotechnical stability and safety.
Councillors had questions about the wildlife corridors and monitoring.	**Appendix 04.01.04 was added** showing the wildlife corridors. Environmental standards are not lessened by the PDA.
Council requested details about the timing of the various phases (related to the Term) and internal roads and their delivery.	The project timing was reviewed, noting that while the market ultimately determines the pace of development, each phase is expected to take approximately 4–5 years. Each phase will also include the necessary road network functionality and access provisions to meet safety, operational, and functional requirements, as approved by the District Engineer. A 20-year term is the only timeframe

	that reasonably allows the project to be completed in full.

ALTERNATE RECOMMENDATION(S)

1. THAT Phased Development Agreement Bylaw 1318, 2026 be deferred to a future council meeting pending receipt of additional information as identified by Council.

Respectfully Submitted.
Matthew Salmon, Infrastructure & Development Engineering Director

Report Approval Details

Document Title:	ASP00005 - Lakestone PDA Bylaw 1st and 2nd.docx
Attachments:	- Phased Development Agreement (Lakestone) Bylaw 1318, 2026.docx - 00 - LAKESTONE PHASED DEVELOPMENT AGREEMENT - 20 YEAR TERM.pdf - 01 - HOW TO USE THIS PDA.pdf - 02 - PHASING PLAN.pdf - 03 - Zoning Bylaw Provisions CD3 as of 03-03-2026.pdf - 04 - ENVIRONMENTAL, WILDFIRE and GEOTECHNICAL POLICY.pdf - 05 - INTERIM ACCESS and EGRESS CONDITIONS.pdf - 06 - Subdivision and Development Servicing Bylaw 1121, 2020.pdf - 07 - CIVIL INFRASTRUCTURE.pdf - 08 - LAKESTONE SPECIFIC STANDARDS.pdf - 09 - AMENITIES AND PARKS.pdf - 10 - SERVICING CAPACITY OWNERSHIP.pdf - 01.01 - EXISTING LEGAL OVERVIEW.pdf - 02.01.01 - PHASING PLAN.pdf - 02.03 - ROADS PHASING HIGHLANDS CENTRAL.pdf - 02.04 - Roads Phasing Highlands Central.pdf - 04.01.02 - Environmental Scope.pdf - 04.01.03 - Masterplan Environment and Mitigation.pdf - 04.01.04 - Wildlife Corridor Plan.pdf - 05.03A.01 - Eastern Access Crimson.pdf - 05.03A.02 - ROADS PHASING HIGHLANDS EAST PARTIAL.pdf - 05.03A.03 - CRIMSON and CROFTON ROAD EXTENSION.pdf - 07.01.00 - Roads Phasing HIGHLANDS CENTRAL.pdf - 07.01.01 - ROADS SPINE PLAN VIEW.pdf - 07.01.02 - INTERSECTION SOUTHERN ACCESS and OKCRW.pdf - 07.01.03 - INTERSECTION BEACON HILL SPINE ROAD.pdf - 07.01.04 - ROADS SPINE PROFILE VIEW.pdf - 07.01.05 - WALLS and ROCK CUTS HIGHLANDS SOUTH.pdf - 07.01.06 - 10080 Chase Road Network.pdf - 07.02.01 - OKCRW ALIGNMENT.pdf - 07.02.02 - CHASE ROAD and OKCRW INTERSECTION.pdf - 07.02.03 - Intersection Spine and OKCRW.pdf - 07.03A.02 - Roads Phasing Highlands East Partial.pdf - 07.04.01 - Eastern Storm Routing Brief.pdf - 07.04.02 - STORM EAST.pdf - 07.05.01 - SOUTHERN STORM.pdf - 07.06.01 - WATER.pdf - 07.06.02 - SANITARY.pdf - 07.07.01 - ROADS PHASING GLENMORE RESIDENTIAL.pdf - 07.07.02 - CHASE ROAD ROW EXISTING and PROPOSED.pdf - 08.01.01 - ROADS.pdf - 08.04.01 - WALLS and ROCK CUTS HIGHLANDS CENTRAL.pdf - 08.04.02 - WALLS and ROCKS CUTS HIGHLANDS EAST.pdf - 08.04.03 - Highlands East Walls Private.pdf - 08.04.04 - Highlands South Walls Private.pdf - 09.03.01 - PARKS and OPEN SPACE.pdf - 09.05.01 - LakestoneMasterPlan L1-L9.pdf - 09.08.01 - Lakestone Conceptual Trail Plan 2024.pdf - 09.08.02 - Lakestone Conceptual Trail Plan Difficulty.pdf
Final Approval Date:	Mar 12, 2026

This report and all of its attachments were approved and signed as outlined below:

Steven Gubbels, Development Engineering Manager - Mar 10, 2026 - 11:40 AM

Carie Liefke, Manager of Current Planning - Mar 10, 2026 - 12:26 PM

Jeremy Frick, Director of Development Approvals - Mar 11, 2026 - 4:13 PM

Task assigned to Darren Lee, Fire Chief was completed by Brent Penner, Deputy Fire Chief - Mar 11, 2026 - 8:31 PM

Matt Vader, Director Parks, Recreation and Culture - Mar 12, 2026 - 9:02 AM

Brad Savoury, Director of Legal Services and Risk Management - Mar 12, 2026 - 9:16 AM

Task assigned to Reyna Seabrook, Director of Corporate Services was completed by workflow administrator Makayla Ablitt, Manager of Corporate Administration - Mar 12, 2026 - 10:01 AM

Paul Gipps, Chief Administrative Officer - Mar 12, 2026 - 10:30 AM

DISTRICT OF LAKE COUNTRY

BYLAW 1318

A BYLAW TO AUTHORIZE A PHASED DEVELOPMENT AGREEMENT

The Council of the District of Lake Country, in open meeting assembled, enacts as follows:

1. The District enters into, and the Mayor and Corporate Officer are authorized to execute the Phased Development Agreement attached to and forming part of this bylaw as Attachment "A".

2. If any section, subsection, sentence, clause or phrase of this Bylaw is for any reason held to be invalid by a court of competent jurisdiction, the invalid portion shall be severed and the holding of invalidity shall not affect the validity of the remainder of the Bylaw.

3. This bylaw may be cited as "Phased Development Agreement (Lakestone) Bylaw 1318, 2026".

READ A FIRST TIME this xx day of xx , xxxx.
READ A SECOND TIME this xx day of xx , xxxx

PUBLIC NOTICE POSTED on the xx day of xx, xxxx and a Public Hearing held pursuant to Section 518 and Division 3 of the Local Government Act on the xx day of xx, xxxx.

READ A THIRD TIME this day of xx, xxxx.

Certified correct at third reading.

_____ _____

Dated at Lake Country, B.C. Corporate Officer

Approved pursuant to section 517(d) of the Local Government Act by the Inspector of Municipalities this _____ day of _____, 20____

ADOPTED this xx day of month, 202X.

_____ _____

Mayor Corporate Officer

Schedule 00 - Phased Development Agreement

PHASED DEVELOPMENT AGREEMENT

THIS AGREEMENT made this _____ day of _____, 20_____,

BETWEEN:

DISTRICT OF LAKE COUNTRY, a municipal corporation pursuant to the *Local Government Act*, RSBC 2015, c. 1, with an address at 10150 Bottom Wood Lake Road, Lake Country, BC V4V 2M1

(the “**District**”)

AND:

MACDONALD LAKESHORE PROPERTIES LTD., a corporation incorporated pursuant to the laws of British Columbia, with an address at 1100-938 Howe Street, Vancouver, BC V6Z 1N9

(the “**Developer**”)

1.1 WHEREAS:

A. The Developer is the registered owner in fee simple of the Lands, which are located in the District of Lake Country, British Columbia and shown in Schedule 2.1 to this Agreement;

B. In 2007, section 219 covenants in favour of the District were registered on title to the Lands that attached a “Master Plan” document to it. On May 8, 2012, Council for the District approved amendments to the Master Plan which were registered on title to the Lands through new section 219 covenants, replacing the original covenants;

C. The “Lakestone Master Plan 2012” summarized the parties’ vision for the Proposed Development;

D. The Developer has completed certain phases of the Proposed Development known as Lakestone, and wishes to proceed with the final phases of the Proposed Development. To date, development of the plan has progressed over three completed phases (Waterside, Benchlands, Highlands North), and one phase in progress at the time of this Phased Development Agreement (PDA) being ratified (Summit);

E. The District will bring forward bylaw amendments to Council recommending the removal of all references to the Masterplan in the Zoning Bylaw and OCP with the proposed Phased Development Agreement Bylaw;

F. The Developer wishes to provide the Required Services and Amenities as defined herein;

G. The Developer wishes to ensure that the Specified Provisions apply to the Lands for the Term;

H. Section 516 of the *Local Government Act* permits this Agreement pursuant to the *Phased Development Agreement Bylaw*; and

I. The Parties have agreed to register this Agreement in the Land Title Office under Section 219

of the *Land Title Act*.

NOW THEREFORE in consideration of the mutual covenants and agreements set out in this Agreement, the Parties covenant and agree as follows:

1.2 PART 1 – INTERPRETATION

1.1 In this Agreement:

“**Agreement**” means this Phased Development Agreement;

"**Amenities**" includes the community benefits shown in Schedules 9 that the Developer will provide to the District;

“**Approving Officer**” means the subdivision approval official appointed by the District for that purpose under the *Land Title Act*;

“Council” means the municipal council of the District of Lake Country;

“DCC” means a Development Cost Charge levied under the *DCC Bylaw*;

“*DCC Bylaw”* means the District of Lake Country *Development Cost Charge Bylaw* No. 950, 2016;

“District Engineer” means the person appointed as such by the District from time to time, and their delegates;

“**Glenmore Residential**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Highlands Central**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Highlands East**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Highlands East (partial)**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Highlands South**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Highlands West**” means the phase of the Proposed Development approximately as shown on the Phasing Plan and as described in section 2.2 of Schedule 2;

“**Lands**” means the parcels of land legally described in Schedule 2.1;

“Lakestone Emergency Access Road” means the private gravel road connecting Beacon Hill

Drive to Chase Road on the undeveloped portion of the Lands and as described in detail in Schedule 5.1;

“Minor Amendment” has the meaning described in section 3.6 “Minor Amendment”;

“*OCP*” means the District of Lake Country *Official Community Plan (2018-2038) Bylaw* No. 1065, 2018;

“**Parks**” means the parks, greenways, trails, and other open space areas shown as such on the Parks Plan attached as Schedule 9;

“**Party**” or “**Parties**” means a party or parties to this Agreement;

"**Phase**" means a phase of the Proposed Development, including all Services and Amenities contemplated or required in connection with that Phase, as depicted in Schedule 2 and “**Phases**” means more than one Phase;

“***Phased Development Agreement Bylaw***” means the bylaw authorizing this Agreement pursuant to section 516(1) of the *Local Government Act* and attached as Schedule 12;

"Phasing Plan” means the phasing plan, as shown in Schedule 2 at appendix 02.01.01;

“PLR” means preliminary layout review;

“Proposed Development” means the Developer’s proposal to develop the Lands for residential, service, commercial, and recreational uses, as set out in this Agreement, the *OCP,* and the *Zoning Bylaw*;

“**Required Services and Amenities”** include certain Services and Amenities in the Proposed Development, as described and detailed in Schedules 2, 5 and 9;

“**Servicing Bylaw**” means the District of Lake Country *Subdivision and Development Servicing Bylaw* No. 1121, 2020, as amended and in place on the adoption date of the *Phased Development Agreement Bylaw* and stated in Schedule 6;

"**Specified Provisions**" has the meaning ascribed thereto in section 2.2.1;

“**Subdivide**” “**Subdivided**” or “**Subdivision**” means to divide, apportion, or subdivide the Lands or portion thereof, or the ownership or right to possession or occupation of the Lands into two or more lots, strata lots, parcels, parts, portions, or shares, whether by plan, descriptive words or otherwise, under the *Land Title Act*, the *Strata Property Act*, or otherwise, and includes the creation, conversion, organization, or development of "cooperative interests" or "shared interest in land" as defined in the *Real Estate Development Marketing Act*;

“Term” means the term of this Agreement set out in section 2.3.1;

“**Trail”** or **“Trails**” means the multi-use public trails system described in Schedule 9;

“**Works and Services”** means infrastructure and services and includes highways, sidewalks, boulevard, boulevard crossings, transit bays, street lighting, wiring, water distribution systems, walkways, roads, sewage collection and disposal systems, drainage collection and disposal systems, paving, curbs and gutters, and such other infrastructure,

systems and any other improvements required to be constructed, erected, or installed, both onsite and offsite as described in the *Servicing Bylaw* and this agreement that the Developer will build and dedicate to the District; and

“*Zoning Bylaw*” means the District of Lake Country *Zoning Bylaw* No. 561, 2007 as amended and in place on the adoption date of the *Phased Development Agreement Bylaw*.

1.2 Headings and captions in this Agreement are for convenience only and do not form part of the Agreement. They will not be used to interpret, define, or limit the scope, extent, or intent of this Agreement and its provisions.

1.3 The word "including" when following any general term or statement will not be construed as limiting it to the specific items following it, or to similar terms or matters, but rather, as permitting it to include other items or matters that could reasonably fall within its scope.

1.4 A reference to a statute includes every regulation made pursuant thereto and all amendments to the statute or to any such regulation in force from time to time, and any statute or regulation that supplements or supersedes such statute or any such regulation.

1.5 A reference to a bylaw means a District bylaw, and unless specified to the contrary, includes all amendments in force from time to time, and any bylaw that supplements or supersedes it.

1.6 A reference to time or date is to the local time or date in Lake Country, British Columbia.

1.7 A reference to approval, authorization, consent, designation, waiver, or notice means written approval, authorization, consent, designation, waiver, or notice.

1.8 A reference to a section means a section of this Agreement unless a specific reference is provided to a statute or bylaw.

1.9 A reference to a Schedule means a schedule attached to this Agreement, unless a specific reference is provided to another enactment, instrument, or other document.

1.10 Wherever the singular, masculine, or personal form of a word is used throughout this Agreement, the same is to be construed as meaning the plural, the feminine or gender neutral, or the body corporate or politic as the context so requires.

1.11 This Agreement is governed by and construed in accordance with the laws of the Province of British Columbia.

1.12 The following Schedules are attached to and form part of this Agreement:

Schedule “00” - Phased Development Agreement

Schedule “1” – How to use this PDA

Schedule “2” - Phasing Plan

Schedule “3” - *Zoning Bylaw* Provisions

Schedule “4” - Environmental Wildfire Geotech and Safety Policy

Schedule “5” - Interim Access and Egress Conditions

Schedule “6” - *Servicing Bylaw*

Schedule “7” - Civil Infrastructure

Schedule “8” – Lakestone specific Standards

Schedule “9” - Amenities and Parks

Schedule “10” - Servicing capacity ownership

PART 2 – AGREEMENT PARAMETERS

2.1 APPLICATION

2.1.1.1 This Agreement applies to the Lands, including any parcels into which the Lands are Subdivided.

2.1.2 The Developer covenants and agrees with the District that the Lands will not be developed, Subdivided, or built on for any purpose whatsoever, except in strict accordance with this Agreement.

2.2 BYLAW AMENDMENTS

2.2.1 For the purposes of this Agreement, the “Specified Provisions” are as follows:

(a) all provisions of the *Zoning Bylaw* (including but not limited to section 19.3) applicable to the Lands as of the date of this Agreement, as set out in Schedule 3 to this Agreement; and

(b) all provisions of the *Servicing Bylaw* applicable to the Lands as of the date of this Agreement, as set out in Schedule 6 to this Agreement

(collectively, the “**Specified Provisions**”).

2.2.2 For the duration of the Term, no amendment or repeal of the Specified Provisions within the *Zoning Bylaw* or the *Servicing Bylaw* applies to the Lands, except:

(a) as provided in section 516(6) of the *Local Government Act;*

(b) as provided in any other provision of the Local Government Act or another statutory enactment in force and binding on the Parties from time to time; or

(c) to the extent that the Developer agrees in writing that the amendment or repeal applies to the Lands.

2.2.3 For certainty, and without limiting section 2.2.1, the District agrees that any amendment or repeal of the Specified Provisions that would prevent the issuance of any development approval, development permit, or building permit in respect of the Lands, the issuance of which was not prevented by the Specified Provisions, will not operate to prevent issuing such approval or permit for the Term.

2.2.4 If future legislative amendments permit changes to the Proposed Development that the Developer seeks to implement, for example, greater density than is currently contemplated in this Agreement, the Developer acknowledges and agrees that the Proposed Development must satisfy additional infrastructure requirements, if any, and must provide updated Transportation and Water, Sewer, and Drainage Plans if reasonably required by the District.

3 2.3 TERM AND TERMINATION OF AGREEMENT

2.3.1 The Term of this agreement twenty (20) years from the adoption date of the *Phased Development Agreement Bylaw*.

2.3.2 The Parties may terminate this Agreement at any time by mutual written agreement, subject to section 6.4.

2.3.3 If, in the District’s opinion, the Required Services and Amenities have not materially been provided to the standards and at the times set out in this Agreement the District may give written notice to the Developer (the “**Default Notice**”), that there has been an alleged material failure to provide the Required Services and Amenities in accordance with this Agreement and setting out the nature of the default (the “**Deficiency**”).

2.3.4 If the Developer has not substantially remedied the Deficiency to the reasonable satisfaction of the District within one (1) month after receipt of the Default Notice, or, where the Deficiency reasonably requires longer than one (1) month to remedy, the Developer has failed to substantially commence remedying to the reasonable satisfaction of the District the Deficiency within one (1) month after receipt of the Default Notice, or has failed to substantially remedy the Deficiency to the reasonable satisfaction of the District within the period of time after receipt of the Default Notice reasonably necessary to complete the remedial work, then the District is entitled to terminate this Agreement by further written notice without prejudice to any other rights or remedies that the District may have at law or in equity. For clarity, the Developer will be considered to have commenced remedial efforts where it has commenced investigation and planning work (including drawings, design, etc.) in furtherance of the required remedial work.

2.3.5 Upon expiry or earlier termination of this Agreement, the District is no longer bound by section 2.2.2 and any amendment or repeal of the Specified Provisions during the Term applies to the Lands.

PART 3 – DEVELOPMENT

3.1 THE DEVELOPMENT

3.1.1 The Proposed Development is subject to the terms and conditions of this Agreement.

3.1.2 Subject to section 2.2.1, the Developer will develop the Lands for the Proposed Development in accordance with all District bylaws, and without limiting the foregoing, in accordance with the schedules referenced in section 1.12.

3.1.3 If there is any conflict between the bylaws and any of the Schedules included in this agreement, the Schedules prevail. If the Schedules do not provide direction the bylaws shall be applicable.

3.1.4 For clarity, the inclusion of the Specified Provisions and the Schedules in this Agreement

does not abrogate the District’s right to request updated reports as needed throughout the development process.

3.1.5 Intentionally left blank

3.1.6 For certainty, the Developer’s obligation to provide the Required Services and Amenities includes the obligation to transfer to the District certain interests in the Lands on the terms set out in this Agreement, and any improvements thereon, that are reasonably required to ensure the District’s ongoing right, title, and interest in and to the Required Services and Amenities and to their use by the District and the public (where applicable).

3.2 PUBLIC LANDS USE DESIGNATIONS

3.2.1 The Developer acknowledges that the Specified Provisions zone certain portions of the Lands for public use only, in contemplation of those portions being transferred to the District pursuant to this Agreement, and agrees that such designations do not, considered together with the effect of the Specified Provisions in respect of the other portions of the Lands, effect any reduction in the value of the Developer’s interest in the Lands. The Developer agrees that such designations and providing the Required Services and Amenities do not entitle the Developer to any compensation whatsoever from the District. The Developer irrevocably waives any entitlement to such compensation and the right to challenge validity of the Specified Provisions that zone certain portions of the Lands for public use only.

3.3 PHASING REQUIREMENTS

3.3.1 The Developer covenants and agrees with the District to provide the Required Services and Amenities as set out in the Schedules.

3.3.2 Though not a requirement, for planning purposes, as of the date of this Agreement, the most likely sequence of the Proposed Development is:

(a) Highlands East (partial);
(b) Highlands Central;
(c) Highlands South including the Key infrastructure item Schedule 7.1.1 (Southern Access);
(d) remainder of Highlands East;
(e) Highlands West; and
(f) Remainder of Highlands South

For clarity, the development of the Glenmore Residential phase does not require the prior development of other areas or phases of the Proposed Development, such that the Glenmore Residential phase could be developed at any time and independently (whether concurrently or sequentially) of the other phases.

3.4 SERVICING

3.4.1 As the Lands will be serviced by the District’s sanitary sewer, storm and water services and accessed by District’s highways, the Developer covenants and agrees with the District that it will, at its own cost, design and construct all Works and Services required

for each Phase to service all development on the Lands to standards acceptable to the District and that comply with its bylaws, including the *Servicing Bylaw*.

3.4.2 The Developer will have the right to all capacity of water, sewer and storm infrastructure Works and Services it is constructing as part of the Development unless explicitly noted otherwise in this Agreement. Ownership of the capacity will be regulated via the concept described in Schedule 10.

3.5 ASSIGNMENT OF AGREEMENT

3.5.1 The Developer may assign this Agreement in whole or in part to a subsequent owner of the Lands, provided that:

(a) the subsequent owner is a corporation which is a subsidiary of the Developer within the meaning of the *Business Corporations Act*; or

(b) to any other person or corporation if the District agrees to the assignment.

3.5.2 The District’s Agreement to an assignment under Section 3.5.1(b) will not be unreasonably withheld or delayed where the person or corporation receiving the assignment is:

(a) in the case of a corporation, duly registered in the Province of British Columbia or Canada and is in good standing with the applicable corporate registrar;

(b) not the subject of bankruptcy or insolvency proceedings; and

(c) in the business of land development.

3.5.3 Prior to any assignment of this Agreement, whether in whole or in part, the subsequent owner or owners must enter into an agreement with the District in a form satisfactory to the District (acting reasonably) whereby the subsequent owner(s) assumes all of the Developer’s covenants, agreements, and other obligations under this Agreement.

3.5.4 Notwithstanding sections 3.5.1 through 3.5.3, the District’s consent is not required for the Developer completing the sale of single-family residential lots created in accordance with this Agreement.

3.6 AMENDMENTS

3.6.1 No amendment to this Agreement will be effective unless made in writing and duly executed by the Developer and the District.

3.6.2 The District and the Developer may agree to Minor Amendments of this Agreement. For the purposes of this Agreement, a **“Minor Amendment”** is any amendment other than one that:

(a) contemplates renewal or extension of this Agreement;

(b) modifies the Lands that are the subject of this Agreement (Schedule “2.1”);

(c) modifies the definition of Specified Provisions (section 2.2.1);

(d) modifies the Term of this Agreement, unless the amendment will reduce the length of the Term (section 2.3.1);

(e) modifies the definition of Minor Amendment (section 3.6.2); or

(f) modifies the provisions of this Agreement regarding assignment to a subsequent owner (section 3.5).

3.6.3 The District may authorize a Minor Amendment by Council resolution without having to adopt a bylaw or hold a public hearing.

3.6.4 At Council’s discretion, the District may convene a public hearing or other proceeding to consider public opinion regarding the proposed Minor Amendment, notwithstanding that it is not required by any enactment. If Council convenes a public hearing, the Developer agrees to participate in such hearing or other proceeding for the purpose of providing information to the public on the proposed Minor Amendment.

3.6.5 A public hearing and adoption of a bylaw is required as a precondition to an amendment to this Agreement that is not a Minor Amendment.

3.6.6 The Developer and the District will meet on the two, five, ten, and fifteen year anniversary of this Agreement’s ratification to consider if any amendments to this Agreement or related procedures are mutually desired.

PART 4 – DISPUTE RESOLUTION

4.1 DISPUTE RESOLUTION

4.1.1 If a dispute arises between the parties in connection with this Agreement, the parties agree to first use the following procedure prior to pursuing any other remedies:

(a) either Party will notify the other by written notice (“**Notice of Dispute**”) of the existence of a dispute;

(b) promptly, a meeting will be held between the Parties and attended by the individuals with decision-making authority regarding the dispute, to attempt in good faith to negotiate a resolution; and

(c) if, within forty-eight (48) hours after such meeting or such further period mutually agreed to by the Parties (the “**Negotiation Period**”), the Parties have not succeeded in negotiating a resolution, the Parties will proceed in accordance with sections 4.1.2 or 4.1.3, as applicable.

4.1.2 If a dispute relates to technical standards pursuant to a bylaw, and was not successfully resolved during the Negotiation Period:

(a) the Parties must, within fourteen (14) business days of the conclusion of the Negotiation Period, jointly appoint a mutually acceptable third party who is an

expert in the subject matter of the dispute to provide their non-binding opinion and recommendations for resolution of the dispute, which the Parties will consider and use in further good faith dispute resolution negotiations, with the costs of the opinion to be borne mutually by the Parties; and

(b) if the dispute is not resolved pursuant to section 4.1.2(a):

(i) either Party may pursue recourse through BC courts;

(ii) if the Parties mutually agree, they may proceed with and bear equally the costs of mediation, in which case the Parties will jointly appoint a mutually acceptable mediator (preferably an expert in the subject matter of the dispute) and secure mediation dates within fourteen (14) business days of agreeing to mediation; or

(iii) if the Parties mutually agree, the dispute may be settled by a single arbitrator under the *Arbitration Act*, SBC 2020, c. 2**.**

4.1.3 If a dispute relates to interpretation of this Agreement, or anything else arising in connection with this Agreement, and has not been resolved pursuant to section 4.1.1 and section 4.1.2 does not apply:

(a) either Party may pursue recourse through BC courts;

(b) if the Parties mutually agree, they may proceed with and bear equally the costs of mediation, in which case the Parties will jointly appoint a mutually acceptable mediator (preferably an expert in the subject matter of the dispute), within fourteen (14) business days of the conclusion of the Negotiation Period; or

(c) if the Parties mutually agree, the dispute may be settled by a single arbitrator under the *Arbitration Act*, SBC 2020, c. 2**.**

4.1.4 In no circumstances will sections 4.1.2, or 4.1.3 be construed as impeding or affecting the District's authority to enforce any of its bylaws, including, without limitation, its *Zoning Bylaw* and its *Servicing Bylaw*.

PART 5 – WAIVER, RELEASE, INDEMNITY, AND BAR TO RECOVERY

5.1 WAIVER, RELEASE, AND INDEMNITY

5.1.1 The Developer agrees to indemnify the District from any and all claims, causes of action, suites, demands, fines, penalties, costs, deprivation, expenses, and actual legal fees and disbursements whatsoever, whether based in law or equity, whether known or unknown, which anyone has or may have against the District or which the District incurs as a result of any loss, damage, or injury, including economic loss or deprivation, arising out of or in any way connected to any breach by the Developer of this Agreement.

5.1.2 The Developer hereby releases, saves harmless, and forever discharges the District from any claims, causes of action, suits, demands, fines, penalties, costs, deprivation,

expenses, or legal fees whatsoever which that Developer may have or claim against the District, whether based in law or equity, whether known or unknown, for any loss, damage, or injury, including economic loss or deprivation, that the Developer may sustain arising out of or connected with this Agreement, including the restrictions and requirements of this Agreement, the provisions of the Required Services and Amenities and the development of the Lands as contemplated under this Agreement, save and except as a result of any intentional acts or negligence by the District or any breach by the District of this Agreement.

5.1.3 The provisions of sections 5.1.1 and 5.1.2 and will survive the expiry or earlier termination of this Agreement.

5.2 NO RECOVERY OF AMENITIES

5.2.1 The developer expressly acknowledges and agrees that the expiry of this Agreement or any termination in accordance with section 3 or otherwise unless due to a breach by the District of this Agreement, does not entitle the Developer to recover any interest in or portion of the costs incurred in providing the Amenities or other contributions specified in the Schedules or elsewhere in this Agreement, or to seek restitution in relation thereto or in relation to any other obligation of the Developer as performed, and the Developer specifically agrees that the Specified Provisions of this Agreement for the period prior to expiry or termination provides sufficient consideration for the said Amenities and other contributions specified in the Schedule and elsewhere in this Agreement.

5.2.2 Despite section 5.2.1, if prior to final approval of the first application for Subdivision of the Lands after the commencement of the Term, the *Phased Development Agreement Bylaw,* is challenged and overturned in its entirety by a court of competent jurisdiction, the Developer will be entitled to recover any of the Amenities provided under this Agreement prior to final approval of the first application for subdivision of the Lands. In no case will legal fees paid to the District be recoverable.

5.2.3 Except to the extent resulting from the intentional acts or negligence of the District or any breach by the District of this Agreement, the Developer agrees not to commence or advance a legal proceeding of any kind to seek to quash, set aside, hold invalid this Agreement, the *Phased Development Agreement Bylaw,* or to recover any portion of the Amenities or other contributions provided under this Agreement, or seek restitution in relation to any of the Amenities or other contributions provided under this Agreement, and if the Developer does any of the foregoing, the provision of this Agreement to the Court will act as a full, complete, and binding answer and defence (except as to any intentional acts or negligence by the District or any breach by the District of this Agreement).

PART 6 - GENERAL TERMS AND CONDITIONS

6.1 **Costs**. The Developer and the District will perform their own obligations under the Agreement at their sole cost. This does not preclude the opportunity for cost shared projects being conducted in the future (such as Santina Park). Any cost sharing must be agreed to prior to the commencement of work and agreed to in writing.

6.2 **Access and Entry**. On reasonable advance written notice, the Developer will provide the District’s representatives with reasonable access to all plans, permits, specifications, and studies related to the Proposed Development to ascertain compliance with this

Agreement. The Developer agrees that the viewing of this documentation by the District’s representative does not create any legal obligation, in tort or otherwise, on the part of the District or its representative whether or not comments are given to the Developer, and whether or not the Developer chooses to act on comments that may be given. The Developer agrees that on reasonable advance written notice the District may, by its officers, employees, contractors, and agents, enter upon the Lands and within all buildings (subject to residential tenancy laws, as applicable) and structures thereon at all reasonable times to ascertain compliance with this Agreement.

6.3 **Powers Preserved**. Except as expressly set out in this Agreement, nothing in this Agreement prejudices or affects the rights or powers of the District in the exercise of its functions under the *Community Charter* or the *Local Government Act,* or any of its bylaws, or those of the Approving Officer under the *Land Title Act, Strata Property Act,* or *Bare Land Strata Regulations.*

6.4 **Severance**. If any part of this Agreement is held to be invalid, illegal or unenforceable by a Court of competent jurisdiction, the invalid provision may be severed, and will not affect the validity of the remainder of this Agreement, provided that if Section 2.2.1 or any provisions contained in Schedules 2,4,5,7,8,9,10 is severed from this Agreement pursuant to the provisions of this section 6.4, then the Developer may elect to terminate this Agreement in its entirety.

6.5 **Waiver**. No action or statement of either Party will constitute a waiver of any provision of this Agreement unless such waiver is expressly made in writing and signed by the waiving Party. The waiver by either Party of any breach by will not constitute a waiver of any further or other breach.

6.6 **Specific Performance**. The Developer acknowledges and agrees that, because of the public interest in ensuring that all of the matters described in this Agreement are complied with, the public interest strongly favours the award of a prohibitory or mandatory injunction, or an order for specific performance or other specific relief, by the Supreme Court of British Columbia at the instance of the District, in the event of an actual or threatened breach of this Agreement.

6.7 **Enurement**. This Agreement will enure to the benefit of and be binding upon the Parties and their respective heirs, administrators, executors, successors, and permitted assigns.

6.8 **Joint and Several**. The obligations of the Developer, if now or at any time comprised of more than one legal entity, will be joint and several. The Parties agree that as between the District and the Developer, either legal entity comprising the Developer may carry out the responsibilities, obligations and covenants of the Developer under this Agreement on behalf of the Developer and any decision, agreement, or act by either legal entity comprising the Developer with respect to the terms and conditions of this Agreement will bind the other legal entity comprising the Developer. The legal entities comprising the Developer may make agreements between themselves as to the obligations of the Developer under this Agreement.

6.9 **No Representations and Warranties**. It is mutually understood and agreed by and between the Parties that neither Party has made any representations, covenants, warranties, guarantees, promises, or agreements (oral or otherwise) with the other except for those contained in this Agreement.

6.10 **No Fettering**. It is mutually understood and agreed by and between the Parties that except as expressly set out in this Agreement, nothing contained or implied herein will

prejudice or affect the rights and powers of the District in the exercise of its functions under any public and private statutes, bylaws, orders and regulations, or the common law, all of which may be fully and effectively exercised in relation to the Lands as if this Agreement had not been executed and delivered by the Developer.

6.11 **Additional District Remedies**. The Developer acknowledges and agrees that, notwithstanding anything to the contrary herein and in addition to any other remedy in common law or equity, the District, acting reasonably, may, in accordance with applicable public law limitations on the withholding of development permits, building permits, and occupancy permits, withhold such permits for the purpose of ensuring compliance with and administering the terms of this Agreement.

6.12 **Statutory and Bylaw Provisions**. It is mutually understood and agreed by and between the Parties that:

(a) this Agreement does not:

(i) affect or limit any enactment or bylaw applying to the Lands except as provided under Sections 2.2.1 and 2.2.2; or

(ii) relieve the Developer from complying with any enactment or bylaw except as provided under Sections 2.2.1 and 2.2.2;

(b) the covenants herein will charge the Lands pursuant to 516(3)(d) of the *Local Government Act* and Section 219 of the *Land Title Act* and will be covenants, the burden of which will run with the Lands;

(c) all covenants made by the Developer herein will accrue solely to the benefit of the District;

(d) this Agreement may be modified pursuant to section 519 of the *Local Government Act*; and

(e) the Section 219 covenant may be modified by agreement of the District with the Developer, or discharged by agreement of the District and the Developer, pursuant to the provisions of Section 219 of the *Land Title Act,* and in accordance with any requirements to amend this Agreement as detailed in section 3.6.

6.13 **Notice**. Any notices or other communications required or permitted to be sent hereunder must be in writing and will be duly given if personally delivered or sent via courier:

To the District at:

District of Lake Country
10150 Bottom Wood Lake Road,
Lake Country, BC V4V 2M1

Attention: Chief Administrative Officer

To the Developer at:
11th floor, 938 Howe Street
Vancouver, BC V6Z1N9
Attention: John Macdonald

Either party may change his or its address for the sending of notice to such party by written notice to the other party sent in accordance with the provisions hereof.

6.14 **Time**. Time is of the essence for this Agreement and will remain of the essence notwithstanding the extension of any dates.

6.15 **Cumulative Remedies**. Any remedy provided in this Agreement is not exclusive and is be deemed to be cumulative with all available remedies at law or in equity.

6.16 **Relationship of the Parties**. No provision of this Agreement will be construed to create a partnership or joint venture relationship, an employer-employee relationship, a landlord-tenant relationship, or a principal-agent relationship between the Parties.

6.17 **Amendment**. This Agreement, including the Schedules, may not be modified or amended except by mutual written agreement of the Parties.

6.18 **Entire Agreement**. This Agreement, including its Schedules, contains the entire agreement and understanding of the Parties with respect to the matters contemplated by this Agreement and supersedes all prior and contemporaneous agreements between them with respect to such matters.

6.19 **Notice of Breach**. Each Party will promptly notify the other Party of any matter that is likely to give rise to or continue a breach of its or the other Party’s obligations under this Agreement.

6.20 **Legal Fees**. The Parties agree that each of them will bear their own legal fees incurred in relation to or arising out of this Agreement, including but not limited to the development of the Lands, provision of the Required Services and Amenities the drafting and negotiating of this Agreement and other necessary agreements, and legal advice pertaining to same.

6.21 **Counterparts**. This Agreement may be executed in counterparts with the same effect as if both Parties had signed the same document. Each counterpart is deemed to be an original. All counterparts will be construed together and constitute one and the same Agreement.

Intentionally left blank

Signature page is next page

IN WITNESS WHEREOF the Parties have set their hands and seals as of the day and year set out below:

THE DISTRICT OF LAKE COUNTRY, by its authorized signatory, this ___ day of _____, 20___:

_____
Sign Name

_____

Print Name

MACDONALD LAKESHORE PROPERTIES LTD., by its authorized signatory(ies), this ___ day of _____, 20___:

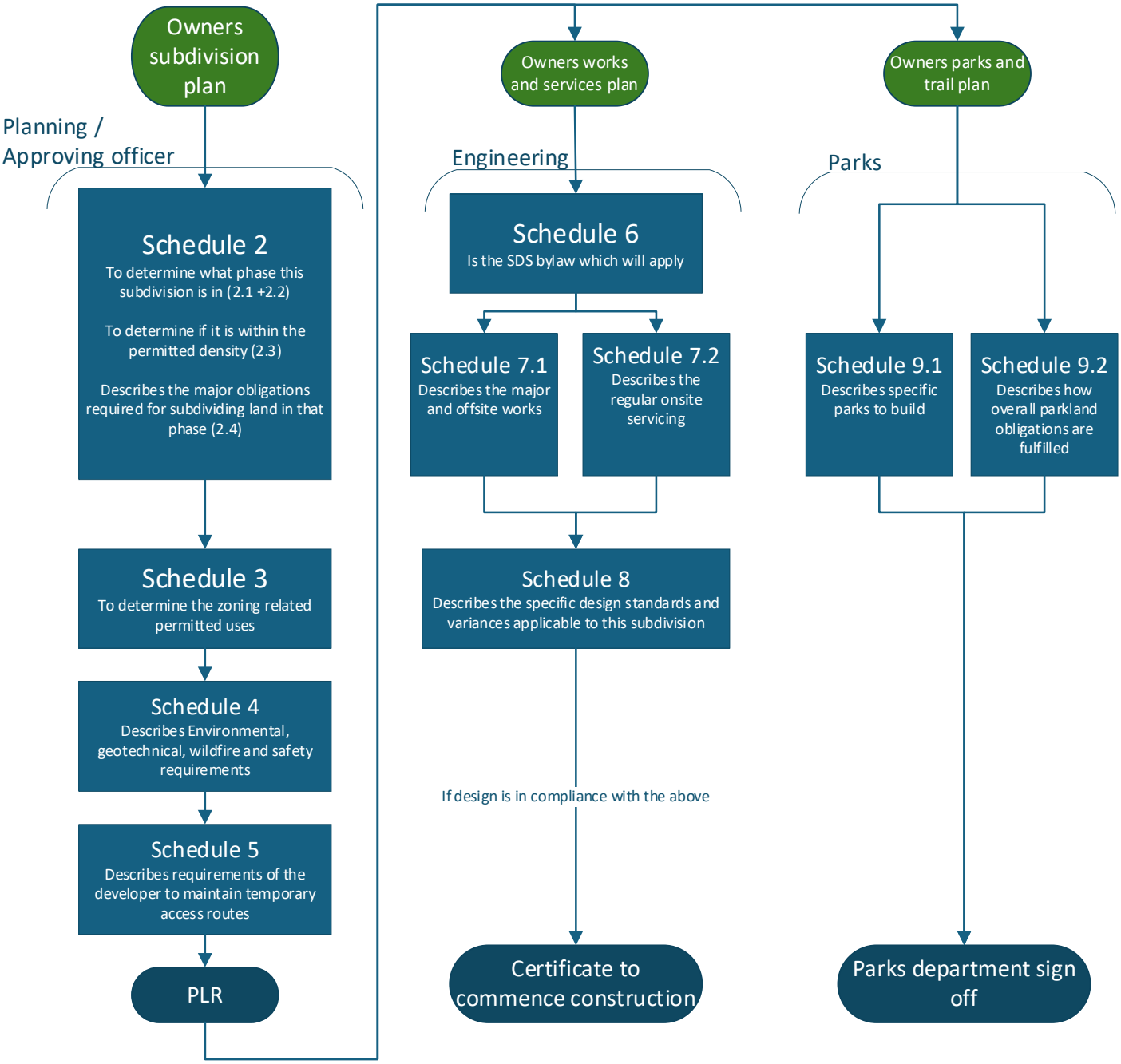
_____

Sign Name

_____

Print Name

Schedule 1
HOW TO USE THIS PDA



SCHEDULE 2
PHASING PLAN

GENERAL POLICY

A. Development will occur in accordance with the Specified Provisions of the Servicing Bylaw (Schedule 6). That bylaw requires a Developer to consider downstream impacts on municipal services and roadways and improve them if necessary. This Agreement defines, or sets the parameters for defining, the remaining major "downstream" servicing and access requirements of the Lakestone development.

B. Those remaining obligations are listed in Schedule 7.1. (Major and offsite works). Different phases of the Proposed Development will require (trigger) the need for each to be completed as a condition of any subdivision of part of that phase.

C. The remaining major parks projects in the Proposed Development (Schedule 9.1) are triggered by development in the same way as those items in Schedule 7.1.

D. For development within each phase, the Proposed Development will be built pursuant to the servicing concept plan (Schedule 7.2) and parks concept plan (Schedule 9.2).

E. The remaining phases of the Proposed Development need not be developed in their entirety at one time nor in any specific sequence.

F. The development of Glenmore Residential does not require development in other areas first and could be done at any time.

G. The Excluded Lands (as identified in the Parcel List on the following page) are owned by the Developer but not part of a Phase. It will continue to have the DC3 zone and all of the development rights attributable to that zone, and any part of the parcel dedicated to the District will form part of the park dedication obligation (Schedule 9.2.1) but development of the parcel will not trigger any works other then what is required by the Works and Services Bylaw.

CONTENTS OF THIS SCHEDULE

2.1 – Development Lands 2

2.2 – Phase Descriptions 5

2.3 – Density Allocation 7

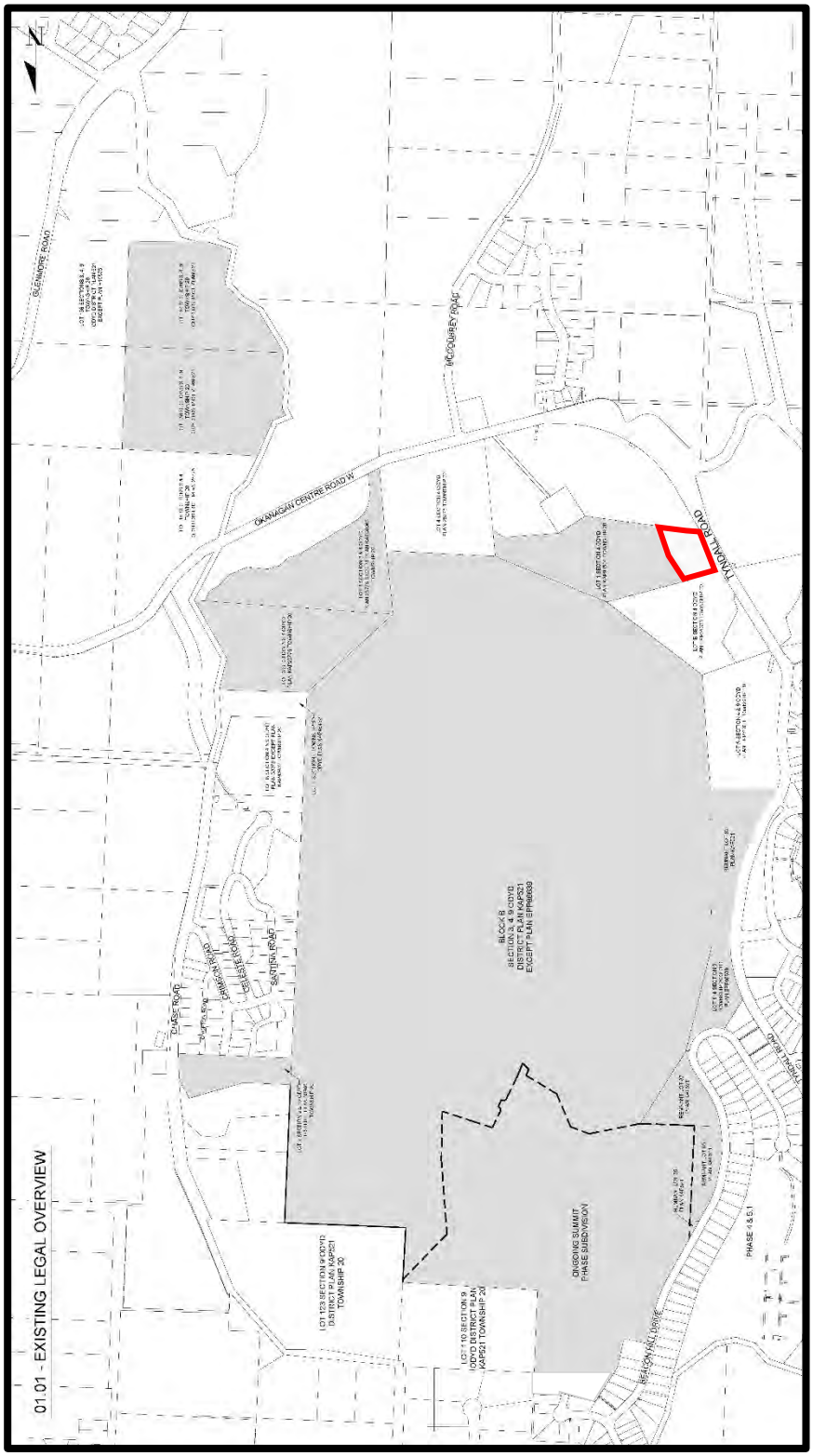
2.4 – Major Servicing and Parks Obligations 7

2.1 – DEVELOPMENT LANDS

PARCEL LIST

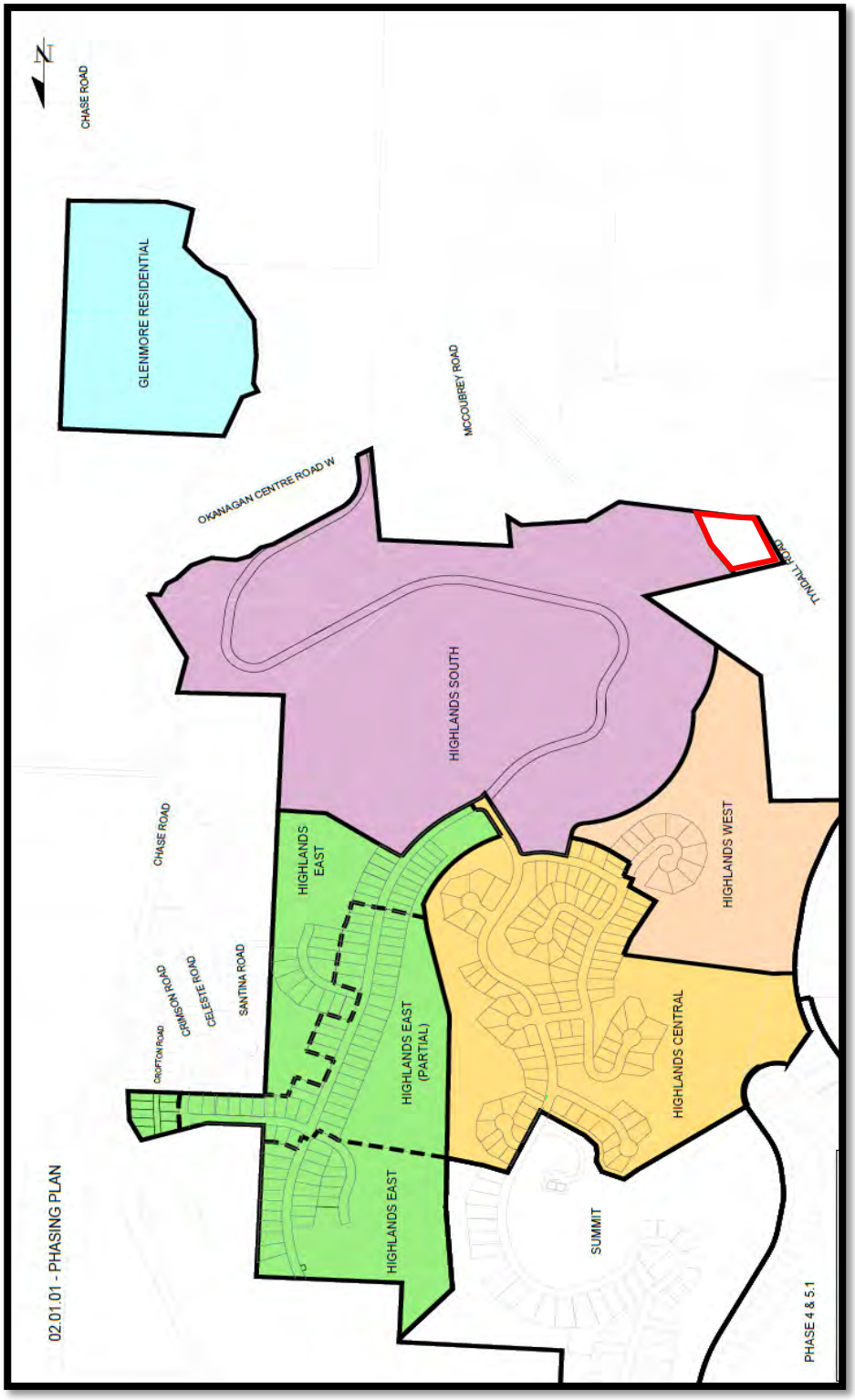
	Parcel Identifier	Legal Description Lands Owned by Developer
1.	012-274-551	BLOCK B SECTIONS 3, 4 AND 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521 EXCEPT PART ON PLAN EPP86639
2.	012-274-526	LOT 138 SECTIONS 3, 4 AND 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521
3.	003-053-334	LOT 2 SECTIONS 9 AND 10 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 33960
4.	028-363-965	LOT 1 SECTION 4 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN KAP91504 (except for the "**Excluded Lands**" shown outlined in red on the 'Parcel Map' below.
5.	012-274-518	LOT 137 SECTIONS 3, 4 AND 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521
6.	005-321-859	LOT 4 SECTIONS 3 AND 4 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 25775 EXCEPT PLAN KAP90965
7.	005-321-832	LOT 3 SECTIONS 3 AND 4 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 25775
		Legal Description **Lands recently dedicated to the District**
8.	012-274-267	THAT PART OF LOT 85 SHOWN ON PLAN B13454; SECTION 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521 EXCEPT PLANS H18660, KAP90967 AND EPP86639
9.	012-274-283	THAT PART OF LOT 86 SHOWN ON PLAN B13454; SECTION 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521 EXCEPT PLAN H18660 AND EPP86639
10.	012-274-305	THAT PART OF LOT 87 SHOWN ON PLAN B13454; SECTION 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521 EXCEPT PLANS H18660, EPP74823 AND EPP86639
11.	012-274-364	THAT PART OF LOT 89 SHOWN ON PLAN B13454; SECTION 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN 521 EXCEPT PLANS H18660 AND EPP74823
12.	030-778-867	LOT 114 SECTION 9 TOWNSHIP 20 OSOYOOS DIVISION YALE DISTRICT PLAN EPP86639

PARCEL MAP



Appendix 01.01 – Legal Overview (copy with red line Excluded Lands)

PHASING PLAN



Appendix 02.01.01 - Phasing Plan (copy with red line Excluded Lands)

2.2 – PHASE DESCRIPTIONS

HIGHLANDS EAST	
Highlands East	**Feature(s)/Description:** Highlands East is defined as the east side of the Lands up to 583m in elevation, which is the elevation to which the Proposed Development can be serviced by the existing Eldorado water pressure zone. **Access:** Full road access will be provided to Tyndall Road by an extension of Beacon Hill Drive and one of: (1) to Okanagan Centre Road by the Spine Road (Appendix 07.01.01) or; (2) to Chase Road by the 10080 Chase access (Appendix 07.01.06)
Highlands East (partial)	**Feature(s)/Description:** In order to allow the opportunity to move infrastructure into the property in an economic way, the Developer may build up to 50 dwelling units of Highlands East without triggering the requirement for the infrastructure described in 07.01.01 or 07.01.04. **Access:** In the scenario where access described in Appendix 07.01.01(Spine Road) or (Appendix 07.01.06 (10080 Chase Road) is not provided, interim full road access may be provided to Chase Road by Schedule 5.2 (Crimson Road Access) provided no more than 50 new dwellings will be accessed from Crimson Road. Construction traffic will follow an alternate route as explained in Schedule 5.2. The intention is to limit the exposure of traffic into the existing Sage Glenn neighborhood.

HIGHLANDS SOUTH	
Highlands South	**Feature(s)/Description:** Highlands South is the portion of the Lands south of a major "T" intersection at Beacon Hill Drive and the Spine Road. This phase includes some of the most challenging terrain at Lakestone and will include a large amount of multi-family structures. **Access:** Full road access will be provided to Tyndall Road by an extension of Beacon Hill Drive and the Spine Road access (Appendix 07.01.01)

HIGHLANDS CENTRAL	
Highlands Central	**Feature(s)/Description:** Highlands Central is an extension of the previously constructed Summit phase. Lots in the Highlands Central phase may have a maximum distance from Tyndall Road and Beacon Hill intersection of 2,700m. There is to be a maximum number of 131 housing units in the Highlands Central phase before a second full time road is required. This results in a maximum of 300 homes using the Tyndall Road and Beacon Hill Drive intersection as their day-to-day access and egress. **Access:** Full road access will be provided to Tyndall Road by an extension of Beacon Hill Drive.

HIGHLANDS WEST	
Highlands West	**Feature(s)/Description:** Highlands West is an extension of Highlands Central and is the portion of the Lands accessed via Highlands Central that are beyond the 2,700m and 300 home limit that define Highlands Central. **Access** Full road access will be provided to Tyndall Road by an extension of Beacon Hill Drive to one of: (1) Okanagan Centre Road by the Spine Road (Schedule 7.1.1) or; (2) Chase Road by the 10080 Chase access (Schedule 7.1.4).

GLENMORE RESIDENTIAL	
Glenmore Residential	**Feature(s)/Description:** Glenmore Residential is the portion of the Proposed Development to be located on the two non-contiguous Lakestone parcels, with PID numbers 012-274-526 and 012-274-518. It is conceived as a dense community of 320 homes. **Access** Full road access will be provided to OK Centre Road via a new road (Schedule 7.1.6) and an emergency access to Glenmore Road via the existing Chase Road which connects to it.

2.3 – DENSITY ALLOCATION

GENERAL POLICY

1. So long as the parameters described in this Agreement are adhered to, the internal lot layout may differ from the concept plans shown in the drawings.
2. Expected sanitary and storm loads on the DLC system are described in Schedule 7.
3. Any change in the lot allocation between the Highlands phase and Glenmore phase is considered a Minor Amendment.
4. Exceeding the total density would be considered a Major Amendment.

DENSITY ALLOCATION

Phase (PDA)	**Density**	**Notes**
Highlands East Highlands Central Highlands South Highlands West	Single family: 229 Multi family: 329 Total: 558	
Glenmore Residential	Single family: 59 Multifamily: 265 Total: 324	Previously referred to as the "floating phase"
Sub-Total	**Single family: 288** **Multi family: 594** **882**	

Phase (Master Plan)	**Density**	**Notes**
Developed to date	Single family: 319 Multi family: 114 Total: 433	Waterside, Benchlands and Highlands North
Pending Development: Summit subdivision Lot 80 EPP86639	Single family: 57 Multi family: 8 Total: 65	Currently approved for construction
Sub-Total	**Single family: 376** **Multi family: 122** **Total: 498**	

Lakestone (complete area)	**Density**	**Notes**
Residential Units: Master Plan Sub-Total PDA Sub-Total **Total**	 498 882 1380	
Commercial Floor Area: Master Plan Sub-Total Remaining **Total**	 641.8m^2 7,310.7m^2 7,952.5m^2	6 CRU at The Zara

2.4 – MAJOR SERVICING + PARKS OBLIGATIONS

GENERAL POLICY

1. In order for any Subdivision to occur, certain components described in Schedule 7.1 and 9.1 must have been completed (or satisfactory arrangements for completion made) prior to registration.
2. The obligation will become part of the PLR for any Subdivision.
3. The Works and Services are the extent and limit of the offsite work and infrastructure that the District can require of the Developer in connection with the Proposed Development.
4. The requirements for the applicable Works and Services differ by Phase, and the Phase-specific requirements are listed in the chart below with reference to the applicable schedules and subsections that describe each requirement.

This space intentionally left blank

DEVELOPER'S OBLIGATIONS TRIGGERED BY DEVELOPMENT IN EACH PHASE

TABLE 2.4.1		Cost					Design			Triggering Phase
Area	Project	MLP	District	DCC	Notes	Concept	Detailed	Approval of detail		
Transport	Southern access (Sch. 7.1.1)	✓	✗	✗	All work onsite	Per PDA	MLP	DLC		Highlands South
	OK center road (Sch. 7.1.2)	✗	✓	✓	DCC project	Per PDA	MLP	DLC		Highlands South or Glenmore Residential
	100800 Chase (Sch. 7.1.4)	✗	TBD	TBD	Would be a requirement of any development on this parcel, but its creation unlocks development onsite.	Future developer	Future developer	DLC		
	Emergency access east (Sch. 7.1.5)	✓	✗	✗		Per PDA	MLP	DLC		Highlands East
	Glenmore residential (Sch. 7.1.6)	✓	✗	✗		Per PDA	MLP	DLC		Glenmore Residentia
Storm water	Eastern storm (property to Seaton road) (Sch. 7.1.7)	✓	✗	✗	MLP is responsible for upgrades that will also cover defieciencies in existing district system.	Per PDA	Per PDA	DLC		Highlands East Highlands Central
	Eastern storm (beyond Seaton road) (Sch. 7.1.7)	✗	✓	✗		DLC	DLC	DLC		
	Southern storm (Sch. 7.1.8)	100% of capacity built to service it's development	Costs beyond MPLs share.	✗	MPL will be responsible for any additional capacity added to either direction created by the DLC.	DLC	DLC	DLC		Highlands South
	Glenmore residential (Sch. 7.2.3)	✓	✗	✗		MLP	MLP	DLC		Glenmore Residentia

TABLE 2.4.1

Area	Project	Cost			Notes	Design			Triggering Phase
		MLP	District	DCC		Concept	Detailed	Approval of detail	
Sanitary	Eastern (Sch. 7.2.2)	X	✓	✓	MLP may flow up to 229 SF and 398 MF units to the east which will be taken by District's system. Any flow above that would be the MLPs responsibility.	DLC	DLC	DLC	
	Southern (Sch. 7.2.2)	X	✓	✓	MLP may flow up to 267 MF units to the east which will be taken by District's system. Any flow above that would be the MLPs responsibility.	DLC	DLC	DLC	
	Glenmore residential (Sch. 7.2.2)	X	✓	✓	MLP may flow up to 320 units to the east which will be taken by District's system. Any flow above that would be the MLPs responsibility.	DLC	DLC	DLC	
Potable water	Offsite (Sch. 7.2.1)	X	✓	✓	MLP has built a resevoir onsite to accommodate its planned development. Servicing that resevoir is the District's responsibility. Any offsite upgrades responsibility of DLC. No offsite upgrades are expected to be needed.	DLC	DLC	DLC	
	Glenmore residential (Sch. 7.2.1)	✓	X	X	MLP is responsible for the costs of bringing water from OK center west to the site.			DLC	

SCHEDULE 3

ZONING BYLAW PROVISIONS

DISTRICT OF LAKE COUNTRY - ZONING BYLAW 561, 2007
Excerpt: Section 19.3 CD3 – Comprehensive Development 3 (Lakestone), including amendments up to March 3, 2026

19.3 CD3 – Comprehensive Development 3 (Lakestone)

19.3.1. Purpose

This zone sets out the land use provisions to be constructed in accordance with the 2012 Lakestone Master Plan as approved by Council on May 8, 2012 and as amended from time to time.

19.3.2. Principal Uses

(a) Multiple dwelling housing
(b) Public park and open space
(c) Single dwelling housing
(d) Two dwelling housing
(e) Participant recreational services, outdoor
(f) Personal service establishments
(g) Retail store, convenience

19.3.3. Secondary Uses

(a) Accessory buildings
(b) Accessory uses
(c) Commercial use
(d) Food primary establishment
(e) Home occupations
(f) Recreational tourist accommodation
(g) Strata Hotel/Motels on Lot 94 Sec 9 Twp 20 ODYD Plan EPP74823; 9652 and 9654 Benchland Drive, where a maximum of up to 26 units (30%) are permitted to be used as Strata Hotel/Motel at any one time, and a minimum of five nights is required.
(h) Utility services, minor impact

19.3.4. Conditions of Use

(a) Siting of Building and Structures - Buildings and structures shall be located in accordance with the following:

(i) Front Setback:

a. Apartment housing: 6.0 metres
b. Single, two and multiple dwelling housing: (excluding apartment housing): The minimum front yard is 4.5 m except it is 6.0 m to a garage door or carport entrance having vehicular entry from the front 6.0 m or 4.5 m or 4.5 m from a side entry garage
c. Accessory Buildings: (Same as principal use)
d. All other Uses: 6.0 metres

(ii) Side Setback:

a. Apartment housing: 4.0 metres
b. Single, two and multiple dwelling housing (excluding apartment housing): 2.0 metres
c. Accessory Buildings: (Same as principal use)
d. All other Uses: 2.0 metres
e. 0.0 m for common lot lines intended for semi-detached housing and multiple dwelling housing developments

(iii) Rear Setback:
  a. Apartment housing: 6.0 metres
  b. Single, two and multiple dwelling housing (excluding apartment housing): 6.0 metres
  c. Accessory Buildings: 1.5 metres
  d. All other uses: 6.0 metres

(b) Minimum Lot Area
  (i) Single dwelling housing: 500 square metres
  (ii) Two dwelling housing: 700 square metres
  (iii) Multiple dwelling housing: 850 metres squared
  (iv) All other uses: 600 metres squared

(c) Minimum Lot Width
  (i) Single dwelling housing: 12.5 metres
  (ii) Multiple dwelling housing: 30 metres
  (iii) All other uses: 18 metres

(d) Minimum Lot Depth
  (i) 30 metres

(e) Maximum Height of Buildings and Structures
  (i) Single and two dwelling housing (excluding apartment housing): 9.5 metres, 3 storeys
  (ii) Multiple dwelling housing: 16.5 metres or 4 storeys, whichever is less, where the developer has provided an amenity in compliance with the density bonusing provisions in Section 7.18
  (iii) Accessory Buildings: (Same as principal use)
  (iv) Commercial: 9 metres or 3 storeys, whichever is less
  (v) All other Uses: 5.0 metres

(f) Maximum Lot Coverage
  (i) Maximum Lot Coverage is 40% and together with driveways and parking areas, shall not exceed 50%.

(g) Minimum Floor Area for Dwelling Unit
  (i) Minimum Floor Area for a Dwelling Unit is to be 40 square metres.

(h) Density of Development
  (i) All dwellings: 1365 units to be constructed in accordance with the 2012 Lakestone Master Plan as approved by Council on May 8, 2012 and as amended from time to time.
  (ii) Commercial: maximum 85,600 square feet

(i) Off-street Parking
  (i) Off-street parking is to be in accordance with Section 9.0 of this Bylaw.

(j) Private Open Space
  (i) Within multiple dwelling housing 15.0m^2 of private open space shall be provided per 1 bedroom dwelling and 25.0 m^2 of private open space shall be provided per dwelling with more than 1 bedroom.

(k) Additional Regulations
  (i) In addition to the regulations listed above, other regulations of the District of Lake Country Zoning Bylaw, as amended from time to time, may apply; these include, but are not limited to, the general development regulations of Section 7, the landscaping and fencing regulations of Section 8, the parking and loading regulations of Section 9, the specific use regulations of Section 10, and the sign regulations of Section 11.

SCHEDULE 4
ENVIRONMENTAL, WILDFIRE, GEOTECHNICAL POLICY, AND COMMUNITY SAFETY

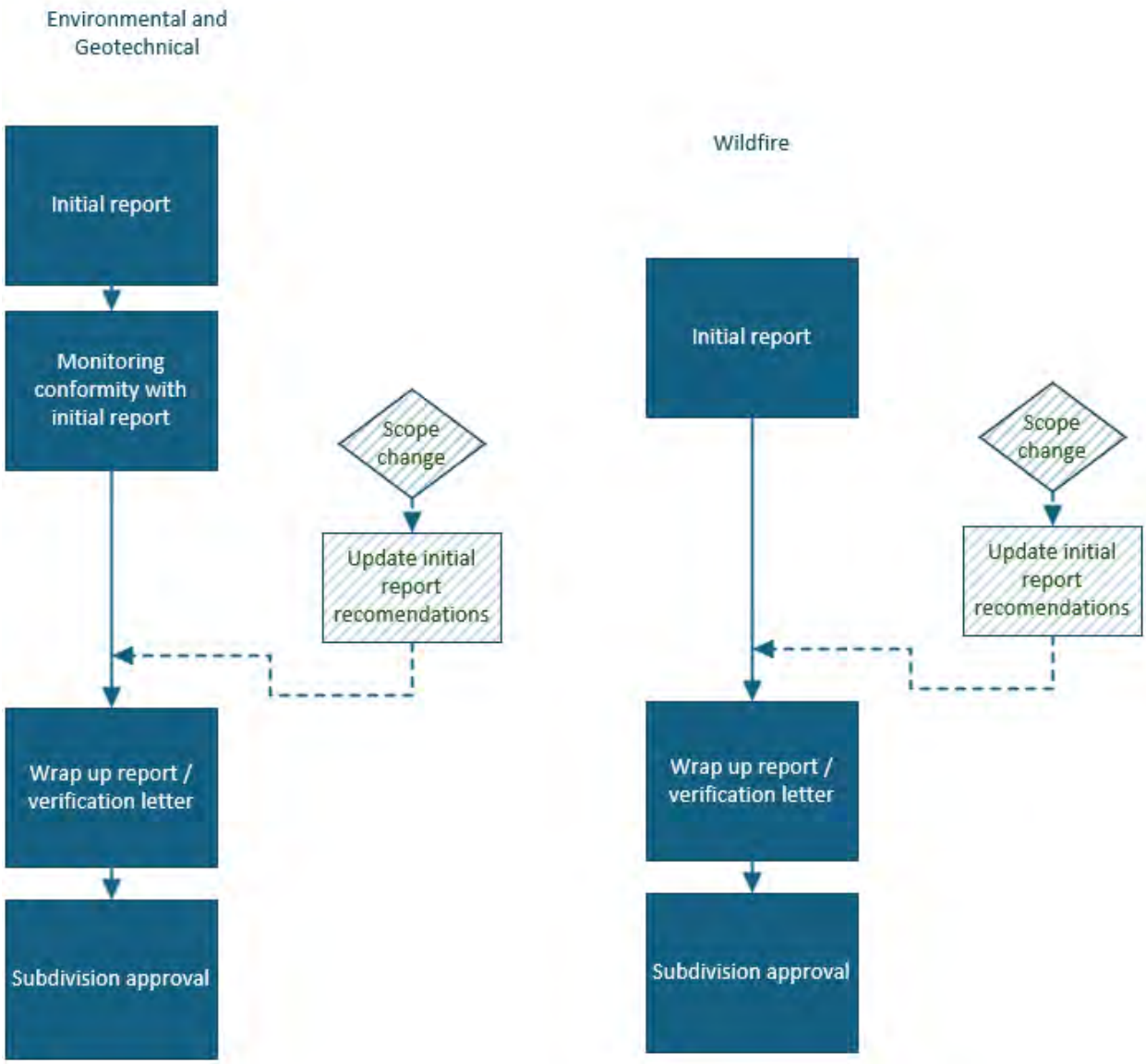
GENERAL POLICY

1. As per the Official Community Plan Section 21.3.1 “Subdivision of land within a development permit area is exempt from applying for and obtaining a development permit except that the Approving Officer shall consider each of the applicable Development Permit Area Guidelines (the “Guidelines”) when processing an application through the Subdivision approval process.”
2. This Schedule provides guidelines on how this obligation will be fulfilled through the Subdivision process.
3. This Schedule provides guidelines on how environmental requirements are to be achieved:
    a. A Phase-specific environmental report will not encompass speculative scenarios or an exhaustive list of potential remediation measures, as these are thoroughly outlined in Appendix 04.01.03 – Environmental & Mitigation Masterplan; and
    b. A Phase-specific environmental report will follow the format provided in section 4.2.
4. This Schedule provides clarity on the formatting of the initial wildfire reports (section 4.3)
5. Geotechnical requirements are satisfied as per the Servicing Bylaw requirements (reproduced in Schedule 4.4)

CONTENTS OF THIS SCHEDULE

4.1 – Flow Chart 2
4.2 – Environmental Requirements 3
4.3 – Fire Mitigation Report 4
4.4 – Geotechnical Report 5
4.5 – Community safety 6

4.1 – FLOW CHART



4.2 – ENVIRONMENTAL REQUIREMENTS

The Qualified Environmental Professional (QEP) Initial reports for each Phase Subdivision will be structured in the following manner:

	Component	Description
1	Executive Summary	Defines the area of disturbance in the Subdivision and speaks to whether the project meets the District's environmental objectives outlined within its relevant bylaws and Official Community Plan.
2	Lakestone Environmental Masterplan findings	Note any features identified in the Lakestone Environmental Masterplan that overlap with the proposed area of disturbance for the Subdivision. (Appendix 04.01.03)
3	Targeted Field Survey findings	Notes on location of any visible snake hibernacula, snags, wildlife trees, potential nesting areas, amphibian presence, badger digs or dens, bat roosts, or other life forms requiring protection under applicable laws that are within the planned area of disturbance for the Subdivision.
4	List of species	Provide a summary of the potential species at risk or critical habitat within 1 km of the boundaries of the Subdivision based on the findings of the Ecoscape 2021 Environmental Assessment and mitigation plan - Lakestone Masterplan (Appendix 04.01.03).
5	Impact statement	Discuss the short- and long-term impacts of the development, considering wildlife connectivity and cumulative effects. If critical habitat loss is to occur, it must be clearly stated, and a rational for why it cannot be avoided must be provided.
6	Mitigation and monitoring	List required mitigation measures as well as relevant monitoring requirements.
7	Restoration Plan	Provide a plan for where and to what degree of restoration of pre-existing environmental conditions shall occur. Include required securities if applicable.
8	Appendices	A figure(s) that overlays the proposed works with the subject property and ESAs

See Ecoscape's Technical Memorandum – Environmental Scope Appendix 04.01.02, 04.01.03 and 04.01.04 (Wildlife Corridor)

4.3 – FIRE MITIGATION REPORT

The Forester's initial reports for each Subdivision will be structured in the following manner:

	Component	Description
1	Executive Summary	Defines the area of disturbance and provides a summary of mitigation work to be completed.
2	Site Plan	A detailed, professionally prepared Site Plan showing all existing and proposed development, site grading, and existing vegetated areas.
3	Landscape Plan	A Landscape Plan showing existing vegetated areas that are to remain undisturbed and any vegetation or trees that will be removed.
4	Description of mitigation	A restatement of the following standards applicable to all Subdivision work done by the Developer: 1. Vegetation within 30m of all proposed structures should be pruned and thinned. Deadfall and other flammable materials should be removed. 2. Remaining trees within 30m of proposed structures should be spaced a minimum of 3m to 6m to prevent the fire from moving from crown to crown. 3. Lower branches should be trimmed up to a minimum of 2.5m in height.

4.4 – GEOTECHNICAL REPORT

GENERAL POLICY

The Geotechnical requirements for each phase of subdivision will include the following:

1. A Landslide Assurance Assessment statement sealed by a Geotechnical Engineer is required prior to final subdivision approval for each future phase. The Geotechnical Engineer will provide review, design, and construction supervision such that, in the engineer's opinion, the site is suitable for the use intended.

2. A Geotechnical Engineer is required to complete all necessary surface and subsurface investigations to provide design recommendations

3. Based on the site topography, it is anticipated that significant lot grading will be required as part of future subdivisions. The owner is required to provide a report prepared by a geotechnical engineer in support of the final lot grading. The Approving Officer may require that the report, complete with an approved lot grading plan showing the area of geotechnical fill, be registered as a Section 219 Land Title Act covenant on the title of all lots affected, as a condition of Final Approval.

4. A post-construction Geotechnical assessment report will be required for inclusion in the Geotechnical Covenant, for registration on title. It must include recommendations for site drainage for the lots, including identifying which lots will have their roof/perimeter drainage directed to the storm system. The report must also include recommendations for maintenance (including frequency) of rock cuts or any other aspects of geotechnical work that require maintenance to be completed by future owners.

5. A 'No Build' Covenant will be required for public retaining walls with geogrid and is to include a survey plan and provide recommendations with setbacks to address acceptable disturbance within the geogrid for structure construction. Recommendations must also include maintenance (if any) and restrictions for permanent placement of other structures (ex. pools, fences, irrigation, sheds, etc.).

4.5 – COMMUNITY SAFETY

GENERAL POLICY

Guiding Safety principles that influence the Proposed Development include:

1. Emergency Access and Egress: The Proposed Development shall maintain a minimum of two evacuation routes for all residents, provided through a combination of permanent public roads and designated emergency access roads. These routes are planned, constructed, and preserved to support safe and efficient evacuation in the event of wildfire.
2. Fire-Smart Construction and Landscaping Requirements: All builders' lots are or shall be subject to registered covenants that enforce FireSmart-aligned construction and design standards (expected to be via the Developers Design Guidelines). These guidelines govern building materials, architectural elements, and landscape requirements to reduce ignition potential and enhance resilience at both the home and neighbourhood level.
3. Parkland Dedication and Proactive Wildfire Mitigation: Wooded areas within each Phase are to be dedicated as parks through the Subdivision process. Prior to dedication—and as part of trail and park construction—certified foresters are to complete wildfire mitigation treatments that meet or exceed the recommendations of the above-referenced Fire Mitigation reports. These longstanding practices have contributed to successful fire mitigation, including the prevention of structural loss during the 2023 wildfire, and continue to receive positive recognition from the District of Lake Country Fire Department as a model for responsible development.

SCHEDULE 5
INTERIM ACCESS AND EGRESS CONDITIONS

GENERAL POLICY

1. The full build out of Phases outlined in this Agreement will have two fully paved access routes (1) via the existing Beacon Hill Drive road to Tyndall Road, (2) down the future Spine Road (Schedule 07.01.01) to OK Centre Road West. There will also be two emergency access points (1) via the existing Long road access to Beacon Hill Drive and (2) via the Sage Glen subdivision to Chase Road which is also existing, but whose access point will change.
2. As an interim condition as the Proposed Development progresses to completion, certain emergency and construction access routes will be maintained on the Lands prior to the second fully paved access route being required.
3. The Developer will maintain these roads pursuant to the requirements set out in this schedule.

LIST OF LAKESTONE SPECIFIC DESIGN STANDARDS

5.1 – Lakestone Emergency Access Road 2
5.2 – Crimson Road Access (Eastern access) 4

5.1 – Lakestone Emergency Access Road

GENERAL CRITERIA

The Lakestone Emergency Access Road will be a private road maintained by the Developer for its use for construction access and for the District and the public's use for emergency access and egress.

5.1.1 – ALIGNMENT

As of the ratification of this Agreement, the Developer has constructed the Lakestone Emergency Access Road pursuant to agreement with the District on its route.

The Developer may reroute the Lakestone Emergency Access Road from time to time to accommodate development of future Phases, provided that it has first received the District's consent, such consent not to be unreasonably withheld or delayed. Any newly aligned road will be built to the same standards as the current road, which are expressed in DP #2022-021.

5.1.2 – RIGHT OF WAY

A charge on title, in favour of the District, on the relevant parcels of the Lands will be registered to give the District the right to use the Lakestone Emergency Access Road and cure rights in the event the Developer breaches its maintenance obligations.

The Right of Way will allow for closures of the Lakestone Emergency Access Road for periods of up to two weeks to accommodate the aforementioned rerouting. The Owner will use commercially reasonable efforts to avoid or minimize temporary road closures.

This space intentionally left blank

5.1.3 – MAINTENANCE

Gravel road maintenance is typically performed on an as-needed basis. However, regular inspections and proactive maintenance are essential to preserving road quality and preventing deterioration. To ensure the Lakestone Emergency Access Road remains in good condition, the following maintenance schedule will be implemented.

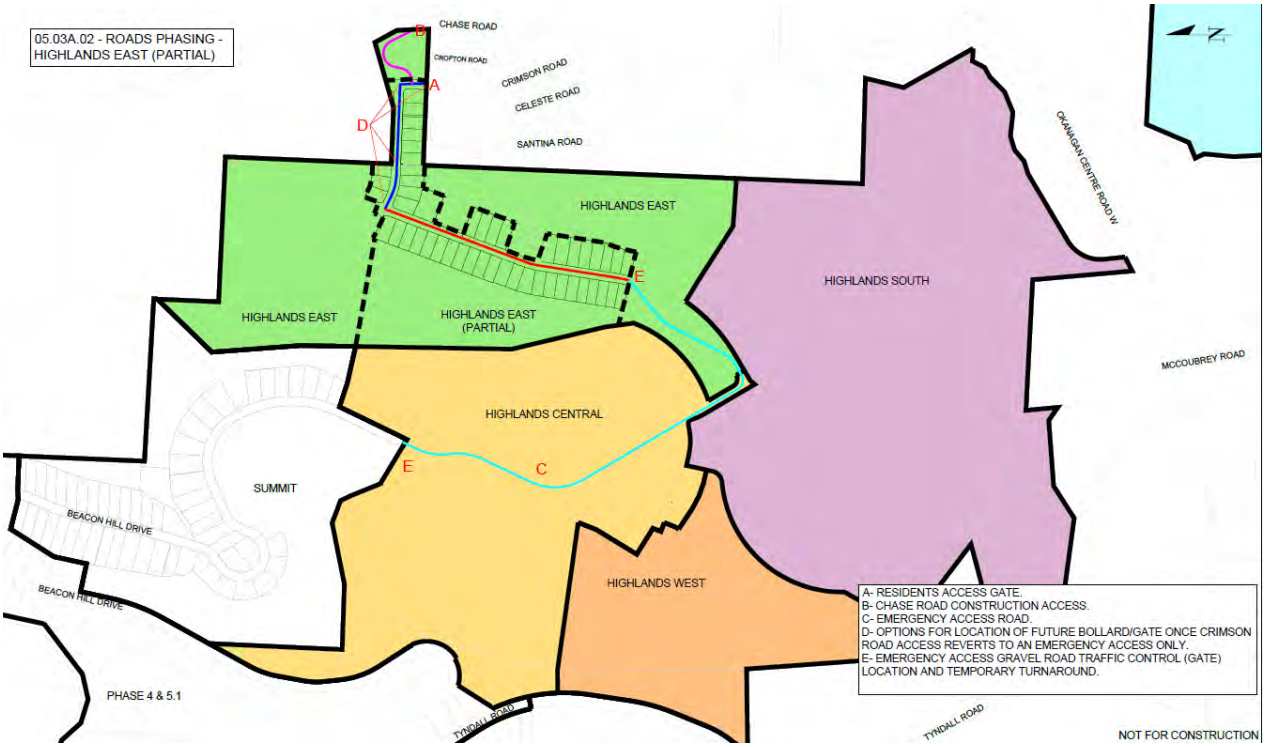
Task	Spring	Fall	Major Storms	Inspection Date & Condition
ROADWAYS				
Clear accumulated winter sand along the roadway and remove false berms.	X			
Maintain the crown of the road surface and shoulder, as needed at least once per year.	X		X	
Clean out sediment within diversions; dips; fords; or high-water bypasses.	X	X	X	
SIDE SLOPES				
Armor eroding areas with riprap or stabilization matting; and/or divert erosive flows to a stable area.			X	
DITCHES AND CULVERTS				
Remove obstruction and accumulated sediment, leaves, and debris.	X	X	X	
Stabilize any erosion.			X	
Remove woody vegetation.		X		
Repair slumping side slopes.			X	
Repair any erosion damage at each culvert inlet.			X	
Dust Controls				
Application of **Formula 35 Premium Dust Control or similar liquid calcium chloride formula for optimal dust control and road stabilization.**	X			Application requirements may change based on construction traffic road use.

5.2 – Crimson Road Access (Eastern access)

GENERAL CRITERIA

1. Full road access to the Highlands East (partial) is to be provided by the road access described in this section. An integral part of this infrastructure is the construction access points contemplated herein, which are designed to minimize construction nuisance to the 25 homes fronting on Crimson Road.
2. At the time of this Agreement, Macdonald Lakeshore Properties Ltd. owns the land required to construct the road connection through what is currently known as 9850 Chase Road.
3. Road construction must be done in a way that provides adequate access for emergency response and minimizes disturbance and delays to the public and District operational staff. The Developer must ensure that its contractors follow the Servicing Bylaw and all applicable Council policies.

OVERVIEW IMAGE



Appendix 05.03A-02 Roads Phasing-Highland East (Partial)

UNIQUE SPECIFICATIONS / VARIANCES

HIGHWAYS AND WALKWAYS

Operation of homeowner access

It will be the responsibility of the Developer to install a gate at the access to the existing Crimson Road into Highlands East (partial) at or about Location A shown above, that will restrict construction traffic from accessing Crimson Road but will allow residents of the 50 homes, as well as municipal and emergency vehicles, access and egress to the paved road network. The Developer will maintain the gate system until no more than 10 of those lots are awaiting occupancy permits.

Operations of Construction Access

Home builders and their contractors will have two options to access Highlands East (partial): via the existing Lakestone Emergency Access Road, or from a new construction access road that will be built on 9850 Chase Road as shown in location B.

The road access via location B is to be a temporary road, will remain private, and is for construction access only. The Developer will be responsible for all maintenance until the road is decommissioned. As it is a private road, typical design bylaws will not apply.

DRAWINGS

Drawing number. Drawing name

- 05.03A.01 - Eastern Access – Crimson
- 05.03A.02 - Roads Phasing – Highlands East (Partial)
- 05.03A.03 - Crimson and Crofton Road Extension

DISTRICT OF LAKE COUNTRY

BYLAW 1121, 2020

CONSOLIDATED VERSION

(Includes amendment as of April 15, 2025)

This is a consolidated copy to be used for convenience only. Users are asked to refer to the Subdivision and Development Servicing Bylaw as amended from time to time to verify accuracy and completeness.

Amending Bylaw	Summary of Amendments	Adoption
1161	Delete & replace sec B.1, F.1, N.9, S.1.3, & T.2 Add figures B-1 & B-2 Add sec B.9, B.10 & Q.1.4 Delete sec Q.2	July 20, 2021
1193	Delete sec H.2, H.2.1 & Q.3.1 (r)	October 4, 2022
1228	Delete and replace sec 9.2. In the entire Bylaw, replacing the words “his”, “her”, or “his or her” with the word “their. Delete and replace the words “direct”, “directed” or “direction” with “require”, “required” or “requirement”, in the following sections: • G.3.1 • H.1.2 • H.1.3 (b) • H.1.3 (c) • I.6.7 • I.7.3 • 1.12.1(a)(iii) • M.18.4.(a). Delete definition of “Preliminary Layout Review”. Delete sec B.2. Delete and Replace sec B.6.2. Add sec B.6.4. Delete and replace sec G.1.5. Delete sec G.1.6. Delete subsection G.3.1 (m). Amened title of Table G-1 Delete texts of footnotes 1, 2, 6, and 7. Delete and replace section G.3.2. Delete and replace G.3.4.	May 21, 2024
1241	Delete and replace Schedule M	September 3, 2024
1262	Delete and replace subsection T.1.4 Cash in Lieu	January 21, 2025
1269	Definitions deleted, replaced, and added Delete and replace subsection C.1.2 Delete subsection C.1.3	

Amendments to Table C-1 Delete and replace subsection I.2.1 Add Table I-I-2 Delete and replace table I.4.1 Add subsection I.4.3 Delete and replace schedule J Delete and replace subsection K.2.1 Delete and replace subsection K.2.3(a) Delete and replace schedule L

DISTRICT OF LAKE COUNTRY
SUBDIVISION AND DEVELOPMENT SERVICING BYLAW 1121, 2020

TABLE OF CONTENTS

CONSOLIDATED VERSION i

1. APPLICATION OF BYLAW 1
2. GRAMMATICAL 1
3. SEVERABILITY 1
4. ENACTMENT 1
5. SCHEDULES 1
6. COSTS BORNE BY OWNER 1
7. DELEGATION 2
8. APPLICATION PROCEDURES 2
9. OWNER'S ENGINEER 2
10. MMCD 3
11. DUTY OF CARE 3
12. COMPLIANCE 3
13. OFFENCE AND PENALTY 4
14. RIGHT TO ENTER 4
15. REPEALS 4
16. CITATION 4

SCHEDULE A DEFINITIONS 5

SCHEDULE B APPLICATION REQUIREMENTS 9

B.1 General 9
B.2 *Section deleted by Bylaw 1228, 2024* 13
B.3 Phased Strata or Strata Conversion 13
B.4 Building Permit 13
B.5 Subdivision 14
B.6 Exemptions 14
B.7 Statutory Rights of Way 15
B.8 Construction Contractors 16
B.9 Engineering Design Submissions 16

B.10	Variances	17
SCHEDULE C	**SERVICING REQUIREMENTS**	**18**
SCHEDULE D	**GENERAL REQUIREMENTS**	**19**
D.1	Geotechnical Requirements	19
D.2	Removal of Accumulated Soils	19
D.3	Systems Modelling	19
D.4	Test Procedures	19
D.5	Existing Structure or Utility	20
D.6	Obstructions and Repair	20
D.7	Protection from Damage	20
D.8	Connection to or use of Existing Works	20
D.9	Flushing	20
SCHEDULE E	**SUPPLEMENTALS TO THE MMCD SPECIFICATIONS**	**21**
E.1	General	21
E.2	Supplemental MMCD Tables	29
SCHEDULE F	**QUALITY CONTROL AND QUALITY ASSURANCE**	**31**
F.1	Administration and Design Requirements	31
SCHEDULE G	**DESIGN AND CONSTRUCTION OF HIGHWAYS AND WALKWAYS**	**32**
G.1	General	32
G.2	Classification of Highways	33
G.3	Transportation Requirement Assessment	33
G.4	Consistency with Official Community Plan	35
G.5	Local highways	35
G.6	Culs-de-sac	35
G.7	Lanes	35
G.8	Walkways	35
G.9	Transit Bays	36
G.10	Intersections	36
G.11	Reverse Curves	36
G.12	Mailboxes	36
G.13	Road Names, Traffic Signs, and Pavement Markings	36
G.14	Appurtenances	37
G.15	Vertical Alignment	37
G.16	Design Speeds	37
G.17	Road Crossfall	37
G.18	Road Grades	37
G.19	Vertical Curves	38
G.20	Horizontal Alignment	38
G.21	Intersection Design	39
G.22	Intersection Grades	39
G.23	Subgrade Preparation	39
G.24	New Pavement Design	41
G.25	Standard Pavement Structures	42
G.26	Design of Overlays for Existing Pavements	45

G.27	Materials	45
G.28	Testing	49
G.29	Notification	50
G.30	Testing Frequency and Procedures	50
G.31	Non-Compliance with Specifications	51
G.32	Penalty for Non-Compliance	52
SCHEDULE H	**DESIGN AND CONSTRUCTION OF SIDEWALKS, CURBS, GUTTERS, BOULEVARDS AND LANDSCAPING**	**54**
H.1	General	54
H.2	Driveway Access – *deleted by Bylaw 1193, 2022*	54
H.3	Wheelchair Ramps	54
H.4	Barrier Curb Crossing	54
H.5	Landscaping	55
H.6	Irrigation	58
SCHEDULE I	**DESIGN AND CONSTRUCTION OF WATER DISTRIBUTION SYSTEMS**	**62**
I.1	General	62
I.2	Capacity of System and Sizing of Water Mains	62
I.3	Domestic Demand Criteria	63
I.4	Fire Demand Criteria	63
I.5	Design Pressures	64
I.6	Location and Grade of Water Mains	64
I.7	Services	65
I.8	Blow Offs	66
I.9	Water Sampling Stations	66
I.10	Air Valves	67
I.11	Fire Hydrants	67
I.12	Valving	67
I.13	Thrust Blocking	68
I.14	Reservoirs	68
I.15	Pump Stations	69
I.16	Pressure reducing valve (PRV) Stations	72
I.17	Facility Access	72
I.18	Waterworks Approved Materials	72
SCHEDULE J	**DESIGN AND CONSTRUCTION OF A WATER SUPPLY**	**73**
J.1	General	**Error! Bookmark not defined.**
J.2	Water supply	**Error! Bookmark not defined.**
J.3	Requirements for Wells	**Error! Bookmark not defined.**
J.4	Requirements for Surface Water supplys	**Error! Bookmark not defined.**
SCHEDULE K	**DESIGN AND CONSTRUCTION SANITARY SEWER SYSTEMS**	**74**
K.1	General	74
K.2	Design Flows	74
K.3	Pipe Flow Formulas	75
K.4	Minimum Grade	75
K.5	Alignment of Sewer Mains	76

K.6	Service Connections	76
K.7	Minimum Sewer Main Diameter	77
K.8	Depth of Cover	77
K.9	Manholes	78
K.10	Hydraulic Losses Across Manholes	78
K.11	Clean-Outs	78
K.12	Sanitary Lift Stations	79
K.13	Operation and Maintenance Manual	82
K.14	Sanitary Force Mains	83
K.15	Noise Control Criteria	83
K.16	Corrosion and Odour Criteria	83
SCHEDULE L	**DESIGN AND CONSTRUCTION SEPTIC SYSTEM**	**84**
L.1	General	84
SCHEDULE M	**DESIGN AND CONSTRUCTION OF STORM DRAINAGE SYSTEMS**	**85**
M.1	General	85
M.2	Design Overview	86
M.3	Runoff Analysis	87
M.4	Site Design	92
M.5	Minor System	93
M.6	Major System	105
M.7	Detention Facilities	108
M.8	Erosions Control	112
M.9	Stormwater Quality	113
M.10	Pumping Systems	116
SCHEDULE N	**DESIGN AND CONSTRUCTION OF SEDIMENT AND EROSION CONTROL SYSTEMS**	**117**
N.1	General	117
N.2	Design Criteria	117
N.3	Clearing Limits	117
N.4	Cover Measures	117
N.5	Perimeter Protection	117
N.6	Traffic Area Stabilization	118
N.7	Sediment Retention	118
N.8	Surface Water Controls	118
N.9	Drainage, Sediment and Erosion Control Plan	118
N.10	Construction within sensitive areas and buffers	118
N.11	Maintenance	118
N.12	Final Stabilization	119
SCHEDULE O	**DESIGN AND CONSTRUCTION OF STREET LIGHTING**	**120**
O.1	General	120
O.2	Design Criteria	120
O.3	Decorative Street lighting	120
O.4	Codes and Standards	121
O.5	Permits	122
O.6	Levels of Illumination	122

O.7	Light Loss Factor	122
O.8	Pole Specifications	122
O.9	Products	123
O.10	Scheduling	123
O.11	Approval	123
O.12	Connection to Utility	123
SCHEDULE P	**DESIGN AND CONSTRUCTION OF ELECTRICAL AND COMMUNICATIONS WIRING AND GAS DISTRIBUTION SYSTEMS**	**124**
P.1	General	124
P.2	Utility Locations	124
SCHEDULE Q	**DESIGN AND CONSTRUCTION OF HILLSIDE DEVELOPMENT AREAS**	**125**
Q.1	General	125
Q.2	Pre-design Report – *deleted by Bylaw 1161, 2021*	125
Q.3	Detailed Design	125
SCHEDULE R	**DRAWINGS**	**130**
R.1	General	130
R.2	MMCD	130
R.3	As-Constructed Drawings	130
R.4	Design Drawings	130
R.5	Standard Drawings	130
R.6	Preparation	131
R.7	Sheet Layout	131
R.8	Dimensions and Units	131
R.9	Lettering	132
R.10	Scales	132
R.11	Title Page	132
R.12	Key Plans	132
R.13	Building Envelope Plan	133
R.14	Composite Utility Plan	133
R.15	Plan and Profile Drawings	133
R.16	Electronic Drawings	135
SCHEDULE S	**FORMS, AGREEMENTS, AND CERTIFICATES**	**136**
S.1	Subdivision and Development Servicing Agreement	136
S.2	Commitment by Owner and Engineer	137
S.3	Commitment to Design and Field review	137
S.4	Certificate to Commence Construction	137
S.5	Certification of Bylaw Compliance	138
S.6	Certification of Slope Stability	139
S.7	Certification of Total Performance	139
S.8	Maintenance Security Agreement	139
SCHEDULE T	**FEES AND SECURITY**	**141**
T.1	Fees and Deposits	141
T.2	Fees	142

LIST OF TABLES

TABLE C-1 SERVICING REQUIREMENTS....18
TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS....21
TABLE E-2-WATERWORKS APPROVED MATERIALS (MMCD 33 11 01 Section 2.0)....27
TABLE E-3-PHYSICAL PROPERTIES FOR GRANULAR SUB-BASE AND CRUSHED GRANULAR BASE COURSE....29
TABLE E-4-SELECT GRANULAR SUB-BASE GRADATION....29
TABLE E-5-GRANULAR BASE GRADUATIONS....29
TABLE E-6-HOT-MIX ASPHALT AGGREGATE GRADATION SPECIFICATION....29
TABLE E-7-SPECIFIED PHYSICAL REQUIREMENTS OF HOT-MIX ASPHALT....30
TABLE E-8-MIXING TOLERANCES....30
TABLE G-1-TYPICAL HIGHWAY CROSS SECTION REQUIREMENTS AND AMENITIES....34
TABLE G-2-DESIGN SPEED....37
TABLE G-3-HIGHWAY GRADES....37
TABLE G-4-MINIMUM K VALUES FOR VERTICAL CURVE DESIGN (METRES)....38
TABLE G-5-MINIMUM CENTRE LINE RADIUS....38
TABLE G-6-CURB RETURN RADII....38
TABLE G-7-INTERSECTION CURVES MINIMUM K VALUES....39
TABLE G-8-DESIGN CRITERIA FOR LIMITED ADVERSE TOPOGRAPHIC CONDITIONS....39
TABLE G-9-MINIMUM ASPHALT AND GRANULAR BASE DEPTH VS DESIGN TRAFFIC....42
TABLE G-10-STANDARD PAVEMENT STRUCTURES....43
TABLE G-11-EXAMPLE PAVEMENT STRUCTURE [1]....44
TABLE G-12-BENKELMAN BEAM CRITERIA FOR OVERLAYS....45
TABLE G-13-CRUSHED GRANULAR SUB-BASE LIMITS....46
TABLE G-14-GRADATION OF CRUSHED GRANULAR AGGREGATE FOR ASPHALTIC CONCRETE....46
TABLE G-15-TOLERANCE LIMITS....47
TABLE G-16-ASPHALTIC CEMENT....48
TABLE G-17-ASPHALTIC CONCRETE....48
TABLE G-18-ASPHALTIC CONCRETE CONSTRUCTION....49
TABLE G-19-CONSTRUCTION NOTIFICATION REQUIREMENTS....50
TABLE G-20 -PAYMENT ADJUSTMENT FOR NON-COMPLIANCE WITH TOLERANCE....51
TABLE G-21-PAYMENT ADJUSTMENT FOR DENSITY NON-COMPLIANCE....52
TABLE I-I-1- DAILY DOMESTIC DEMAND CRITERIA....63
TABLE I-2-COMMUNITY WATER SYSTEM DENSITIES....63
TABLE I-3- REQUIRED FIRE FLOW.... Error! Bookmark not defined.
TABLE K-1-SANITARY SEWER SYSTEM DENSITIES....74
TABLE O-1 LEVELS OF ILLUMINATION....122
TABLE Q-1 -HILLSIDE DEVELOPMENT STANDARDS....127
TABLE Q-2-HILLSIDE ALIGNMENT DESIGN CRITERIA....128
TABLE T-1-MAINTENANCE SECURITY TABLE[1]....141

LIST OF FIGURES

FIGURE B-1....10
FIGURE B-2....11
FIGURE G-1....44
FIGURE M-1....101
FIGURE O-1 Bottom Wood Lake/Woodsdale Roads....120
FIGURE O-2 Town Centre Road....121

DISTRICT OF LAKE COUNTRY

BYLAW 1121

A BYLAW TO REGULATE THE PROVISION OF WORKS FOR SUBDIVISION AND DEVELOPMENT OF LAND

The **Council** of the **District** of Lake Country, in open meeting, enacts as follows:

1. **APPLICATION OF BYLAW**

1.1. This Bylaw applies to all land, buildings and structures within the geographical area incorporated as the **District** of Lake Country.

1.2. All works required in this bylaw apply to all **Owners** who make an application for **Subdivision** or **Development** unless the **District** determines that the proposed Subdivision or **Development** does not require works.

1.3. All works required in this Bylaw shall be designed and constructed in accordance with the provisions of this Bylaw.

2. **GRAMMATICAL**

2.1. In this Bylaw the singular shall also include the plural, and the masculine shall also include the feminine.

3. **SEVERABILITY**

3.1. If any part of this Bylaw is for any reason held invalid by any court of competent jurisdiction, the invalid portion shall be severed and the severance shall not affect the validity of the remainder of this Bylaw.

4. **ENACTMENT**

4.1. Any enactment referred to herein is a reference to an enactment of British Columbia and regulations thereto, as amended, revised, consolidated or replaced from time to time.

4.2. Any Bylaw referred to herein is a reference to an enactment of the **Council** of the **District** of Lake Country, as amended, revised, consolidated or replaced from time to time.

5. **SCHEDULES**

5.1. Schedules A through T are attached to and form part of this bylaw and are enforceable in the same manner as this bylaw.

6. **COSTS BORNE BY OWNER**

6.1. The **Owner** shall bear sole responsibility for all costs related to documentation, design, provision of works and fees or charges required under this Bylaw.

7. DELEGATION

7.1. The **District Engineer** is hereby delegated the powers to execute and amend all forms related to this Bylaw, including:

(a) Statutory Right of Way;
(b) Subdivision and **Development** Servicing Agreement;
(c) Maintenance Agreement;
(d) Section 219 Covenant for Onsite Water Treatment;
(e) Section 219 Covenant for Septic system;
(f) Drawing Standards Policy; and
(g) Latecomer Agreements.

7.2. Delegation contained with this Bylaw includes the successor, lawful deputy, and any person designated to act in their place.

8. APPLICATION PROCEDURES

8.1. Under the procedures set out in this Bylaw, if an Owner of land intends:
(a) to subdivide a parcel of land; or
to develop a parcel of land the **Owner** must make application to the **District** for **subdivision** or **development**.

8.2. An application must:
(a) be signed by the Owner of each parcel of land that is the subject of the application or by a person authorized in writing by the Owner to act as their agent for the purpose of making the application;
(b) be made in writing on the application forms prescribed by the **District**;
(c) include the information required under this Bylaw; and
(d) be accompanied by the applicable fees.

9. OWNER'S ENGINEER

9.1. Unless exempted by the **District Engineer** the **Owner** must retain, at the **Owner's** sole expense, a Professional Engineer who shall:
(a) prepare engineering design drawings in accordance with the provision of this bylaw.
(b) be responsible for the design, layout, approval of materials, field reviews of installation, information for and certification of as-built drawings and documents, for all services that are the responsibility of the **Owner** under this Bylaw;
(c) be responsible for coordinating communication between the **District** and the **Owner**, the **Owner's Engineer**, and the **Contractor**.
(d) ensure that the work is performed in accordance with all applicable laws, ordinances, rules, regulations, codes, Bylaws, and orders of the **District** or other authorities having jurisdiction.
(e) ensure all permits, licenses, approvals and certificates required for the performance of the work are obtained

Deleted and replaced by Bylaw 1228, 2024

9.2 If the Owner's Engineer can demonstrate and certifies that an alternative solution meets the intended safety, operational and functional objectives set out in the provisions of this bylaw, then, the District Engineer may permit the alternative solution. Notwithstanding permission granted by the District Engineer in this section, the Owner and Owner's Engineer retain full responsibility for the alternative

solution. The District Engineer may require third-party consulting engineer to evaluate the alternative solution, at the Owner's Expense."

10. **MMCD**

10.1. **MMCD** Specifications are hereby incorporated by reference into and form part of this Bylaw.

10.2. **MMCD** Specification provisions shall apply to all works constructed within the **District**. Where the provisions contained in this Bylaw are in conflict with the **MMCD** Specifications, this Bylaw shall supplement or supersede the **MMCD** Specifications.

11. **DUTY OF CARE**

11.1. This Bylaw does not create any duty at law on the part of the **District**, its **Council**, **District Engineer**, officers, employees or other representatives concerning anything contained in this Bylaw. All works, services, improvements and all matters required pursuant to this Bylaw are the responsibility of the **Owner** and **Applicant** and all persons acting on their behalf. No approval of any kind, certificate, permit, review, inspection, or other act or omission by the **District** or any of its representatives, including any enforcement, or lack of enforcement of the provisions of this Bylaw shall relieve the **Owner** and **Applicant** and all persons acting on their behalf from this duty pursuant to this Bylaw and shall not create any cause of action in favour of any person against the **District**, its **Council, District Engineer**, officers, employees or other representatives concerning anything contained in this Bylaw.

12. **COMPLIANCE**

12.1. No parcel may be subdivided or **developed** unless the subdivision or **development** conforms to the provisions set out in this Bylaw.

12.2. The **District Engineer** or the **Building Inspector** may issue a compliance order to the **Owner** or any other person found to be in contravention of this Bylaw, which may:

(a) require a person who contravenes this Bylaw to comply with the Bylaw within a time limit specified in the order;
(b) include an order to Stop Work or otherwise cease construction or **development** of works;
(c) require tests and evidence of proof of materials, equipment devices, construction methods, assemblies or soil conditions meet the requirements of this Bylaw;

12.3. If a compliance order is issued, approval may not proceed until the **District Engineer** or **Building Inspector** is satisfied that the required actions or repairs and any required fees or charges have been paid;

12.4. All costs associated with rectifying non-compliance issues shall be the sole responsibility of the Owner.

12.5. If the required actions or repairs, or any part thereof, are not completed in accordance with the provisions of this Bylaw the **District** may draw funds from the Letter of Credit and may complete the works at the expense of the Owner. If there is insufficient security, then the **Owner** will pay such deficiency to the **District** immediately upon receipt of an invoice from the **District**. The **District** may do such work either by itself, or by **contractor**s employed by the **District**.

13. **OFFENCE AND PENALTY**

13.1. Any person who violates any provision of this Bylaw or who suffers or permits any act or thing to be done in contravention or in violation of any of the provisions of this Bylaw or who neglects to do or refrains from doing anything required to be done by any of the provisions of this Bylaw, commits an offence and is liable on summary conviction to a penalty not exceeding Fifty Thousand Dollars ($50,000.00) plus the cost of prosecution.

13.2. Each day that the violation continues to exist shall constitute a separate offence

14. **RIGHT TO ENTER**

14.1. The **District Engineer**, **Approving Officer**, and the **Building Inspector** or their designates shall have the right to enter upon the property of any **Owner** or occupier at all reasonable times and in a reasonable manner for the purposes of inspecting property and declaring whether the property is otherwise not in compliance with the provisions of this Bylaw

15. **REPEALS**

15.1. Subdivision and Development Servicing Bylaw 985, 2016, and all amendments thereto, are hereby repealed in their entirety.

16. **CITATION**

16.1. This bylaw may be cited as “Subdivision and Development Servicing Bylaw 1121, 2020".

READ A FIRST TIME this 5th day of May, 2020.
READ A SECOND TIME this 5th day of May, 2020.

READ A THIRD TIME this day of, 2020.

ADOPTED this 20th day of October, 2020.

Original signed by James Baker
Mayor

Original signed by Reyna Seabrook
Corporate Officer

I hereby certify the foregoing to be a true and correct copy of the Bylaw cited as “Subdivision and Development Servicing Bylaw 1121, 2020”, as adopted by the Municipal Council on the 20th day of October, 2020.

Dated at Lake Country, B. C.

Corporate Officer

SCHEDULE A DEFINITIONS

A.1.1 Unless otherwise defined in this Bylaw, a word or expression in this Bylaw has the meaning assigned to it in the *Local Government Act, Interpretation Act, Community Charter, Transportation Act* or *Land Title Act* or any of successor legislation.

(a) In this Bylaw:

"Applicant" means an **Owner** of land or their agent duly authorized in writing, who applies for approval to subdivide or develop that land.

"Approving Officer" means the person appointed as the Approving Officer of the District of Lake Country, or their designate, appointed pursuant to the provisions of the *Land Title Act*.

"arterial highway" means a highway where the primary use is to provide connection from collector highways to other collector highways with limited access from local highways.

"boulevard" means that portion of highway between:
(a) the curb and the adjoining property,
(b) the curb and a separate sidewalk,
(c) the road boundary and the adjoining property, and
(d) the curb lines on the median strips or islands.
does not include curbs, sidewalks, ditches, or driveways.

"Building Inspector" means the person appointed by the District as the Chief Building Inspector or their designate.

"Certificate of Total Performance" means documentation signed by the District Engineer indicating that total performance has been achieved and approved in accordance with this Bylaw.

"collector highway" means a highway where the primary use is to provide connection from local highways to other collector highways and arterial highways while providing limited access to properties.

"community sewer system" means a system of works for the collection, treatment, and disposal of sewage that is owned, operated, and maintained by the District.

"community water system" means a system of works for the distribution of water and connection to a system of water works as referred to in Part 2 of the *Drinking Water Protection Act* which is owned, operated, and maintained by the District, or a private water utility.

"contractor" means the person, firm or corporation retained by the Owner, directly or indirectly to construct, erect, or install the works.

"Council" means the elected Council of the District of Lake Country.

"cul-de-sac" means a highway which has only one point of intersection with another highway except for access by way of emergency access, and that terminates in a vehicle turning area that is to be permanently closed.

"**designated integrator"** means the company or individual designated by the **District** to carryout PLC, HMI, and SCADA programming.

"development" or **"developed"** means the construction, alteration, or extension of buildings and/or structures for any use authorized by the Zoning Bylaw that requires issuance of a Building Permit or through an approved Development Permit, but does not include internal alterations of a building and/or structure where the principal use of the building and/or structure, or part thereof, is not changing. The altering of land for any use authorized under the Zoning Bylaw or through an approved Development Permit is considered to be Development.

"District" means the municipality of the District of Lake Country.

"District Engineer" means the Director of Engineering and Environmental Services for the District of Lake Country or their designate.

added by bylaw 1269, 2025
"dwelling unit" has the same meaning as the **District's** Zoning Bylaw

"engineer" means a person who is registered, or duly licensed as such, under the provisions of the *Engineers and Geoscientists Act of British Columbia*.

***"*field reviews"** mean such reviews of the *works*:

(a) at the site of subdivision or development to which the subdivision application or building permit relates, and
(b) where applicable, at the fabrication site where components of the required works are fabricated,

that the Owner's Engineer, in their professional discretion, considers to be necessary in order to ascertain that the *work* conforms in all material respects to the design drawings and supporting documents prepared by the Owner's Engineer and marked, "Reviewed for Construction" by the District Engineer. This will include keeping record of all site visits and any corrective actions taken as a result thereof.

"final approval" with respect to subdivision, means approval of a subdivision pursuant the *Land Title Act* and; with respect to development, means issuance of a Certificate of **Substantial Completion**.

"frontage" means the width of a parcel measured along the shortest parcel boundary which immediately adjoins a highway other than a lane or a walkway.

"geoscientist" means a person who is registered, or duly licensed as such, under the provisions of the *Engineers and Geoscientists Act of British Columbia*.

"highway" means a public street, road, trail, lane, bridge, trestle, tunnel any other public way or any other land or improvement that becomes or has become a highway by any of the following:

(a) deposit of a subdivision, reference or explanatory plan in a land title office under section 107 of the Land Title Act;
(b) a public expenditure to which section 42 applies;
(c) a common law dedication made by the government or any other person;
(d) declaration, by notice in the Gazette, made before December 24, 1987;
(e) in the case of a road, colouring, outlining or designating the road on a record in such a way that section 13 or 57 of the Land Act applies to that road;
(f) an order under section 56 (2) of this Act;

(g) any other prescribed means;
added by bylaw 1269, 2025
"Infill housing" means **Development** of four (4) units or less within existing urban areas serviced by municipal infrastructure

"local highway" means a highway where the primary use is to provide access to properties while providing limited access to other local highways and collector highways.

"lane" means a highway intended to provide secondary access to parcels of land.

"minimum building elevation" means the elevation of the underside of the lowest floor in a building or if lower, the lowest floor elevation in a crawl space.

"MMCD" means the Master Municipal Construction Specifications, 2009 Platinum Edition Volume II, prepared by the Master Municipal Construction Document Association as amended from time to time.

Definition of "offsite" deleted by Bylaw 1269, 2025

Definition of "onsite" delete by Bylaw 1269, 2025

added by Bylaw 1269, 2025
"Onsite Water Supply" means a way of providing water to a property through any method other than a **Community Water System,** as defined herein.

"**Overhead wiring"** means the installation of above ground electrical and communication wiring usually installed from pole to pole.

"**Owner**" means, in respect of real property, the person registered as an Owner of an estate in fee simple, the tenant for life under a registered life estate, or the registered holder of the last registered agreement for sale, and includes their agent duly authorized in writing.

"Owner's Engineer" means the engineer or firm of engineers engaged by the Owner to design and prepare engineering drawings for a subdivision or development and to co-ordinate all design work and quality assurance/quality control required for the works under the provisions of this Bylaw.

"parcel" means any lot, block, or other area in which land is held or into which land is subdivided but does not include a highway.

Preliminary Layout Review definition deleted by Bylaw 1228, 2024.

"private water utility" means a water utility operated under the authority of the Comptroller of Water Rights.

"repair(s)" means restore to original or new condition.

"reviewed for construction" means documents, including construction drawings that have been reviewed by the District and stamped as such.

"road" means the portion of the highway that is improved, designed, or ordinarily used for vehicular traffic and excludes the road shoulder.

Definition of "Sewerage System" deleted by Bylaw 1269, 2025

added by Bylaw 1269, 2025
"Septic System" means a privately owned, onsite wastewater disposal system. **Septic Systems** are wholly regulated by the Province of British Columbia.

"sidewalk" means a concrete-surfaced pedestrian walkway.

"**steep slopes**" means lands in their natural state that have a slope angle of 20% or greater for a minimum horizontal distance of 10 meters, or adjacent areas where existing or potential sloughing or stability warrants concern. The definition applies to all properties which are 0.5 hectares or greater in size, and where 10% or greater of the parent property contains slope of more than 20%.

"storm drainage system" means a system of works designed and constructed for the collection, direction, storage, treatment and disposal of **stormwate**r, snow melt and/or ground water.

"**stormwater**" means water resulting from natural precipitation, groundwater that has surfaced, and water from street cleaning.

"street lighting" means single or double davit or ornamental streetlights serviced by underground or overhead wiring.

"subdivision" means a subdivision as described in the *Land Title Act*.

"substantial performance" means the stage of completion of works, certified by the Owner's Engineer when:
(a) all portions of the works are ready for use or are being used for the intended purpose; and
(b) the total of the incomplete, defective and deficient works can be completed at an estimated cost of no more than 3% of the total value of the works.

"surveyor" means a person entitled to practise as a land surveyor under the *Land Surveyors Act* in the province of British Columbia.

"total performance" means the stage of completion of the works, certified by the District Engineer when all works including deficiencies have been completed in accordance with this Bylaw.

"Transportation for Tomorrow" means the District's Transportation for Tomorrow Plan as adopted by Council and amended from time to time.

"underground wiring" means electrical and communications wiring installed underground in ducts or by direct bury with an alignment approved by the service provider.

"walkway" means a highway intended for pedestrian and non-motor traffic save and except for maintenance vehicles, emergency vehicles, and conveyances used by persons with disabilities.

amended by Bylaw 1269, 2025
"Water Distribution System" means a network of infrastructure that delivers water from a source to end users, ensuring sufficient water pressure and storage capacity to support firefighting needs as required by this Bylaw.

Definition of "water source" deleted by Bylaw 1269, 2025

Definition of "water supply" deleted by Bylaw 1269, 2025

"work(s)" means infrastructure and services and includes highways, sidewalks, boulevard, boulevard crossings, transit bays, street lighting, wiring, water distribution systems, walkways, roads, sewage collection and disposal systems, drainage collection and disposal systems, paving, curbs and gutters, and such other infrastructure, systems and any other improvements required to be constructed, erected, or installed, both onsite and offsite, under the provisions of this Bylaw.

"zone" means an area created by the District Zoning Bylaw.

SCHEDULE B APPLICATION REQUIREMENTS

B.1 General

Section B.1 deleted and replaced by Bylaw 1161, 2021

B.1.1 An **Applicant** for a **subdivision** or **development** may request a pre-application meeting prior to submitting an application under this Bylaw.

B.1.2 The **Owner's Engineer** shall ensure that all inspections and testing are carried out in accordance with the provisions of this Bylaw.

B.1.3 Figures B-1 and B-2 summarize the steps for completing the works and services required under this Bylaw.

B.1.4 It is the **Applicant**'s responsibility to ensure that the requirements, regulations, and approval procedures of all agencies are met. Where the standards and specifications of other agencies having jurisdiction conflict with this Bylaw, the more stringent standards and specifications shall apply.

Figures B-1 and B-2 added by Bylaw 1161, 2021

FIGURE B-1 Subdivision and Development Servicing Process

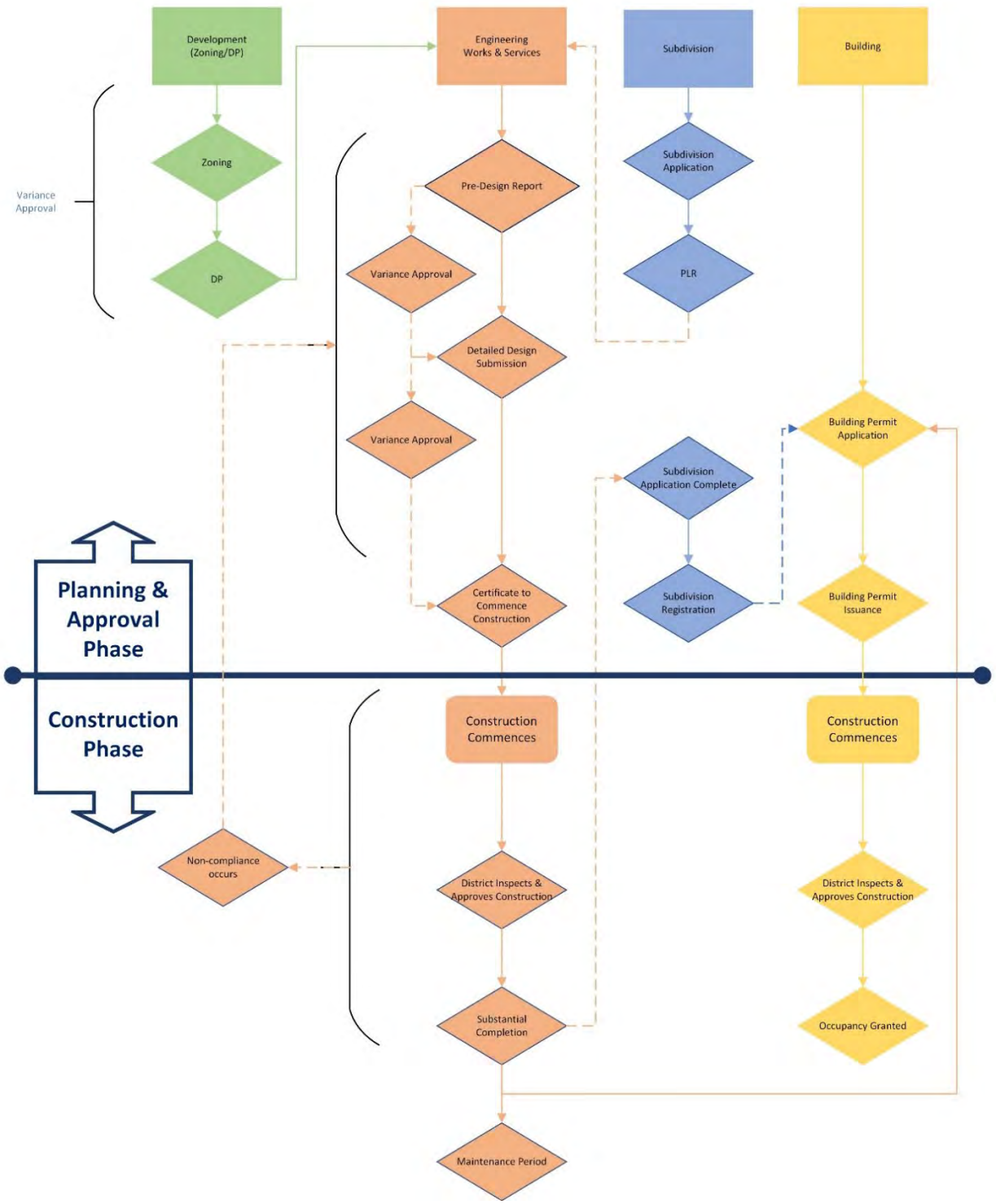


FIGURE B-2 Works and Services Application Process

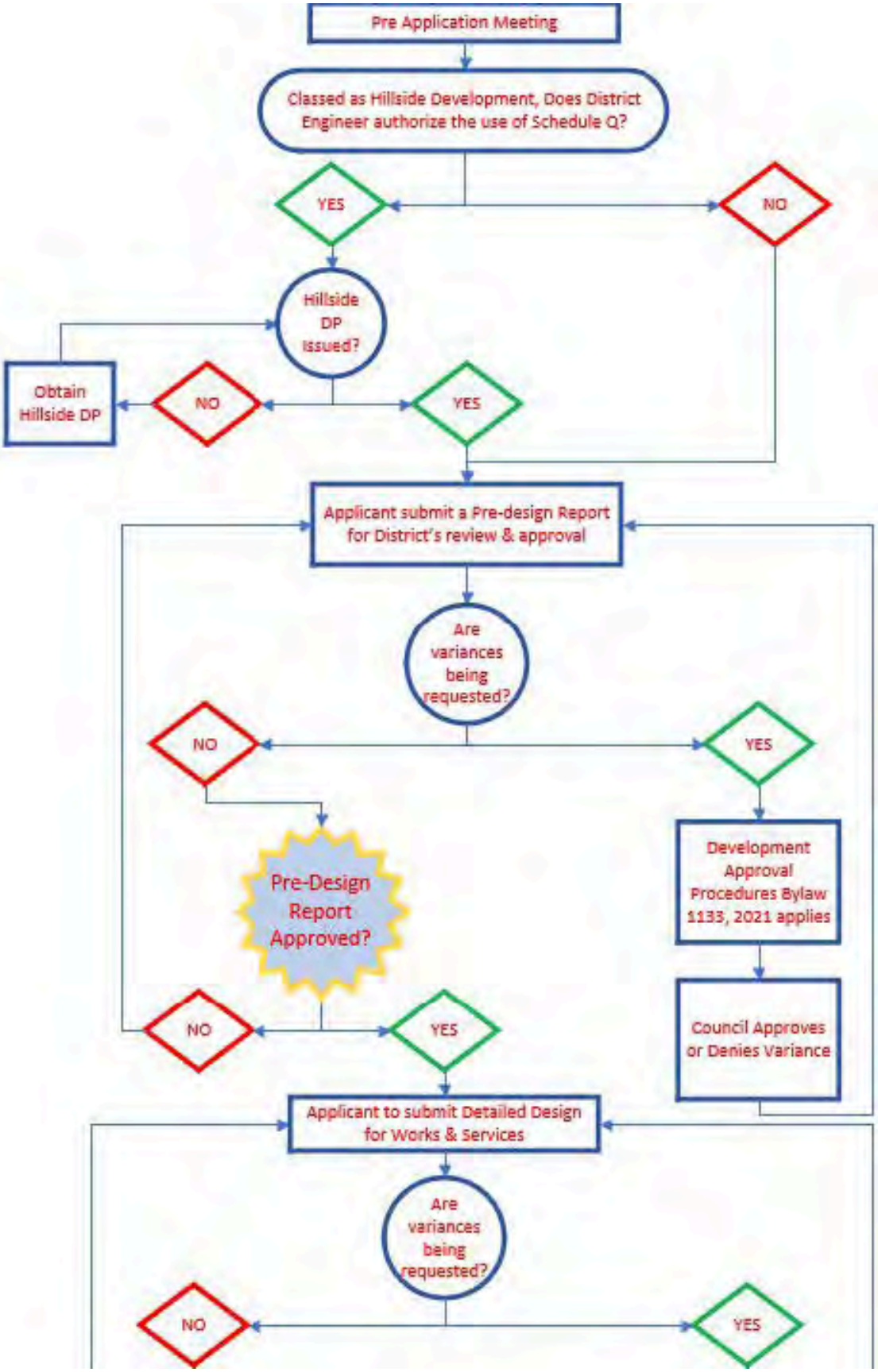
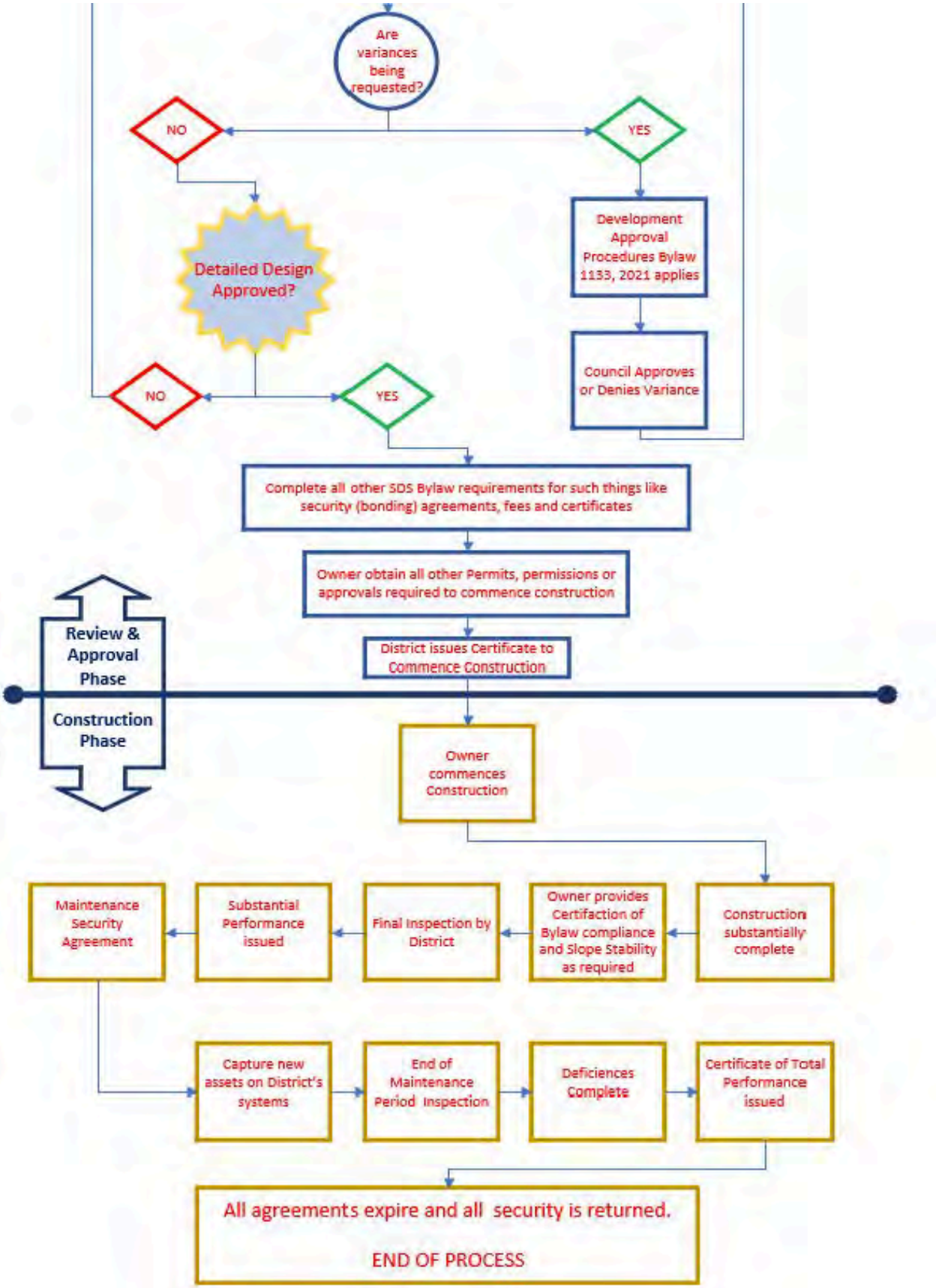


FIGURE B-2 Works and Services Application Process continued



B.2 *Section deleted by Bylaw 1228, 2024*

B.3 **Phased Strata or Strata Conversion**

B.3.1 Applications for approval of a phased strata plan declaration or strata conversion must be accompanied by applicable fees in accordance with **District** Bylaw**s**.

B.4 **Building Permit**

B.4.1 An **Owner** of a **parcel** who applies to develop land must submit a Building Permit application in accordance with the Building Bylaw.

B.4.2 The **Building Inspector** may impose conditions on the approval of a Building Permit required in connection with the **development**, including, but not limited to a **Subdivision and Development Servicing Agreement.**

B.4.3 If **works** are required for a Building Permit application:

(a) on a **highway** immediately adjacent to any **parcel** being **developed** up to the centre line of the **highway** and

(b) on the **parcel** itself,

the **Owner** must provide the **works** that are required to be provided under this Bylaw.

B.4.4 If required, a grant or charge over land on which the **works** are located shall be provided to the **District** in a form required, in priority over liens, charges and encumbrances, and executed in registerable form. The grant or charge may include a **highway** dedication, statutory right of way, **highway** reservation, permit or license, as required by the **District.**

B.4.5 The **District Engineer**, in their sole discretion, may approve the issuance of a building permit in advance of the **offsite work** having been completed provided that a valid servicing agreement, with security for **works**, is in place and that the signatories to the servicing agreement and building permit are one and the same.

B.4.6 For a partial or phased **development,** the **Owner** shall:

(a) construct a percentage of the **offsite work** proportional to the percentage of the site being **developed**, or

(b) provide cash in lieu in accordance with this Bylaw

B.4.7 In addition to design drawings required by the Building Bylaw, the **Owner** must submit design drawings prepared by an **engineer** to the **District Engineer** for approval, identifying:

(a) the **works** to be constructed on the **parcel** being **developed**; and on the **highway** abutting the **parcel**; and

(b) the intended connection of **onsite works** to **offsite works**.

B.4.8 The construction, installation, and connection of all **works** must conform to:

(a) the design drawings marked, “Reviewed for Construction”, and initialed by the **District Engineer**; and

(b) the provisions of this Bylaw and all other Bylaw**s** of the **District**.

B.5 **Subdivision**

B.5.1 An **Owner** of a **parcel** who applies for **subdivision**:
(a) on a **highway** immediately adjacent to the **parcel** up to the centre line of the **highway**, and
(b) on the **parcel** itself,
must provide the **works** that are required to be provided under this Bylaw.

B.5.2 No **works** shall be required on **highways** immediately adjacent to the **frontage** of a proposed remainder **parcel** that has potential for further **subdivision** under the existing **zoning** designation.

B.5.3 The construction, installation, and connection of all **works** must conform to:
(a) the design drawings marked, "Reviewed for Construction" and initialed by the **District Engineer**, and
(b) the provisions of this and all other **District** Bylaws.

B.6 **Exemptions**

B.6.1 Boundary Adjustment Subdivisions involving lands that have been:
(a) **developed** with a permitted use;
(b) appropriately serviced; and
(c) do not create additional **parcels**,
shall not be subject to the requirements of this Bylaw except:
(i) unprotected or existing services shall be protected by way of easement or statutory right-of-way, or relocated as required by the **District Engineer**;
(ii) **parcels** currently serviced with on-site sewage disposal shall provide confirmation from a qualified professional that the existing system is satisfactory for its intended purpose;
(iii) lots served by other than a **water distribution system** shall adhere to the applicable **water source** design and construction requirements of this Bylaw;
(iv) where connection to a community sewer, storm sewer, and/or **water distribution system**, which in the **District Engineer's** opinion can be achieved cost effectively without a main extension, each adjusted **parcel** shall be connected to the applicable system.

Deleted and replaced by Bylaw 1228, 2024

B.6.2 Where a Building Permit has been issued for:
(a) the construction, renovation or addition to a single-family or two-family building, or for an associated accessory building, the **Owner** shall not be required to:
(i) construct, install or pay monies in lieu of **highways**, **walkways**, curb, gutter, **sidewalk**, **street lighting**, and **underground wiring**;
(ii) connect to a **water distribution system** unless, in the opinion of the **District Engineer,** the connection can be achieved with a cost-effective main extension.
(iii) connect to the **District**'s **community sewer system** unless:
A. in the opinion of the **District Engineer** the connection can be achieved with a cost-effective main extension or;
B. the construction, renovation or addition complies with the **septic system** requirements of this bylaw. For clarity, where the construction, renovation or addition does not comply with septic system requirements, a connection to the District's Community Sewer System is required.
(b) A renovation of a building where there is no increase to the floor area, the **Owner** shall not be required to construct, install or pay monies in lieu of **highways**, **walkways**, curb, gutter,

sidewalk, **street lighting**, and **underground wiring**, unless there is a significant change of use that warrants any or all of these improvements, in the opinion of the District Engineer.

B.6.3 In simple servicing cases where a standard drawing contained in **District** policy is deemed by the **District Engineer** to be sufficient for construction purposes, the **District Engineer** may, in their sole discretion, where a **District** approved **contractor** is being used, waive the requirement for engineering design drawings.

Added by Bylaw 1228, 2024

B.6.4 Subdivision or Building Permit applications where the District is the owner or agent are exempted from the Works and Services requirements of this Bylaw, unless Council passes as resolution imposing such requirements.

B.7 **Statutory Rights of Way**

B.7.1 **Works** under this Bylaw must be located within dedicated **highway**s or statutory rights of way in favour of the **District**.

B.7.2 Where the **District Engineer** requires rights of way to allow for eventual construction or installation of a system of water, sewer, or drainage ***works*** constructed and installed under this Bylaw must be located within dedicated ***highway***s or within statutory rights of way granted by the ***Owner*** in favour of the ***District*** or other agencies having jurisdiction.

B.7.3 Where **works** are not required to be constructed or installed under this Bylaw, the **District** may require rights of way to be granted by the **Owner,** in favour of the **District,** to allow for the eventual construction or installation of a system of water, sewer, or drainage **works.**

B.7.4 Where the **Owner** is required to grant rights of way in favour of the **District**, the **Owner** must enter into and register in the Land Title Office a Statutory Right of Way pursuant to Section 218 of the *Land Title Act* in a form acceptable to the **District Engineer** registered in priority to all financial and other charges as required by the **District**. All right of way agreements and plans must be signed by the **District**.

B.7.5 Upon registration of the rights of way and before release of any security being held by the **District**, the **Owner** must submit a copy of the registered right of way plan and agreement to the **District**.

B.7.6 All costs pertaining to the acquisition, surveying, and registration of all rights of ways shall be at the expense of the **Owner**.

B.7.7 For **District works,** the minimum width for a statutory right of way shall be 4.5 m for the first system of **works**, plus 1.5 m for each additional system of **works**. For deep sewers, the **Owner** may be required to provide additional width in order to comply with WorkSafeBC regulations and additional right of way may be required to accommodate appurtenances.

B.7.8 At **substantial performance**, **works** installed under this Bylaw in public rights of way or in a statutory right of way in favour of the **District** become the property of the **District** or if in favour of another agency having jurisdiction become the property of that agency subject to no encumbrances.

B.8 **Construction Contractors**

B.8.1 The **Owner** shall demonstrate to the satisfaction of the **District Engineer** that the **Owner** has or shall retain the services of one or more qualified **contractors** to undertake the construction of the **works**. The **Owner** shall provide the **District** with the name and address of its **contractor**(s) together with a summary of the projects that the **contractor**(s) has undertaken that are similar in scope, nature, and value to the **works** prior to awarding the contract(s) to the **contractor**(s).

B.8.2 In the case where the **contractor** has not performed similar **works** within the Regional **District** of Central Okanagan, the **District** may require that the **Owner** provide a list of projects and references from other municipalities that demonstrates that the **contractor**(s) is qualified to undertake the **works**.

B.8.3 The **Owner** shall ensure that its **contractor**(s) constructs the **works** in accordance with the design, drawings, plans, and specifications reviewed for construction by the District Engineer and the provisions of this Bylaw**.**

Sections B.9 and B.10 added by Bylaw 1161, 2021

B.9 **Engineering Design Submissions**

B.9.1 Owners must submit engineering designs and associated information for review by the **District** as part of the process for obtaining a Certificate to Commence Construction.

B.9.2 All Engineering Design Submissions must meet the requirements of this Bylaw and be complete to the satisfaction of the **District Engineer**.

B.9.3 The **District** employs a two-part process for reviewing Engineering Design Submissions, these are:

(a) Pre-Design
(b) Detailed Design

B.9.4 The following is the minimum information required for a Pre-Design Report submission:

(a) Quality Assurance Plan
(b) Concept engineering drawings
(c) Class D construction cost estimate
(d) Summary design brief that includes;
    (i) safety, functional, operational and environmental aspects of the proposed design,
    (ii) servicing requirements,
    (iii) design constraints and assumptions,
    (iv) list of non-compliance specifications that will require variances to this bylaw,
    (v) assumed **Owner**ship of infrastructure upon completion.

B.9.5 Once the **Owner**'s Pre-Design Report has been reviewed and accepted by the **District Engineer**, the **Owner** will be invited to submit the Detailed Design to the **District** for review.

B.9.6 The following is the minimum information required for a Detailed Design Submission.

(a) Quality Assurance and Quality Control Plan; (in accordance with Schedule F)
(b) Detailed Design Drawings (in accordance with Schedule R)
(c) Detailed design calculations for all **works** and services covered by this Bylaw
(d) Drainage, Sediment and Erosion Control Plan (in accordance with Schedule N)
(e) Detailed Design Brief (in accordance with Schedule F)
(f) Letter of Commitment by **Owner** and **Owner**s Engineer (in accordance with Schedule S)
(g) Letter of Commitment to Design and field review (in accordance with Schedule S)
(h) If required, letters approving design from the Ministry of Transportation and Infrastructure, and other agencies having jurisdiction.

B.9.7 The **Owner** shall ensure that its contractor(s) constructs the works and services in accordance with the design drawings, plans, and specifications reviewed for construction by **the District Engineer** and the provisions of this Bylaw.

B.10 **Variances**

B.10.1 Variances to this Bylaw must be identified through the Engineering Design Submission process and resolved prior to proceeding to the next step in the process as shown in Figure B-1 and Figure B-2.

B.10.2 All variances are to follow the process contained within the Development Approval Procedures Bylaw 1133, 2021, as amended from time to time.

B.10.3 It is the responsibility of the Owner and the Owner's Engineer to identify any variances required and to formally request variances as part of the Pre-Design and the Engineering Design Submission.

SCHEDULE C SERVICING REQUIREMENTS

C.1.1 **Works** required for a **subdivision** or **development** is based on the **zone** in which the land is located.

C.1.2 **Work**s indicated by a checkmark (✓) in the corresponding column must be constructed and installed in accordance with the provisions set out in this Bylaw.
Works required under this bylaw must be constructed and installed prior to obtaining final approval.

TABLE C-1 SERVICING REQUIREMENTS

TYPE OF WORKS		**Highways** and **Walkways**	**Sidewalks**	Curb & Gutter	**Boulevard** & Landscaping	**Community Water System**	**Onsite Water Supply**	Community Sewer System	**Septic systems**	Storm Drain System	Drainage, Sediment & Erosion Control	**Street lighting**	**Overhead wiring**	**Underground Utilities**
See Schedule		**G**	**H**	**H**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**P**
Zone														
C	ALL COMMERCIAL ZONES	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
DC	(Direct Control) **zone**s	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
DC10	Pixie Beach Resort	✓				✓			✓		✓		✓	
I-1	General Industrial	✓	✓	✓		✓		✓		✓	✓	✓		✓
I-3	Heavy Industrial	✓	✓	✓		✓		✓		✓	✓	✓		✓
I-5	Gravel/Soil Extraction	✓	✓			✓			✓	✓	✓		✓	
P-1	Public Park/Open Space	✓	✓	✓	✓	✓		✓			✓	✓		✓
P-2	Administration, Public Service and Assembly	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
P-3	Minor Utilities													
P-4	Utilities	✓	✓	✓		✓		✓		✓	✓	✓		✓
RU	ALL RU ZONING	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
RM	ALL RM ZONING	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓
A	ALL A ZONING	✓					✓		✓	✓	✓		✓	
RLP	ALL RLP ZONING	✓					✓		✓	✓	✓		✓	
RR1	Rural Residential	✓					✓		✓		✓		✓	
RR2	Rural Residential	✓				✓			✓		✓		✓	
RR3	Rural Residential	✓				✓		✓		✓	✓		✓	

SCHEDULE D GENERAL REQUIREMENTS

D.1 Geotechnical Requirements

D.1.1 The **Owner** shall engage a qualified geotechnical **Engineer** to investigate and provide a pre- and post-construction report on surface and subsurface conditions within the proposed **subdivision** or **development.** The geotechnical **Engineer** shall prepare a report outlining their findings and shall provide clear, definitive recommendations on the geometry and placement of fill sections, compaction requirements unique to the project, cut slope geometry and recommendations for surface treatments (in consultation with the **Owner's** Qualified Landscape Professional) required to prevent erosion, pavement structures for **roads**, and any other geotechnical issues affecting construction within the proposed **subdivision** or **development**.

D.1.2 Pursuant to Section 86 of the Land Title Act, the **Approving Officer** may at their sole discretion, require a report certified by a professional **engineer** or **geoscientist** experienced in geotechnical engineering stating that the land may be used safely for the use intended; and/or require one or more covenants under Section 219 of the Land Title Act in respect to any of the parcels that are being created by the **subdivision**.

D.2 Removal of Accumulated Soils

D.2.1 Where soil accumulates on public **road**s, **sidewalk**s, or in drainage systems as a result of construction activity in the **subdivision** or **development**, the **Owner** must remove and dispose of the accumulated soil. The **District** may remove and dispose of the accumulated soil at the expense of the **Owner** if it has not been completed within 72 hours of notification from the **District Engineer**.

D.3 Systems Modelling

D.3.1 Where modelling of infrastructure systems including, but not limited to, water, sanitary sewer, storm water and transportation networks is required, the modelling will be done by the District at the **Owner's** expense.

D.4 Test Procedures

D.4.1 For the following test procedures:

(a) pressure testing,
(b) leakage testing,
(c) flushing and cleaning,
(d) video inspection,
(e) disinfection, and
(f) inspection chamber water test.

The following requirements must be adhered to.

(i) The **Owner's Engineer** must be present for the results to be accepted by the **District Engineer**.
(ii) The **Owner** must notify the **District Engineer** as specified in the District New Watermain Connection Policy or at least twenty-four (24) hours in advance of the procedure.
(iii) If 24 hours has elapsed since proper notification was provided, the **Owner's Engineer** may instruct the test procedure to proceed.

(iv) Proceeding without proper notification to the **District Engineer** may require the procedure to be performed again in the presence of the **District Engineer.**

D.5 **Existing Structure or Utility**

D.5.1 Where an existing structure or utility may be affected by the **works** the **Owner's Engineer** must provide sufficient advance notification to the **District Engineer** and the **Owner** of the structure or utility so that inspection and protective measures can be identified and implemented.

D.5.2 Where alignment of an existing structure or utility conflicts with the **wor**ks, the **Owner** must relocate the existing structure or utility in accordance with Standard Drawings at the **Owner's** sole expense and responsibility.

D.5.3 When existing water, sanitary sewer, or storm drainage alignments conflict with the offsets shown on Standard Drawings or when community sewer is not required pursuant to this Bylaw, alternative alignments may be submitted for approval.

D.6 **Obstructions and Repair**

D.6.1 Where an unforeseen or other obstruction is encountered and interferes with the **work**s, construction must cease until revised proposals are approved by the **District Engineer**. The **Owner** must **repair** all items damaged or destroyed.

D.6.2 The **Owner** is responsible for **repair**ing all **highway**s, **lane**s, driveways, **boulevard**s, other areas traversed by trenches or damaged during construction and any damage to unforeseen obstructions.

D.7 **Protection from Damage**

D.7.1 The **Owner** must ensure that due care is taken in order to protect the **work**, existing underground utilities and structures, and other person's property from damage. Any damage must be **repair**ed at the expense of the **Owner**.

D.7.2 The **Owner** must ensure the provision of the necessary safety devices and supervision to protect the public.

D.8 **Connection to or use of Existing Works**

D.8.1 The **Owner** must not use any of the existing **work**s until a Certificate of Substantial Performance has been issued by the **District Engineer**.

D.9 **Flushing**

D.9.1 No flushing water shall be discharged into any sanitary sewer or storm sewer without the approval of the **District Engineer**.

SCHEDULE E SUPPLEMENTALS TO THE MMCD SPECIFICATIONS

E.1 General

E.1.1 This Schedule provides supplemental requirements that are to be applied in conjunction with the **MMCD** Specifications. Where the provisions contained in this Bylaw are in conflict with the **MMCD** provisions, this Bylaw shall supplement or supersede the **MMCD**.

E.1.2 References to the following within the **MMCD** Specifications shall be as follows:

(a) Contract Administrator shall mean **Owner's Engineer**

(b) Contract Drawings shall mean Design Drawings marked "Reviewed for Construction" and signed by the **District Engineer.**

(c) **Contractor** shall mean **Owner**

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS

MMCD SECTION	SUB SECTION	SUPPLEMENTARY SPECIFICATIONS
01 57 01 Environmental Protection	1.4 Environmental Protection .3 Pollution Control	Delete and replace .1 with Maintain drainage, sediment, and erosion control features in accordance with the Drainage, Sediment and Erosion Control Plan submitted to the **District**.
03 30 53 Cast-In-Place Concrete	1.6 Inspection and Testing	Delete and replace .1 with The **Owner** must retain an independent materials testing firm to carry out comprehensive testing of concrete which must include unit weight determination, slump test, air test, and casting of test cylinders. One test consisting of three test cylinders must be made for every 175 meters of curb, gutter, and **sidewalk**. In no case shall there be less than one test on any given day which concrete is poured.
31 05 17 Aggregates and Granular Materials	1.0 GENERAL	Add .2 Maximum aggregate particle size to be no more than 50% of total thickness of sub-base layer.
31 05 17 Aggregates and Granular Materials	2.1 Materials – General	Add .3 The physical properties of the materials for granular sub-base and crushed granular base course shall meet the specifications set out in TABLE **E-3**
31 05 17 Aggregates and Granular Materials	2.7 Granular Pipe Bedding and Surround Material	Delete and replace .2 with Pit run sand as specified in Section 31 05 17 (2.4) may also be used unless other specified by the **Owner's Engineer** Add .3 Other permissible materials: only where shown on Design Drawings Marked **reviewed for construction** or directed by the **Owner's Engineer** shall drain rock or approved native materials be used for bedding and pipe surround.
31 05 17 Aggregates and Granular Materials	2.8 Select Granular Sub-base	Delete and replace the table with **TABLE E-4**
31 05 17 Aggregates and Granular Materials	2.10 Granular Base	Delete and replace .1 with to be 25 mm crushed gravel conforming to the gradations referenced in TABLE **E-5**
31 05 17 Aggregates and Granular Materials	2.11 Recycle Aggregate Material	Amended .1 by deleting and replacing the third sentence with: Recycled material should consist only of crushed portland cement concrete and asphaltic pavements; other construction demolition materials such as bricks, plaster, etc. are not acceptable.

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS		
MMCD SECTION	**SUB SECTION**	**SUPPLEMENTARY SPECIFICATIONS**
		Add .2 Material retained on the 4.75 mm sieve to be not more than 20% recycled material. Minimum size of processed recycled material is to be retained on the 4.75 mm sieve. Add .3 Recycled material and granular sub-base material is to be mechanically blended to produce a homogeneous mixture prior to delivery to site. Blending on site will not be permitted. Add .4 Acceptable recycled material to be used in sub-base material only.
31 22 01 Site Grading	3.2 Grading	Delete and replace .1 with Rough grade to levels, profiles and contours in accordance with the Sediment and Erosion Control Plan submitted to the **District**.
31 23 01 Excavating, Trenching and Backfilling	3.6 Surface Restoration .7 Permanent pavement restoration	Delete and replace .5, with the following new sections: .1 Restore pavement as detailed on District Standard Detail Drawing DLC R14. If thickness of existing permits, grind 50 mm depth along edge of pavement. Dry if necessary and paint clean, dry edge with asphalt emulsion (tack coat). .2 All asphalt shall be saw cut 500 mm wider and longer than the surface dimensions of the actual trench excavation. This saw cut must extend cleanly through the existing asphalt to the base material prior to asphalt removal. .3 If the thickness of the existing asphalt is greater than 75 mm, grind it to a depth of 50 mm and a width of 400 mm along the saw cut edge. This can be done just prior to the final asphalt restoration. .4 Where the edge of the saw cut or milled asphalt, whichever is wider, extends into the travel **lane or bike lane**, it must be extended to the full width of that **lane**. .5 Where the edge of the saw cut or milled asphalt, whichever is wider, is less than 1.5 m from the lip of gutter or edge of paved shoulder, it must be extended to the lip of gutter or edge of paved shoulder. .6 When an area of existing asphalt between two transverse trenches is less than 5 metres in width, the existing asphalt shall be removed and the area paved in conjunction with the paving of the two trenches. .7 Regardless of 7.5.5, if the longitudinal distance between two trenches is less than three (3) meters it shall be removed and the area paved in conjunction with the paving of the two trenches. .8 Longitudinal trenches must be paved with a paving machine. .9 Hot-mix paving shall meet the thickness of the existing pavement or that shown on the design drawings, whichever is greater. If the thickness of the hot-mix paving is 75 mm or less, it shall be placed in one

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS		
MMCD SECTION	**SUB SECTION**	**SUPPLEMENTARY SPECIFICATIONS**
		lift. If the thickness of the hot-mix paving is greater than 75 mm it shall be placed in two lifts as shown on Drawing G5 .10 Vertical faces and the surface of the bottom lift of asphalt must be painted with bituminous material prior to hot mix paving.
31 24 13 Roadway Excavation, Embankment and Compaction	3.3 Inspection of Native Surface	Add .2 Top 150 mm of Native Surface to be scarified, moisture conditioned to optimum moisture content and compacted to a minimum of 95% of Modified Proctor density in compliance with ASTM D1557, before placing of embankment or sub-base material.
31 32 19 Geosynthetics	2.1 Geosynthetic	Add .6 Woven Geotextile Fabric Products providing plant and root barriers shall conform to the following Woven Geotextile Fabric Products providing plant and root barriers shall conform to the following: • *Minimum Tensile Strength - 900 N /m • *Maximum elongation at break - 22% • *Minimum Tear Strength - 500 N /m • *Minimum Bursting Strength (Mullen) - 2200 kPa • *Maximum Equivalent opening size - 300 um
31 32 19 Geosynthetics	3.1 Installation	Add .5 Installation of geotextile fabric which provides plant and root barriers, shall conform to the following: • *Geotextile fabric shall be installed in accordance with the manufacturer's recommendations. • *Fabric shall be placed by unrolling into place and not by dragging across the subgrade. • *The fabric shall be inspected for punctures or tears prior to any materials being placed upon it and any such defects shall be **repair**ed by overlapping new material or replacement. • *The entire fabric roll shall be placed and rolled out as smoothly as possible. Wrinkles and folds in the fabric shall be removed by stretching and staking, as required. • *Overlap at roll ends shall be a minimum of 1 meter and the overlaps shall be stapled or pinned to maintain them during construction activities. *No vehicles shall be permitted to pass over the fabric.
32 12 16 Hot-Mix Asphalt Concrete Paving	2.1 Materials	Delete and replace .2 with Gradations to be within limits specified when tested to ASTM C136 and ASTM C117. See **TABLE E-6** Delete and replace .6 with Sand Equivalent: to ASTM D2419. Min: 50 (New Arterial), Min: 40 (All other street classifications). Delete and replace .10 with Lightweight particles: to ASTM C123. Maximum % by mass less than 1.95 relative density: Surface course: 1.0 % Lower course: 1.5% Delete and replace .11 Flat and elongated particles: (with length to thickness ratio greater than 5): Maximum % by mass: Coarse aggregate, surface course: 10% Coarse aggregate, lower course: 10% Delete and replace .12 Crushed Particles (fraction retained on 4.75 mm sieve), 2 faces, % minimum:

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS		
MMCD SECTION	**SUB SECTION**	**SUPPLEMENTARY SPECIFICATIONS**
		New arterial streets: 85% All other street classifications: 70%
32 12 16 Hot-Mix Asphalt Concrete Paving	2.2 Mix Design	Delete and replace .1 The **Owner**, at their cost, must retain an independent testing consultant to perform trial mix designs and to submit the job mix formula. The trial mix design must be performed in accordance with ASTM D1559 (75 blows per face) and must include five (5) separate trial values of asphalt content. **Contractor** must pay for trial mix designs and submissions. Delete and replace .2 Mixes for construction of asphalt base course may contain up to 20% of RAP, provided that the properties of RAP material are considered in the trial mix design. Submissions for RAP mixes must contain all data relevant to RAP utilized in the mix design. Delete and replace .3 with Design of Mix: Include the following data with the trial mix design submission: • Aggregate bulk specific gravity and water absorption. • Sand equivalent values. • Asphalt cement properties including mixing and compaction temperatures, based on temperature viscosity properties of asphalt cement. • Aggregate gradations and blending proportions. • Maximum theoretical density of trial mixes. • Asphalt absorption values. Delete and replace .2 with Mix Physical requirements to meet **TABLE E-7**. Do not change job-mix without prior approval of **Owner's Engineer**. Should change in material source be proposed, new job-mix formula to be submitted to **Owner's Engineer** for review and approval.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.1 Plant and Mixing Requirements .1 Batch and continuous mixing plants	Delete and replace .3 with Before mixing, dry aggregates to a moisture content not greater than 1% by mass or to a lesser moisture content if required to meet mix design requirements.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.1 Plant and Mixing Requirements .9 Where RAP is to be incorporated into mix:	Delete and replace .3 with RAP must not be fed through the aggregate dryer system.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.1 Plant and Mixing Requirements .11 Mixing time:	Add .3 Mixing period and temperature to produce a uniform mixture in which particulates are thoroughly coated, and moisture content of material as it leaves mixer to be less than 0.2%.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.1 Plant and Mixing Requirements .4 Mixing Tolerances	Delete and replace .1 with Permissible variation in aggregate gradation from job mix (percent of total mass) see TABLE E-8
32 12 16 Hot-Mix Asphalt Concrete Paving	3.2 Equipment .1 Pavers	Add .1 Paving equipment must be capable of placing a standard mat width not less than 3 m and must be capable of paving wider widths in 150 mm and 300 mm increments by means of equipment supplied by the manufacturer of the equipment. The screed must include a tamping bar or strike-off device. Add .2 Control of the screed must be by automatic sensing devices. Longitudinal control must be by a sensor that follows a string-line, ski or other reference. The grade sensor must be movable and mounts provided so that grade control can be established on either side of the

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS		
MMCD SECTION	**SUB SECTION**	**SUPPLEMENTARY SPECIFICATIONS**
		paver. A slope control sensor must be provided to maintain the proper transverse slope of the screed.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.6 Compaction .2 General	Delete and replace .1 with Provide sufficient compaction equipment to ensure that the compaction rate meets or exceeds the placement rate and to ensure that specified density is achieved before the temperature of the mat falls below 100 degrees C.
32 12 16 Hot-Mix Asphalt Concrete Paving	3.7 Joints .1 General	Add .4 When placing final pavement layer against concrete curbing, compacted pavement must meet the gutter at the same elevation or a maximum of 10 mm above and along the entire lip of the gutter.
33 01 30.1 CCTV Inspection of Pipelines	3.0 Execution	Delete and replace with Immediately upon completion of the **works,** including all backfilling and compaction and prior to paving, the **Owner** must video inspect a completed sewer. Prior to any video inspection, the sewer must be thoroughly flushed to remove all deleterious materials so that defects can be observed. Immediately prior to the video inspection, water must be introduced into all sewers with slopes of less than 1% in sufficient quantities to flow the entire length of the section being videoed. Once the water has been added, the water shall be turned off. Video inspection must not take place while the water is running. Picture quality shall be such to produce a continuous 500-line resolution picture showing the entire periphery of the pipe. Picture quality and definition shall be to the satisfaction of the **District Engineer.** Video inspection must be continuous between manholes. A measuring device shall be provided to measure depth of ponding and shall be continuously visible from the video camera. The measuring device must be capable of measuring ponding to a depth of 100 mm and to an accuracy of 10 mm increments. Upon completion of the video inspection, a report must be submitted to the **District Engineer**. The report must include the following information: (d) Title page with video company's name, address and phone number, **contractor**'s name, **engineer**'s name, location, date, and report number. (e) A schematic plan showing manholes, sewer mains, **road** names and manhole numbers. Manhole numbers must correspond to the as-constructed drawings. (f) Summary page with upstream and downstream manhole number and corresponding inspection report page number.

TABLE E-1 SUPPLEMENTAL MMCD SPECIFICATIONS		
MMCD SECTION	**SUB SECTION**	**SUPPLEMENTARY SPECIFICATIONS**
		(g) Individual inspection report for each pipe section with street name or location, upstream manhole number, downstream manhole number, direction of video, length of pipe section, type of material, pipe use, diameter of pipe, grade of pipe, technician's name, and a section for notes. In addition, the inspection report shall include: (i) A log of distances to pertinent information such as services, defects, ponding, and debris. (ii) A description of the pertinent information including length and depth of ponding. (iii) The tape count to each occurrence of pertinent information. Upon completion of the video inspection a video must be submitted to the **District Engineer.** The video must conform to the following: (h) Type of video must be digital in full colour. (i) Videos must be numbered and cross referenced to inspection report with labels located on all media. (j) Date and running distance in meters to an accuracy of two decimal places. The date and distance must be displayed continuously. (k) Direct voice communication at the start of each section identifying test section, manhole numbers, location, and any other information required to describe section being videoed. (l) Direct voice communication at all service locations, defects, ponding and deleterious materials. Communication shall be factual information only. (i.e. type of defect, depth of ponding, length of ponding, and type of obstruction).
33 11 01 Water**work**s	2.0 Products	Only materials listed in E -2 are approved for installation in any water systems owned and operated by the **District**.
33 30 01 Sanitary Sewers	2.2 Plastic Pipe, Mainline Smooth Profile	Add to .1 Ribbed piping shall not be permitted.
33 30 01 Sanitary Sewers	3.0 Execution	Add New Subsection 3.21 Inspection Chamber Water Test Add .1 Prior to paving, the **contractor** must introduce a minimum of 20 liters of water in each inspection chamber to visually inspect for ponding.

TABLE E-2-WATERWORKS APPROVED MATERIALS (MMCD 33 11 01 Section 2.0)			
MANUFACTURER	**MAKE/MODEL**	**SIZE**	**COMMENT**
Pipe			
Ipex, Royal Pipe	PVC to C900	100 mm-300 mm	Only SDR 18, class 150 or better as required
	PVC to C905	350 mm- 900 mm	
Canada Pipe	Ductile Iron	100 mm – 900 mm	Pressure Class 350
Service Pipe			
Wolverine	Type K Copper	min. 19 mm (3/4”)	Must conform to CSA HC.7.6 and ASTM B88
Poly Tubes/Ipex	Polyethylene	Min. 19 mm (3/4”) up to 50mm (2”)	Only series 200 conforming to CAN/CSA- B137.1-M
Fittings & Appurtenances			
Terminal City	Iron Fittings	100 mm- 600 mm	All fittings must be properly thrust blocked
Sigma	Iron Fittings	100 mm-600 mm	All fittings must be properly thrust blocked
Ipex	PVC Fittings	150 mm- 200 mm	Shall be AWWA C-907 approved
Restraining Joints			
Clow	Series 1200 & 1350	100 mm – 600 mm	Subject to Owner Engineer’s design and District Engineer’s approval
Smith Blair	Model 982	100 mm – 600 mm	Subject to Owner Engineer’s design and District Engineer’s approval
Uniflange	Series 1300, 1390 & 1400	100 mm – 600 mm	Subject to Owner Engineer’s design and District Engineer’s approval
Ebba	1500- 15PF	100 mm – 600 mm	Subject to Owner Engineer’s design and District Engineer’s approval
Service/Tapping Saddles			
Robar	2616 DS		Full stainless steel up to 25 mm (1”)
Robar	2506 DS		Double strap bronze body over 25 mm (1”)
Cambridge	812		38 mm to 50 mm (1.5” X 2”)
Canada Pipeline	SC-2 & CD-2		19 mm-25mm only (¾” – 1”)
Clamps & Couplers			
Robar	1506 & 1509R	100 mm-600 mm	Epoxy coated complete with stainless steel bolts
Hymax		100 mm – 600 mm	
Smith Blair	411, 413 415, 611, 525	100 mm-600 mm	Epoxy coated complete with stainless steel bolts
Smith Blair	Top Bolt 441		
Gate Valves			
Clow	Clow Resilient	50 mm – 300 mm	Resilient seat gate valves to C-509
Mueller	Super-Seal	50 mm – 300 mm	Resilient seat gate valves to C-509
Butterfly Valves-AWWA C504			

TABLE E-2-WATERWORKS APPROVED MATERIALS (MMCD 33 11 01 Section 2.0)			
MANUFACTURER	**MAKE/MODEL**	**SIZE**	**COMMENT**
Centerline	Series 200 350 mm+	350 mm +	For installation in chamber only
Pratt	Groundhop	350 mm +	For buried service
Mueller	Lineseal III	350 mm +	For buried service
Valmatic	Series 2000	350 mm +	
Kflow	Series 500 or 47	350 mm +	
Air Valves			
Apco	143C, 145C, 147C, 149C, 150C	25 mm-150 mm	
Valmatic	201C, 202C, 203C, 204C	25 mm- 150 mm	
Fire Hydrant			
Canada Valve	Century EM		2 ½ ports: BC Fire Thread Centre Ports – 100 mm (4”) Storz Cap Painted Black
Sampling Station			
Kupferle Foundry	Eclipse 88		
Service Brass			
Mueller	13 mm - 50 mm		
Cambridge	13 mm – 50 mm		
Service Boxes			
Trojan			Stainless Steel Rods and Pins

E.2 **Supplemental MMCD Tables**

TABLE E-3-PHYSICAL PROPERTIES FOR GRANULAR SUB-BASE AND CRUSHED GRANULAR BASE COURSE			
Physical Property	**Test Designation**	**Granular Sub-base**	**Granular Base**
$MgSO_4$ Loss %	ASTM C88	20	20
Course Ag (Max) Fine Ag (Max)	ASTM C88	25	25
Sand Equivalent % (Min)	ASTM D2419	25	35
Plasticity Index % (Max)	ASTM D4318	6.0	6.0
Crushed Particles (one face) % (Min)	MoT I-11 (A)		60
California Bearing Ratio (Soaked) % (Min)	ASTM D1883	20	80

TABLE E-4-SELECT GRANULAR SUB-BASE GRADATION	
Sieve Designation	**Percent Passing**
150 mm	100
100 mm	85 -100
50 mm	65 -100
19 mm	40 – 100
4.75 mm	20 – 70
0.150 mm	0 - 20
0.075 mm	0 - 8

TABLE E-5-GRANULAR BASE GRADUATIONS	
Sieve Designation	**Percent Passing**
25 mm	100
19 mm	80 – 100
9.5 mm	60 – 90
4.75mm	35 - 70
2.36 mm	25 – 50
1.18 mm	15 – 35
0.300 mm	5 – 20
0.075 mm	2 -8

TABLE E-6-HOT-MIX ASPHALT AGGREGATE GRADATION SPECIFICATION		
Sieve Designation	**Percent Passing**	
	Lower Course	**Surface Course**
25 mm	100	-
19 mm	80-100	100
12.5 mm	-	84-95
9.5 mm	50-84	73-90
4.75 mm	25-55	50-75
2.36 mm	20-45	35-57
1.18 mm	15-35	25-45
0.600 mm	-	18-34
0.300 mm	5-20	10-26
0.150 mm	-	6-17
0.075 mm	3-7	3-7

TABLE **E-7-SPECIFIED PHYSICAL REQUIREMENTS OF HOT-MIX ASPHALT**		
Property	**Mix Type**	
	Lower Course [1]	**Surface Course**
Stability @ 60^0 C, kN (min)	8.0	9.0
Flow Index, 0.25 mm units	8-14	8-14
Voids in Mineral Aggregate % (min)	12.0	14.0
Air Voids, % [2]	3-6	3-5
Index of Retained Stability after Immersion in Water for 24 hrs @ 60^0C, % (min)	75	85

[1] If lower course mix is used in staged construction, i.e. exposed for at least one winter, specified properties for surface course mix must apply.

[2] Percent air voids in compacted trial mixes must be determined in accordance with ASTM D3203, with asphalt cement absorbed into the aggregate compensated for in the calculation.

TABLE **E-8-MIXING TOLERANCES**	
4.75 mm and larger	± 4.5
2.36 and 1.18 mm	± 4.0
0.600 mm	± 3.5
0.300 mm	± 2.5
0.150 mm	± 1.5
0.075 mm	± 1.0”

SCHEDULE F QUALITY CONTROL AND QUALITY ASSURANCE

Section F.1 deleted and replaced by Bylaw 1161, 2021

F.1 Administration and Design Requirements

F.1.1 The Detailed Design Brief Submission Requirements are specified in this section.

F.1.2 Each design Detailed Design submission to the District Engineer shall include a project Detailed Design Brief which provides comprehensive information relating to the safety, functional, operational and environmental aspects of the proposed design, at. At a minimum the Detailed Design Brief, shall include the following elements where applicable:

(a) Title page
(b) Table of contents
(c) Introduction
(d) Objectives and Policies
(e) Description of the proposed subdivision or development
(f) List of non-compliant specifications that will require variances to Subdivision and Development Serving Bylaw
(g) Methodology /rationale for design solutions developed
(h) Design options considered
(i) Assumptions
(j) Description of Infrastructure requirements
(k) Constraints
(l) Operations and Maintenance (O & M) requirements
(m) Schedule
(n) Modelling and Analysis
(o) Geotechnical considerations
(p) Environmental considerations
(q) Risks/Benefits
(r) Planned Solutions
(s) Sketches
(t) Synopsis
(u) Conclusion/Summary

SCHEDULE G DESIGN AND CONSTRUCTION OF HIGHWAYS AND WALKWAYS

G.1 General

G.1.1 All **highway**s and **walkway**s must be constructed in accordance with this Bylaw. It is recommended that Local **highways** and **walkways** within strata **subdivisions** or **developments** shall be designed and constructed in accordance with this Bylaw.

G.1.2 A **highway** proposed to be dedicated by a plan of **subdivision** must not be shown on the plan of **subdivision**, dedicated, laid out, or constructed unless the dimensions, locations, alignment and gradient meet the requirements for **highway**s prescribed in this Bylaw.

G.1.3 **Developments** may require **frontage road**s, double **frontage** lots, deep lots with rear service **lane**s or such other treatment as may be necessary in the public interest for the separation of through and local traffic.

G.1.4 Where the **Approving Officer** believes that, due to terrain and soil conditions, a **highway** of a specified width under this Bylaw cannot be supported, protected, or drained, he may determine that the **Owner** provide, at the **Owner**'s expense, land of a width that, in the **Approving Officer**'s opinion, would permit the **highway** to be supported, protected, or drained pursuant to the *Local Government Act*.

Deleted and replaced by Bylaw 1228, 2024

G.1.5 In the preparation of the Pre-Design Report submission for **highways**, the **Owner's Engineer** shall address the following general design considerations:

(a) the sufficiency and suitability of the proposed road system;
(b) the arrangement, width, grade, and location of all roads in relation to existing and planned roads;
(c) all District bylaws, plans, programs and policies;
(d) topographical features;
(e) public convenience and safety;
(f) the proposed uses of the land to be serviced by such roads.
(g) Operation and Maintenance (O&M) requirements
(h) Continuation of existing **roads**
    (i) The design and arrangement of **highways** within a **subdivision** shall provide for the continuation or projection of existing **roads** in the surrounding area. In no case shall the arrangement of **highways** within a proposed **subdivision** make impractical the extension of **roads** and the **subdivision** of adjoining **parcels.**
    (ii) The design and arrangement of **highways** must consider the impact of new development on the surrounding road network. Traffic calming measures must be implemented if the following conditions are expected:
        A. Potential for short-cutting due to the new connections having a shorter route to a main road;
        B. Geometric conditions that may facilitate speeding (e.g., high operating speeds and straight roadways; and
        C. Unsafe conditions due to geometric conditions.

G.1.6 *Section deleted by Bylaw 1228, 2024*

G.1.7 Driveways, retaining walls, vegetation and other private or municipal improvements on private or municipal property or **highway**s affected by the **road** construction shall be restored at minimum to the condition existing prior to construction and to the satisfaction of the **District Engineer**.

G.1.8 Paving shall not be undertaken until all underground utilities have been constructed in accordance with this Bylaw nor during snow, heavy rain, temperatures below 5 degrees C, or other unsuitable conditions. Asphaltic concrete shall not be placed on a frozen, muddy or rutted base.

G.1.9 Tie-ins to existing pavement shall be made in accordance with Standard Drawings. The existing pavement shall be cut back to produce a neat vertical face with a straight edge as described in Table E-1 Supplemental MMCD Specification 31 23 01.

G.1.10 The timing for the installation of the top lift of asphalt shall be at the **District Engineer's** discretion and dependent on District requirements with respect to ensuring **stormwater** is able to enter catch basins on steeper sections of road.

G.2 **Classification of Highways**

G.2.1 Prior to design of the **road** system, the **Owner's Engineer** shall consultant with the **District Engineer**, to classify each **road** proposed adjacent to and within the **subdivision**.

G.3 **Transportation Requirement Assessment**

G.3.1 The **District Engineer** may, in their sole discretion, require the **Owner's Engineer** to prepare a transportation requirement assessment that considers the following requirements and amenities:

(a) Criteria set out in **TABLE G-1**;
(b) traffic volumes and expected speeds;
(c) the need for and applicability of alternate intersection configurations, including roundabouts;
(d) the need to accommodate normal traffic, emergency vehicles, transit, pedestrians, cyclists, and parking;
(e) drainage constraints/options;
(f) street or intersection lighting;
(g) traffic calming;
(h) snow storage;
(i) hillside slope/width restrictions;
(j) right of way width availability;
(k) desire to encourage use of certain routes for varying types of traffic (e.g. truck, farm, and commercial traffic);
(l) minimize capital costs as well as future maintenance and rehabilitation costs; and
(m) *deleted by Bylaw 1228, 2024.*

Title amended by Bylaw 1228, 2024

TABLE G-1-TYPICAL HIGHWAY CROSS SECTION REQUIREMENTS AND AMENITIES										
	Lane		Urban-Undivided				Rural-Undivided			Urban Divided
	Residential	Commercial	Local Hillside	Local	Collector	Arterial	Local	Collector	Arterial	Arterial
Lane Width	6	7.5	3.2	3.2	3.5	3.5	3.2	3.5	3.5	3.5
Bike Lane [6]	n/a	n/a	1.5	1.5	1.5	1.8	1.5	1.5	1.8	1.8
Parking	No	No	2.4 [1]	2.4 [1]	2.4 [1]	2.4 [1]	None	None	None	2.4 [1]
Shoulder	n/a	n/a	n/a	n/a	n/a	n/a	1.5	1.5	2.0	n/a
Ditch	n/a	n/a	n/a	n/a	n/a	n/a	2.5	2.5	2.5	n/a
Curb & Gutter (type)	n/a [8]	n/a [8]	Barrier	Barrier	Barrier	Barrier	None	None	None	Barrier
Sidewalk	n/a	n/a	One side [2]	One side [2]	Two sides	Two sides	None	None	None	Two sides
Pathway [6]	n/a	n/a	None	None	None	None	None	2.0 [3]	2.0 [3]	None
# of Lanes	n/a	n/a	2	2	2-4	4	2	2	2-4	4
Pavement Width	5	7.5	9.4 [4, 5, 9]	9.4 [4, 5, 9]	12.4 [4, 5, 9,]	20 [9]	9.4	10	10-17 [9]	18 [9]
R/W width	6	7.5	18 20 [5]	18 [9]	22	30	20	20	28	25-35 [1, 7]
Standard Dwg #	DLC R2	DLC R3	DLC R4	DLC R5	DLC R6	DLC R7	DLC R8	DLC R9	DLC R10	DLC R11

1 *deleted by Bylaw 1228, 2024*
2 *deleted by Bylaw 1228, 2024*
3 Trail/bike path to be asphalt surface.
4 Pavement width is measured from back of curb to back of curb except for rural **roads** where it is measured to edge of asphalt.
5 Pavement is widened to accommodate parking where required. Alternate locations for parking that are not in the **road** carriage way may be considered by the **District Engineer** at a rate of one space per home where **road** right of way width is available.
6 *deleted by Bylaw 1228, 2024*
7 *deleted by Bylaw 1228, 2024*
8 Curb may be required for drainage.
9 Pavement width and right of way width may vary depending on configuration of driving, bike and parking **lanes**.

Deleted and Replaced by Bylaw 1228, 2024

G.3.2 Where parts of a proposed subdivision or development front on an existing road, the configuration of the improvements will take into consideration the existing road setting and existing and proposed cross section improvements as shown in the District's Mobility Master Plan and Mobility Improvement Program, as amended from time to time

G.3.3 Where reasonably practical, driveway access will be from local **road**s rather than from collector and/or **arterial highway**s.

G.3.4 In determining the Highway Cross Section Requirements, the Owner's Engineer shall consider the following:

(a) Systems Modelling (Section D.3)

(b) The sufficiency and suitability of the proposed road (Section G.1.5)
(c) Transportation Requirement Assessment (Section G.3)
(d) Typical Highway Cross section Requirements and Amenities (Table G-1)
(e) Whether the proposed subdivision or development front an existing road (Section G.3.2).

G.4 **Consistency with Official Community Plan**

G.4.1 The location, classification, and standards all **highway**s proposed within a **subdivision** shall take into account the proposed use of the land and shall conform to the provisions of the **District** of Lake Country Official Community Plan.

G.5 **Local highways**

G.5.1 Local **highway**s within a proposed **subdivision** shall be arranged so that their use by through traffic will be discouraged.

G.6 **Culs-de-sac**

G.6.1 Cul-de-sac streets shall not exceed 300 metres in length and shall be provided with a turning area of not less than 12.5 m radius designed to permit safe and adequate space for the turning of emergency and motor vehicles at the terminus of the cul-de-sac.

G.6.2 Where circumstances are such that a cul-de-sac bulb is impractical, the **District Engineer** may, at their discretion, permit a hammerhead configuration in accordance with Standard Drawings.

G.6.3 Turning areas in all culs-de-sac shall be designated as no parking areas with signs and pavement markings in conformance with G.13.

G.6.4 For culs-de-sac greater than 200 metres and less than 300 metres, an emergency access route is required. The emergency access route must be within 50 metres of the terminus of the cul-de-sac and must provide connection to another public **highway**. The emergency access route shall be designed in accordance with Standard Drawing DLC R2 – Residential lane. The maximum grade of the emergency access shall be no greater than 12 %. The minimum width of the emergency access route shall be 6.0 metres with a 5.0 metre drive aisle. The emergency access route must be paved and closed to vehicle traffic with a suitable traffic control device approved by the **District Engineer**.

G.6.5 Where a cul-de-sac abuts adjacent developable lands, the Approving Officer may require that the cul-de-sac be configured such that it does not preclude future continuation of the road.

G.7 **Lanes**

G.7.1 Lanes, meeting the standards set out in this Bylaw, shall be provided where the **District Engineer** deems them to be necessary. Lanes are permitted for access, subject to approval by the **District Engineer**, where access from the street is not practical.

G.8 **Walkways**

G.8.1 Walkways shall be provided where the **District Engineer** deems them to be necessary to provide access through a **subdivision** to schools, parks, playgrounds, commercial areas or other community facilities, or for the safe and efficient circulation of pedestrian traffic.

G.8.2 Walkways shall be provided with chain link fencing in accordance with **MMCD** 32 31 13, on both sides of the **walkway**. The height shall be 1.0 m in the set back area of the adjacent property and 1.8 m for the remaining length.

G.9 **Transit Bays**

G.9.1 Transit bays shall be provided where the **District Engineer** deems them necessary.

G.10 **Intersections**

G.10.1 Intersections shall be designed as follows:

(a) intersecting **highway**s shall meet substantially at right angles (between 70 degrees and 110 degrees);

(b) jogs in **highway** alignment at intersections shall be avoided except where the distance between centrelines is sufficient to ensure traffic safety. The minimum spacing between tee intersections along a street shall be 60 m;

(c) intersections having more than four intersecting legs shall not be permitted;

(d) intersections shall provide adequate crossing sight distances and stopping sight distances, whichever is greater.

G.11 **Reverse Curves**

G.11.1 If reverse curves are required in a **highway** alignment, the **District Engineer** may require that they be separated by means of tangents of sufficient length to prevent superelevation rotation.

G.12 **Mailboxes**

G.12.1 Where required by Canada Post, the **Owner** shall indicate the Canada Post approved locations of the mailboxes on the engineering drawings. The **Owner** is referred to Canada Post for location guidelines and approval.

G.13 **Road Names, Traffic Signs, and Pavement Markings**

G.13.1 Road names shall be approved by the **District** in accordance with current policies and Bylaws. Road name signs, traffic signs, and pavement markings required as a result of constructing or improving **road**s shall be supplied and installed by the **Owner** at the **Owner**'s expense.

G.13.2 Road name signs (street blades) shall be produced using FHWA series C2001 CA font on engineering grade green background. Strata road name signs shall be on a blue background. Signs shall be produced on 2 mm. (0.08 inch) flat Aluminum stock.

G.13.3 Pavement markings and all traffic signs shall conform to the Transportation Association of Canada Manual of Uniform Traffic Devices for Canada.

G.13.4 Pavement marking layout must be inspected by the **District Engineer** prior to painting. 48 hours notice must be provided.

G.13.5 Thermoplastic markings shall be used at all stop bars and cross walks.

G.14 Appurtenances

G.14.1 The **Owner's Engineer** shall detail, on the design drawings, the location of all proposed traffic islands, retaining walls, guardrails, and permanent barricades. These structures shall be designed in accordance with Transportation Association of Canada Guidelines and with good engineering practice.

G.14.2 The design shall show the location of all traffic signs, street signs, pavement markings and other traffic control devices.

G.14.3 Drawings must show all utility poles, ducts, junction boxes, and pipelines. The **Owner's Engineer** shall indicate those utilities which require relocation prior to **road** construction and shall confirm with the utility the feasibility of their relocation prior to design completion. For underground systems, design drawings shall show the location of **underground wiring** and appurtenances including the connections to properties.

G.15 Vertical Alignment

G.15.1 The vertical alignment of **highway**s and **walkway**s shall be set so the grades of driveways to adjacent properties will comply with the **District** Highway Access Bylaw.

G.15.2 The minimum longitudinal gradient at the gutter line shall be 0.50% for all classifications of streets. The minimum longitudinal gradient around **culs-de-sac** and curb returns shall be 0.80%.

G.16 Design Speeds

G.16.1 The design speeds to be used for design of Highways shall be as per TABLE G-2

TABLE G-2-DESIGN SPEED	
Arterial (A)	70 km/h
Collector (C)	60 km/h
Local (L), Recommended for Bare Land Strata	50 km/h
Strata	30 km/h

G.17 Road Crossfall

G.17.1 Minimum **road** crossfall shall be 3%; maximum crossfall shall be 4%.

G.18 Road Grades

G.18.1 Minimum and maximum **road** centre line grades shall conform to TABLE G-3 based on the **road** classification.

G.18.2 Maximum grades are to be reduced by 1% for each (or part of each) 30 metres that the centre line radius is less than 150 metres.

TABLE G-3-HIGHWAY GRADES		
Road Classification	**Min Grade**	**Max Grade**
Arterial	0.5%	9%
Collector	0.5%	9%
Local and recommended for Bare Land Strata	0.5%	8%
Cul-de-sac, (entry downhill)	0.5%	8%

Cul-de-sac (entry uphill)	0.5%	8%
Cul-de-sac (bulbs)	0.5%	6%
Lane	0.5%	9%
Walkway	0.5%	12%

G.19 **Vertical Curves**

G.19.1 Vertical curves shall be designed to provide safe stopping sight distances. Minimum stopping sight distance is the least distance required to bring the vehicle to a stop under prevailing vehicle and climatic conditions. Vertical curves shall be provided at the following grade changes:

(a) Greater than 0.5% for Arterials
(b) Greater than 1.0% for Collectors
(c) Greater than 2.0% for Locals and **Lanes**
(d) Vertical curve length is calculated by the equation L = KA where:
L is the length of the vertical curve (Minimum L = 15 m)
K is a constant related to lines and geometry of the vertical curve
A is the algebraic difference in grades in percent

G.19.2 Minimum K values for vertical curve design shall be as set out in TABLE G-4

TABLE G-4-MINIMUM K VALUES FOR VERTICAL CURVE DESIGN (METRES)

Road Classification	**Crest Curve**	**Sag Curve**	
	Minimum	**Lighting**	**No Lighting**
Arterial	22	15	25
Collector	15	10	20
Local, Recommended for Bare Land Strata	7	6	11

G.20 **Horizontal Alignment**

G.20.1 Centre Line Radii

(a) The minimum required centreline radius for various super elevation rates for each classification of **road**ways are set out in TABLE G-5

TABLE G-5-MINIMUM CENTRE LINE RADIUS

Road Classification	**Horizontal Curve Centreline Radii (m)**			
Superelevation (m/m)	None	0.02	0.04	0.06
Arterial	n/a	230	200	190
Collector	160	140	130	n/a
Local, Recommended for Bare Land Strata [1]	95	n/a	n/a	n/a
Strata	12	n/a	n/a	n/a

[1] Radius may be reduced at the discretion of the **District Engineer**.

G.20.2 Curb Return Radii

(a) Curb return radii shall conform to TABLE G-6 and be based on the lesser classified **Highway**.

TABLE G-6-CURB RETURN RADII

Road Classification	
Arterial	11.0 m
Collector	11.0 m
Local, Recommended for Bare Land Strata	9.0 m

Cul-de-sac	11.5 m connecting radii to tangent =16.0 m
Industrial	11.0 m
Strata	6.0 m roadway – 9.0 m 7.3 m roadway -7.5 m

G.21 Intersection Design

G.21.1 Unless indicated elsewhere herein, all intersection design standards shall conform to those outlined in the latest edition of "Geometric Design Guide for Canadian Roads" as published by the Transportation Association of Canada (TAC).

G.22 Intersection Grades

G.22.1 Approach grades of minor streets at intersections to major streets shall not exceed 75% of the maximum grade allowed for that street classification. The minor street shall be designed to intersect the major street with a vertical curve of minimum length required for that street classification. The vertical curve shall terminate at the curb line using the K values set out in TABLE G-7.

TABLE G-7-INTERSECTION CURVES MINIMUM K VALUES

Intersecting Street	Minimum K Value	
	Crest Curve	Sag Curve
Arterial	17	15
Collector	7	6
Local, Recommended for Bare Land Strata	4	4

G.22.2 Under limited adverse access conditions, the **District Engineer** may allow the criteria listed in TABLE G-8 while considering factors such as length of grade, amount of lower grade approach, amount of direct **road** access, **road** width, and drainage requirements.

TABLE G-8-DESIGN CRITERIA FOR LIMITED ADVERSE TOPOGRAPHIC CONDITIONS

	COLLECTOR	LOCAL ROAD
Design Speed (km/h)	50	50
Curvature (m)	95	85
Grade (%)	11	12
K Sag Curve	6	4
K Crest Curve	6	4

G.22.3 Crossfalling a **road** at an intersection will be permitted where required because of topographical features in keeping with good engineering practices.

G.22.4 The transition length from a normal cross-sectioned **road** to a section of **road** where there is superelevation shall be calculated based on 15 m for every 1% change in grade. If these conditions are to be used the **Owner** must submit a preliminary design showing a centre line profile with existing ground line and the proposed grade for all streets and intersections affected for adverse topography. If prior approval has not been given by the **District Engineer,** then any design submitted will not be approved.

G.23 Subgrade Preparation

G.23.1 The **road** right of way shall be cleared of all trees, stumps, logs, roots, and any other objectionable material likely to cause settlement for the full width of the **highway,** and for such additional width as may be required to contain cut and fill slopes. In addition, buildings, fences, superfluous culverts, or any other structures within the **highway** shall also be removed. Trees may be left within the **highway** only where they do not conflict with utility services and where they are not deemed a hazard at the discretion of the **District Engineer**.

G.23.2 Prior to placing of any granular aggregate on the **highway**, all existing topsoil or other deleterious matter shall be removed from the full width of the **road** right of way and the **road** surface graded to the desired cross section. Those areas not supporting structural portions of the **road**, curb, gutter, or **sidewalk**s do not need to be stripped.

G.23.3 Embankments shall be constructed by placing, shaping, and compacting approved materials as classified in this Bylaw. All material placed in embankments shall be bladed smooth in level layers not exceeding 300 mm uncompacted depth over the entire embankment area and placed in successive uniform layers.

G.23.4 When embankments are to be made on hillsides or where a new fill is to be applied upon an existing embankment, the slopes of the original ground or embankment (except rock embankments) shall be terraced or stepped before filling is commenced.

G.23.5 Each layer shall be compacted to 95% Standard Proctor Density.

G.23.6 The embankment shall be constructed to provide adequate drainage. Should the embankment material become damaged or saturated by rain, flooding, or other effects, **repair**, scarification, or whatever other measures required to restore the embankment to the moisture and compaction requirements this Bylaw shall be undertaken. Unsuitable materials encountered in the excavation areas or at the subgrade elevation shall be excavated and wasted.

G.23.7 Over excavations shall be rebuilt to grade with an approved compacted material.

G.23.8 At transition sections where the profile grade changes from embankment to cut, the natural slope shall be excavated to a depth of 1 meter and replaced with suitable material for a distance of 15 meters in order to prevent abrupt future differential grade changes. These parameters may be varied on the recommendation of a geotechnical **engineer**.

G.23.9 The upper 300 mm of the subgrade shall be compacted to 100% of Standard Proctor density. Subgrade preparation shall extend a minimum of 600 mm out from back of curb, **sidewalk** or edge of asphalt on either side of the **road**.

G.23.10 Subgrade preparation shall be considered integral to the construction of new **road**s.

G.23.11 Frost Susceptible Soils (ML): The susceptibility of soils to frost heave is commonly classified using the US Corp of Army Engineers four categories, as shown in Table 15.2 of the "Canadian Foundation Engineering Manual", 3rd edition, 1992. All geotechnical reports shall address the frost susceptibility of the subgrade soil.

G.23.12 Swelling Soils (CH): Pockets of soils known to change volume with variation of moisture content are known to exist in several locations within the **District**. These soils are typically identified as highly plastic clays (CH) using the Unified Soil Classification System and Atterberg Limits index test

(ASTM D4318). Where these soils are encountered as subgrade, special subgrade preparation considerations are required, as outlined below.

G.23.13 Scarification should render the subgrade to cohesive pieces of a maximum size of 20 mm to allow adequate moisture conditioning of the soil. The soil should be moisture conditioned to achieve a homogeneous moisture content between 0 and 3% over optimum. Following moisture conditioning, the subgrade soil should be compacted to a minimum of 95% of Modified Proctor density, as determined by ASTM D1557. The subgrade should be covered with granular sub-base as soon as practical to minimize the variation of the moisture content in the subgrade. Additional moisture conditioning and compaction may be required, should the moisture content be allowed to vary significantly from optimum prior to placing the sub-base.

G.23.14 Proof Rolling

(a) Upon completion of the subgrade preparation, the subgrade shall be proof rolled with a loaded single axle truck with a minimum rear axle load of 8,000 Kg.

(b) Any areas found to be soft or wet shall be excavated and back filled with select granular sub base, granular material, and compacted to 100% Standard Proctor density.

G.24 **New Pavement Design**

G.24.1 The following four primary factors shall be considered in undertaking a specific design:

(a) Subgrade support quality (geotechnical report)
(b) Design life (20 years)
(c) Traffic loading (expressed in ESALs)
(d) Climate

G.24.2 New pavement structures shall be designed in accordance with the methodologies presented in "AASHTO Guide for Design of Pavement Structures", 1993. The pavement structure shall be designed for a twenty (20) year design life.

G.24.3 The American Association of State Highway and Transportation Officials (AASHTO) design method is based on a Structural Number (SN) for the entire pavement structure (i.e. hot mix asphalt, granular base and granular sub-base). The method incorporates the subgrade strength expressed as the Subgrade Resilient Modulus (Mr), and design loading measured in equivalent single axle loads (ESALs). Each component of the pavement structure is assigned a layer coefficient.

G.24.4 Subgrade strength is frequently characterized utilizing the California Bearing Ratio (CBR) test procedure (ASTM D1883). This test should be performed on soaked subgrade soil specimens compacted to 95% of Modified Proctor density as determined by ASTM D1557. The Resilient Modulus may be approximated from the soaked CBR test values using the following relationships:

Mr (MPa)	=	10.3 CBR, or
Mr (psi)	=	1500 CBR

G.24.5 The soaked CBR properties of subgrade soil should be determined for each major soil type encountered. Where more than one test is required, the tests should be evenly spaced, unless otherwise directed by the geotechnical **engineer**.

G.24.6 The required SN for the pavement structure is the sum of the product of the layer coefficient, the component thickness, and a drainage coefficient for each component:

eq'n (1) $SN = a_{ac}D_{ac} + a_bD_bM_b + a_{sb}D_{sb}M_{sb}$ where:

SN	=	structural number for pavement structure
a_{ac}	=	layer coefficient for hot mix asphalt (0.4)
a_b	=	layer coefficient for granular base (0.14)
a_{sb}	=	layer coefficient for granular sub-base (0.10)
D_{ac}	=	thickness of hot mix asphalt (mm)
D_b	=	thickness of granular base (mm)
D_{sb}	=	thickness of granular sub-base (mm)
M_b & M_{sb}	=	layer drainage coefficient (1.0 for Lake Country)

G.24.7 Road classifications, design traffic values and minimum depths of hot mix asphalt and granular base components of the total pavement structure are as per TABLE G-9.

TABLE G-9-MINIMUM ASPHALT AND GRANULAR BASE DEPTH VS DESIGN TRAFFIC

Road Classification	Design Traffic (ESALs) [1]	Minimum Depth of Hot Mix Asphalt (mm)	Minimum Depth of Granular Base (mm)
Walkways	n/a	50	75
Local, Lanes & Access Roads	2.8×10^4 (28,000)	50	75
Collector	2.8×10^5 (280,000)	100	100
Arterial [2]	1.0×10^6 (1,000,000)	100	100

[1] See Part 1 – Chapter 1 of AASHTO for definition of an Equivalent Single Axle Load (ESAL).
[2] Special design reviews may be requested by the **District Engineer**

G.25 Standard Pavement Structures

G.25.1 Standard pavement structures, including required SN values, are provided on in TABLE G-10 for three strengths of subgrade. The standard pavement structures incorporate the minimum depths of hot mix asphalt and granular base shown.

TABLE G-10-STANDARD PAVEMENT STRUCTURES				
Street Classification	**Structure Component**	**Thickness is mm for Soaked CBR [1] of**		
		3.0 [4] CBR 5	**5.0 CBR 10**	**CBR 10**
Walkways	Asphalt – Surface Course	50	50	50
	Granular Base	75	75	75
	Granular Sub-base [3]	150	150	150
	Required SN Value	n/a	n/a	n/a
Local, Lanes & Access Roads	Asphalt – Surface Course	50	50	50
	Granular Base	75	75	110 [2]
	Granular Sub-base [3]	275	165	0
	Required SN Value	58	47	35
Collector	Asphalt – Surface Course	40	40	40
	Asphalt – Base Course	60	60	60
	Granular Base	75	75	100 [2]
	Granular Sub-base	335	185 [3]	0
	Required SN Value	84	69	53
Arterial	Asphalt – Surface Course	40	40	40
	Asphalt – Base Course	60	60	60
	Granular Base	75	75	75
	Granular Sub-base	535	355	155(3)
	Required SN Value	104	86	66

[1] Soaked CBR value shall be at 95% of Modified Proctor maximum dry density and optimum moisture content, as determined by ASTM D1557.

[2] Placement of equivalent sub-base layer is not practical and shall be replaced with additional granular base.

[3] Maximum aggregate size of sub-base material to be no more than 50% of total depth of sub-base.

[4] Where the top 1 m of subgrade has a soaked CBR value of less than 3, then the subgrade strength should be supplemented with an additional thickness of granular sub-base material in order to achieve a soaked CBR value of 3 or greater. The thickness of the supplemental sub-base and the corresponding composite CBR value for the top 1 m of composite subgrade can be determined by the following formula:

$$\text{CBR Composite} = ((t_{ssb} \times CBR_{ssb}^{0.33} + (100-t_{ssb}) \times CBR_{sg}^{0.33})/100)^3$$

Where CBR Composite is 3 or greater.

t_{ssb} = thickness of supplemental sub-base (cm).

CBR_{ssb} = CBR value of supplemental sub-base.

CBR_{sg} = CBR value of subgrade soil.

G.25.2 Granular base and granular sub-base to have a minimum soaked CBR value of 80 and 20, respectively.

G.25.3 For design purposes, the maximum subgrade soaked CBR value shall not exceed 10.

G.25.4 Staged construction may be considered by the **District Engineer** when a **road** is to be constructed and to be widened at a later date.

TABLE G-10 provides standard pavement structures for **road**s constructed on only three strengths of subgrade. Alternate pavement structures may be designed based on the SN determined using

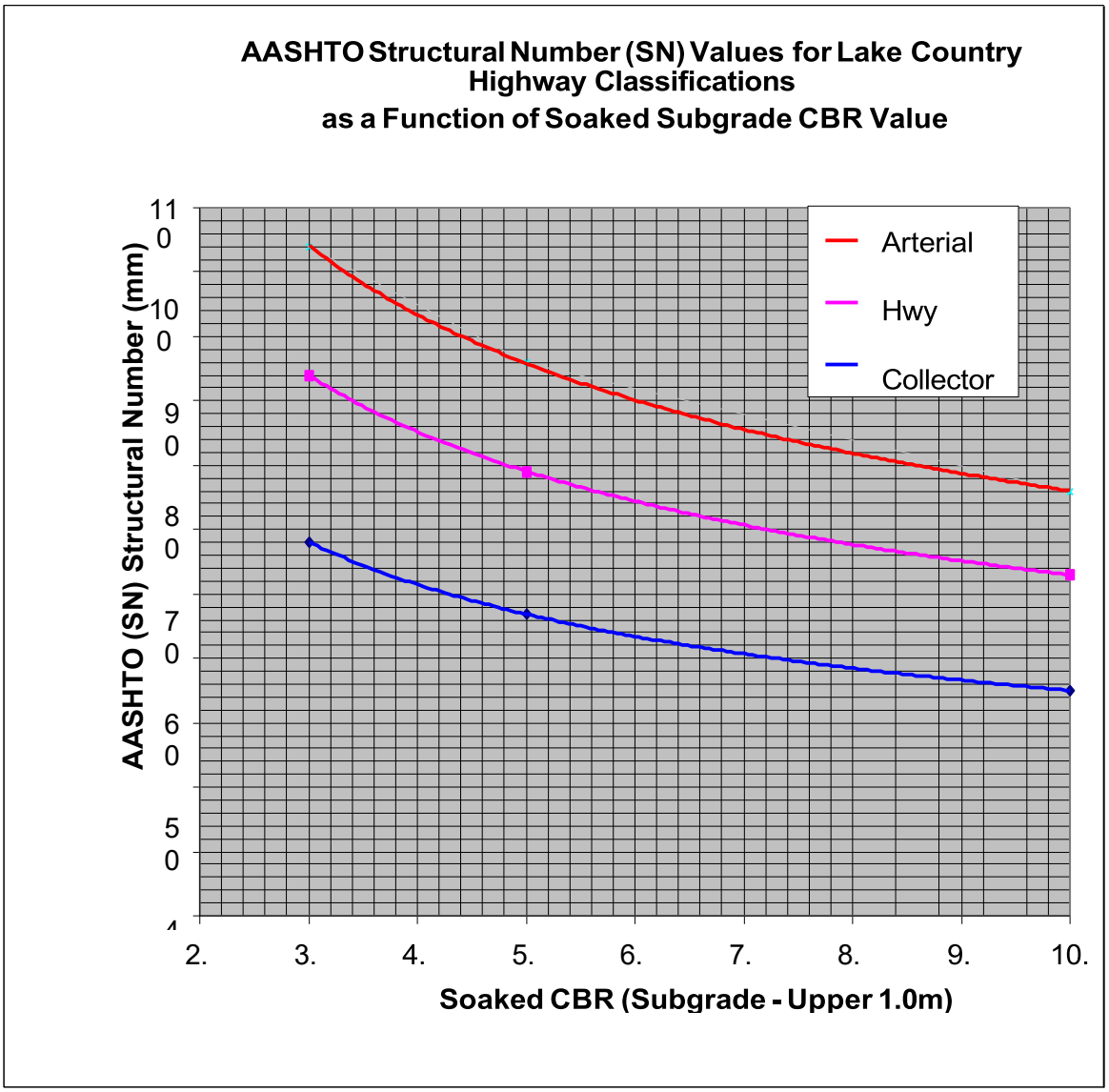
G.25.5 **FIGURE G-1**. For example, for a Collector Road with soaked subgrade CBR value of 4, then the corresponding pavement structure requires a SN of 75. Using eq'n (1), and the specified layer coefficients, a suitable pavement structure alternative may be determined as shown TABLE G-11.

TABLE G-11-EXAMPLE PAVEMENT STRUCTURE [1]			
Pavement Structure Component	**Thickness, D (mm)**	**Layer Coefficient, a**	**SN**
Hot Mix Asphalt	100	0.40	40
Granular Base	100	0.14	14
Granular Sub-base	210	0.10	21
Total SN			75

[1] The minimum depths of hot mix asphalt and granular base shown, and the required SN have been met.

FIGURE G-1

Curves shown are derived from the methodologies presented in AASHTO. A description of all variables used to derive the curves is presented in the Ministry of Transportation Technical Circular T - 9/95, "Pavement Design Standards".



G.26 **Design of Overlays for Existing Pavements**

G.26.1 Design criteria for overlays are based on the limiting Benkelman Beam deflections as per TABLE G-12

(a) The design Benkelman Beam rebound (x + 2σ) should be determined on the basis of at least 10 uniformly spaced readings per two-**lane** kilometre (one half in each **lane**).

(b) The summary rebound statistic for a pavement section should be seasonally adjusted to the spring peak rebound value.

TABLE G-12-BENKELMAN BEAM CRITERIA FOR OVERLAYS

Road Classification	**Maximum Deflection (mm)**
Arterial highways	1.00
Collector highways	1.25
All Other Highway Classifications	1.50

G.27 **Materials**

G.27.1 Subgrade Fill Material

(a) Subgrade fill material shall be free of rock detrimental to proper compaction and free of organic or other deleterious matter. Fill material shall be compacted to a minimum of 95% Standard Proctor density (ASTM 0698). Fill material shall be moisture conditioned to within 3% of its optimum moisture content, as determined by the Standard Test Methods for Moisture-Density Relations of Soils and Soils-Aggregate Mixtures ASTM D698 or ASTM D1557, at the time compaction is undertaken.

G.27.2 Rock Fill

(a) Rock, by definition, shall mean any material excepting hardpan or glacial till over 0.75 cu.m. in volume requiring continuous drilling and blasting. It shall mean masonry or concrete as well as natural boulders fitting this definition.

(b) Rock fill shall be any material containing more than 15% by volume of rock larger than 150 mm in size.

(c) It shall only be used in approved areas and by approved methods to provide maximum stability of the fill, as approved by the geotechnical **engineer**.

G.27.3 Granular Sub-base Course

(a) Granular sub-base shall be well-graded material conforming to the gradation limits as shown on Standard Drawings or suitable blast rock designed and installed under the supervision of a Geotechnical Engineer provided the maximum nominal size is less than or equal to 50 percent of the compacted sub-base layer thickness.

G.27.4 Crushed Granular Base Course

(a) Crushed base course shall be composed of inert, durable aggregate, reasonably uniform in quality, and free from soft or disintegrated pieces, wood wastes, roots, organic material or other deleterious materials.

(b) The gradation shall be within the limits set out in **TABLE G-13** when tested to ASTM C 136 and C 117, using the designated sieve sizes, and to have a smooth curve without sharp breaks when plotted on a semi log grading chart.

TABLE G-13-CRUSHED GRANULAR SUB-BASE LIMITS	
USBC Sieve Size	**Percent by Weight Passing**
25.00 mm (1")	100%
19.00 mm (3/4")	80-100%
9.50 mm (3/8")	50-80%
4.75 mm (# 4)	35-65%
2.36 mm (# 8)	25-50%
1.18 mm (# 16)	15-35%
0.300 mm (# 50)	5-20%
0.075 mm (#200)	3-8%

(c) A minimum of 60% of the material retained on 4.75 mm sieve shall have at least two fractured faces as determined by particle count.

G.27.5 Crushed Granular Aggregate for Asphaltic Concrete

(a) Crushed granular aggregate for asphaltic concrete shall be composed of hard, durable, crushed gravel free from shale, clay, silt, loose coatings, and other deleterious materials.

(b) The gradation of aggregates, when blended to meet the job mix formula shall be within the limits shown in **TABLE G-14** when tested to ASTM C 136 and C 117, using the designated sieve sizes, and to have a smooth curve without sharp breaks when plotted on a semi log grading chart.

TABLE G-14-GRADATION OF CRUSHED GRANULAR AGGREGATE FOR ASPHALTIC CONCRETE			
USBC Sieve Size	**Arterial, Industrial and Collector Streets**		**Residential, Lanes, walkways**
	Percent Passing by Weight		**Percent Passing by Weight**
	Lower Course	**Surface Course**	
25 mm (1")	100		
19 mm (3/4")	85 - 100	100	
12.5 mm (1/2")	65 - 85	85 - 95	100
9.5 mm (3/8")		70 - 85	70 - 90
4.75mm (#4)	40 - 65	50 - 70	45 - 80
2.36mm (#8)		38 - 55	32 - 64
1.18mm (#16)	20 - 38	28 - 44	24 - 51
0.600mm(#30)		20 - 34	17 - 40
0.300mm(#50)	10 - 20	12 - **26**	13 - 29
0.150mm(#100)	8 - 15	**8** - 16	7 - 18
0.075mm(#200)	3 - 8	3 - 7	3 - 8

(c) A minimum of 60% of the material retained on 4.75 mm to 25 mm sieve shall have at least two freshly fractured faces as determined by particle count.

G.27.6 Spreading and Compaction of Granular Aggregate

(a) Granular aggregate shall be placed in maximum 150 mm lifts and shall be spread in an approved manner such that the aggregate is neither segregated nor contaminated with foreign material. Segregated materials shall be remixed until uniform. Immediately following spreading, granular aggregate shall be compacted to 100% Standard Proctor density. The finished surfaces shall be within +/- 15 mm of the design grade and cross section.

(b) The tolerance limits are in relation to the design aggregate gradation submitted with the Marshall mix design. Aggregate short of material passing the 0.075 mm sieve shall have approved mineral filler added. Mineral filler shall be material passing the 0.075 mm sieve and shall be non-plastic when tested in accordance with ASTM D424. The moisture content of the aggregate after leaving the drier and before mixing shall be not more than 0.5% by weight.

TABLE G-15-TOLERANCE LIMITS	
Max Size	**Percent Passing by Weight**
4.75 mm	5.0%
2.36 mm	4.0%
1.18 mm	4.0%
0.600 mm	3.0%
0.300 mm	3.0%
0.150 mm	2.0%
0.075 mm	1.5%

G.27.7 Placing and Compacting Asphaltic Concrete

(a) A self-propelled mechanical paver shall be used to spread the mixture. Compaction shall commence immediately. Compaction methods shall be carried out as specified in the Asphalt Paving Manual published by the Asphalt Institute and the MMCD

G.27.8 Asphalt primer shall be:

(a) Anionic emulsified asphalt, slow setting (SS 1) and shall be diluted with clean water at two (2) parts emulsion to one (1) part water for application, and thoroughly mixed by pumping. The diluted asphalt emulsion shall be applied at a rate of 2 litres per square metre, or as approved by the **District Engineer**. The prepared granular base shall be clean and free of "float" prior to application of prime. Allow prime to absorb and cure for 24 hours prior to paving, unless otherwise approved by the **District Engineer**. Traffic shall not be permitted onto primed areas. Or;

(b) Cutback Asphalt Primer RM20 meeting the requirements, and to application rates, stipulated in the Standard Specifications for Highway Construction (latest edition) of the Province of British Columbia Ministry of Transportation and Infrastructure.

G.27.9 Tack coat:

(a) Bituminous tack coat shall be undiluted SS 1H or SS 1 asphalt emulsion and shall be applied at a rate not greater than 0.5 litres per square metre to a clean pavement surface and provide for adequate curing time prior to placing asphalt paving mixtures. The temperature of the material shall be maintained between 30°C and 40°C at the time of application.

G.27.10 Asphaltic cement:

(a) shall be homogenous, free from water, shall not foam when heated to 175 °C, and meet the requirement of TABLE G-16.

TABLE G-16-ASPHALTIC CEMENT		
REQUIREMENTS	**MIN.**	**MAX.**
Viscosity @ 60° (Pa/s)	65	
Min. Penetration @ 25°C	80	
% Ret. Pen. after T.F.O.T. @ 25°C - 100 g/5 s	55	
Solubility in Trichloroethylene (%)	99.0	
Flash Point, C.O.C. minimum (°C)	235	
Ductility at 25°C, 5 cm/min.cm	100	
Water (%)		0.5

G.27.11 Asphaltic concrete:

(a) shall conform to **TABLE G-17**

(b) The **Owner** shall supply the **District Engineer** with a current 5-point Marshall mix design, performed in accordance with ASTM D 1559, under the signature of a geotechnical **Engineer**. The design asphalt content shall be specified to comply with the requirements of this section.

(c) The asphalt content of hot mix asphalt which is produced in accordance with the approved Marshall design shall be maintained within plus or minus 0.3% of the approved design asphalt content.

TABLE G-17-ASPHALTIC CONCRETE			
Property	**Arterial & Collector Streets**		**Residential**
	Lower Course	**Surface Course**	**Surface Course**
Marshall blows per face	75	75	50
Marshall Stability @ 60°C (kN)	8 min.	8 min.	5.5 min.
Marshall Flow (0.25 mm units)	8 – 14	8 - 14	8 - 15
Voids in Mineral Aggregate (%)	13.0 – 16.5	14.0 - 17.0	14.0 - 17.5
Air Voids in Mixture (%) - at design A.C. - Allowable production range	4.0 + 0.2 3 - 5	4.0 + 0.2 3 - 5	3.5 + 0.3 3 - 5
Index of Retained Stability after water immersion for 24 hours @ 60°C	80% min.	80% min.	80% min.

(d) Density of Completed Asphaltic Concrete Pavement

(i) The minimum allowable density of the completed pavement shall be not less than 97% of the laboratory compacted Marshall Density.

(ii) Flaws in the pavement surface shall be corrected by removal of the complete area and the full lift involved. Pavement which is unsatisfactory in the opinion of the **District Engineer** by reason of faulty materials or methods of placement shall be **repaired,** to the original condition or better, removed, replaced, or otherwise corrected.

(e) Asphaltic concrete shall be constructed in lifts of compacted thickness as per TABLE G-18:

TABLE G-18-ASPHALTIC CONCRETE CONSTRUCTION		
Course	**Permissible Compacted Lift Thickness (mm)**	
	Minimum	**Maximum**
Lower Course	50	100
Surface Course	40	75

G.28 **Testing**

G.28.1 The **Owner** shall retain an independent materials testing firm to carry out comprehensive testing to frequencies defined below, for each stage of construction of **roads** and streets. The materials testing firm must employ a full time, qualified Engineer within the office from which the testing services are provided. He shall review all test data and provide to the **District**, on a daily basis and in summary form at the completion of each stage of the **work**, test data at the following minimum frequencies:

(a) For subgrade construction:
- (i) Moisture density relationship (Standard Proctor) – ASTM D698; - one test for each soil type incorporated into the subgrade.
- (ii) Moisture and density test
- (iii) Subgrade construction and preparation three tests per 150 lineal metres of **road** per lift, to include dry density and moisture content.

(b) For trench backfill
- (i) one test per lift per 50 lineal metres of trench and one test per lift around manholes, valves, catch basins, etc.

(c) For sub base and base course construction (including subgrade enhancement using sub-base material):
- (i) Gradation analysis - one test per 500 m3 or 1100 tonnes of material delivered to the site with a minimum of 1 test per day of placement.
- (ii) Moisture density relationship (Standard Proctor) ASTM D698; one test per class of material for each 5000 m3, or 11000 tonnes delivered to site.
- (iii) Compaction testing three tests per 150 lineal metres of **road** per lift, to include dry density and moisture content.

(d) For hot mix asphalt pavement production and placement:
- (i) Asphalt content and gradation of extracted aggregate - one test per production period, where a production period is defined as that part of the working day either before or after 12:00 Noon local time. In a full working day, the times of test shall be not less than two hours apart.
- (ii) Marshall Analysis of hot mix asphalt - one per work week per mix type; additional tests shall be performed when any of the specified Marshall properties are not met in the initial analysis.
- (iii) Asphalt cement tests one complete analysis per project or one every two work weeks, whichever is the lesser in timing; plus one penetration (ASTM D5) test per work week from product obtained from the **contractor's** asphalt cement storage tanks.
- (iv) Density, air voids and pavement thickness tests 3 cores (100 mm dia.) per 1500 m2 of paved area per lift, with a minimum of 3 cores for each production day. Air void tests shall be performed in accordance with ASTM D3203.
- (v) Tests on prime and tack coat products - one test per product per project.

G.28.2 The **District** shall be provided with copies of all compaction test results pertaining to subgrade, granular base and pavement structure.

G.29 Notification

G.29.1 Prior to undertaking **roadwork**s, adequate notice shall be given to the **District Engineer** by the **Owner** in accordance with TABLE G-19. The **Owner** shall not proceed from one stage to another stage without the approval of the **District Engineer**.

TABLE G-19-CONSTRUCTION NOTIFICATION REQUIREMENTS

Stage	**Minimum Notice Required**
Prior to construction of fills or doing subgrade preparation	24 hours
Prior to placement of sub-base materials	24 hours
Prior to placement of concrete for curbs and **sidewalk**s	48 hours
Prior to placement of base course (19 mm crushed gravel)	24 hours
Prior to paving	48 hours
Prior to top soiling **boulevard**s	24 hours

G.30 Testing Frequency and Procedures

G.30.1 Aggregate Gradation and Asphalt Cement Content

One test per production period as defined in G.33.1 Asphalt content shall be determined in accordance with ASTM D2172 or D6307. Gradation analysis of extracted aggregate shall be performed in accordance with ASTM C136 and C117.

G.30.2 Thickness

(a) The actual pavement thickness, for each unit of **work** area, will be determined on the basis of the average thickness of three (3) cores. The cores shall be spaced at intervals of 150 m of paved **lane** width or less. If the deficiency of any individual core exceeds 10 mm, three (3) additional cores may be extracted in proximity to the location of the core of excessive deficiency, to identify the extremities of the pavement area to be removed and replaced. The **Owner** will initiate and pay for such additional coring.

(b) A unit of **work** area is defined as 1,500 m^2 or fraction thereof, representing pavement placed in an individual placement day.

(c) Sampling and testing for thickness determination shall be in accordance with ASTM D3549.

G.30.3 Density

(a) Density of compacted pavement shall be determined on the basis of tests on core samples taken at a maximum interval of 150 m of paved **lane** width. A test area shall be that area lying between longitudinal joints and between transverse lines located midway between test cores or between such transverse lines and the beginning or end of placement.

(b) With prior approval of the **District Engineer**, the in-situ density of a compacted layer of pavement may also be determined by nuclear methods in accordance with ASTM D 2950. Spacing of tests shall be as stated above, and tests shall be taken in the vicinity of the core samples extracted for testing of the thickness of the pavement layer. In a situation where the in-situ density of the lift does not meet specification, according to D 2950, then the density of the extracted cores shall be determined and will take precedent over the in-situ density. Where the specified compaction has not been met, as confirmed by the direct measurement of

the core, then an additional three cores shall be taken in the immediate area and the average of the three cores shall be used.

G.31 Non-Compliance with Specifications

G.31.1 General

G.31.2 If the **Owner** fails to ensure that their **contractor** complies with the paving and construction specifications as set out in this Bylaw, the following shall apply. Any penalty for deficiencies will be in the form of a reduction in the amount of security for **work**s returned to the **Owner**.

G.31.3 Hot Mix Asphalt Concrete

(a) A Marshall analysis will be performed from a sample obtained at the paving site on a frequency of one analysis per day, with at least one analysis required per project or 700 tonnes of asphalt.

(b) When analysis identifies non-conformance with specified properties, remedial measures must be immediately initiated. Evidence that compliance exists with the approved mix design must be provided. Failure to do so must result in suspension of paving operations.

G.31.4 Aggregate Gradation

(a) When the aggregate fails to comply with tolerances set forth in this Bylaw, the **Owner's Engineer** will initiate the following action:

(b) When two (2) consecutive gradation analyses identify non-compliance with the specified tolerances, the **contractor** must be served notice and a third test will be initiated.

(c) If continued non-compliance is indicated from the third test, the **Contractor**/**Owner** must suspend production. It must not commence construction again until it has demonstrated that corrective action has been taken and that the aggregate gradation is within the specified tolerance limits.

G.31.5 Asphalt Cement

TABLE G-20 -PAYMENT ADJUSTMENT FOR NON-COMPLIANCE WITH TOLERANCE	
Asphalt Content Deviation from Design %	Payment Adjustment Factor
0.30 OR LESS	0.00
0.31 TO 0.40	0.20
0.41 TO 0.50	0.75
0.50 OR GREATER	Remove and replace

G.31.6 Penalty will be applied for asphalt cement content non-compliance where the amount of penalty for Hot Mix Asphalt Paving equals the unit bid price times the payment adjustment factor times the quantity to which the factor is to be applied, i.e.:

$A_C = P (F_C) (Q_n)$

where:

A_C = Adjustment for asphalt cement content non-compliance

P = Unit bid price

FC = Payment adjustment factor for Asphalt Cement Content non-compliance

Q_n = Asphalt measured for payment which was produced during the production period to which a test applies

G.32 **Penalty for Non-Compliance**

G.32.1 Pavement Thickness

(a) Pavement of any type found to be deficient in thickness by more than 10 mm must be removed and replaced by pavement, of specified thickness, at the **Owner**'s expense.

(b) Pavement of any type found to be deficient by less than 10 percent of its specified compacted thickness will not be subject to payment adjustment for thickness non- compliance.

(c) Pavement of any type found to be deficient in thickness by more than 10 percent of its specified thickness but not more than 10 mm shall give rise to an adjustment in the amount of penalty. The penalty shall be calculated as follows:

$$A_t = \frac{T_d}{T_s} \times P \times Q_t$$

Where:

A_t = Adjustment for thickness deficiency

T_d = Deficiency in thickness measured in mm and being greater than 10% of specified thickness but not greater than 10 mm.

T_S = Specified thickness in mm.

Q_t = Asphalt measured for payment lying within a unit of **work** area defined in G.39.2 (b) where the thickness deficiency has been identified.

P = Unit Bid Price.

NOTE: No allowance will be made for the tolerance provided for in G.36.2

(d) The adjusted price will be applied to all asphalt measured for payment which lies within a unit of **work** area defined in G.39.2 (b) where the thickness deficiency had been identified, or to such lesser area as may be defined in accordance with the provisions G.39.2(b).

G.32.2 Density

(a) The minimum specified density for acceptance, without penalty adjustment, must be 97% of the 75 blow Marshall density as most recently determined by the appointed testing agency.

TABLE G-21-PAYMENT ADJUSTMENT FOR DENSITY NON-COMPLIANCE

Density (% of 75 blow Marshall)	Payment adjustment factor
97 and greater	0.0
95.0 to 96.9	As per Density Payment Adjustment Factor Chart (see Standard Drawing)
Less than 95.0	No payment (subject to removal and replacement after review by the Engineer)

(b) Adjustment for density specification non-compliance shall be determined as follows:

A_D = P (F_D) (Q_{nD})

where:

A_D = Adjustment for density non-compliance

P = Unit Bid Price for Hot Mix Asphalt Cement paving

F_D = Payment Adjustment Factor for density non-compliance

Q_{nD} = Asphalt measured for payment within a unit of test area as defined in G.39.3.

G.32.3 Adjusted Payments

(a) The total penalty arising from pavement deficiencies identified in the foregoing shall be determined as follows:

$A_r = A_c + A_t + A_D$

where:

A_r = Total Adjustment

A_c = Adjustment for asphalt cement content non-compliance

A_t = Adjustment for thickness deficiency

A_D = Adjustment for density non-compliance

The total adjustment (A_r) shall be paid by the **Owner** to the **District** and may be withheld by the **District** from any securities held for the **subdivision** or **development**.

SCHEDULE H DESIGN AND CONSTRUCTION OF SIDEWALKS, CURBS, GUTTERS, BOULEVARDS AND LANDSCAPING

H.1 General

H.1.1 All curbs, **sidewalk**s, gutter, **boulevard**, and landscaping must be designed and constructed in accordance with this Bylaw.

H.1.2 The minimum width of sidewalks shall be 1.5 metres. The **District Engineer** may in their sole discretion, require that a sidewalk width be increased.

H.1.3 The location of **sidewalk**s shall be as follows:

(a) **Arterial highways** - **sidewalk**s are required on both sides of **highway**;

(b) **Collector highways** - **sidewalk**s are required on one side of **highway** as required by the **District Engineer**;

(c) **Local highways** - **sidewalks** are required on one side of the **highway**, where the **highway** will be used to provide the public with safe and efficient access to educational facilities, government facilities, parks, recreation sites, hiking trails, pedestrian corridors, shopping centers, entertainment centers, health institutions, religious institutions, or where identified as per Standard Drawings for the **road** class. The location shall be as required by the **District Engineer**.

H.1.4 In accordance with **District** Bylaws and policies, upon completion of **highway**, curb, gutter, and **sidewalk** construction, **boulevards** must be shaped and graded to match and blend with surrounding areas.

H.1.5 Trees, shrubs, dry land grass as well as turf or mulch complete with irrigation must be in accordance with Schedule C-1 and **District** irrigation standards.

H.1.6 In areas of rural cross sections without curb, gutter, or **sidewalk**; **boulevard**s must be shaped and graded to match and blend with surrounding areas seeded with coarse grasses (Okanagan Dryland Grass Mix).

H.2 Driveway Access – *deleted by Bylaw 1193, 2022*

H.3 Wheelchair Ramps

H.3.1 Wheelchair ramps must be provided at all intersections on **road**ways that are being provided with **sidewalk**s and constructed in accordance with Standard Drawings.

H.4 Barrier Curb Crossing

H.4.1 Barrier Curb Crossings must be provided at all access locations and must be constructed in accordance with Standard Drawings.

H.5 **Landscaping**

H.5.1 Landscape Plan Requirements:

For landscape Works that will be owned and maintained by the District, a Qualified Professional with expertise in landscaping, engaged by the Owner, is required to submit landscape drawings for review by the District.

The following information shall be shown on the Landscape Drawings:

(a) property lines and easements.
(b) buildings, edge of pavement, curb lines and curbs, sidewalks, lighting fixture locations, surface utilities and related service boxes or other elements that would affect the landscape and street tree location.
(c) Location of all existing vegetation to remain.
(d) Location of retaining walls and existing or proposed slopes that exceed 3:1 vertical.
(e) Location of all proposed trees, shrubs, ground cover and lawn areas.
(f) Indication of which areas will be seeded grass vs sodded lawn.
(g) Plant list showing botanical name, common name, size at planting, quantity, typical spacing, and root zone volume of supplied growing medium for trees.
(h) Landscape features, if applicable.
(i) Type of mulch and application depth.
(j) Growing medium depths for each planting type.

H.5.2 Boulevard Landscaping:

Unless specified otherwise, boulevards shall be vegetated with sodded lawn or densely planted groundcover. Rough grass and/or wildflower seeding may be used on boulevards and side slopes that are visually backing onto natural or rural areas, or for temporary boulevard treatments, subject to the approval of the District Engineer.

(a) For the boulevards of arterial and collector roads within the Town Centre DP area, the treatment shall be as per the streetscape improvement plan for that area.
(b) For boulevards adjacent to commercial property and locations outside the Town Centre DP area, or where no plan is in place, subject to development permit requirements, the boulevard treatment shall generally be turf or hard-surfaced, and shall include street trees and irrigation, serviced and maintained by the **Owner** of the parcel with the boulevard frontage. Acceptable surface materials for the boulevard include:
    I. unit pavers
    II. exposed aggregate concrete;
    III. stamped and coloured concrete;
    IV. irrigated turf; or
    V. xeriscape or dryland landscaping
(c) For boulevards where the land use of the adjacent property is industrial, institutional or multi-family the boulevard treatment shall generally be street trees and turf or xeriscape landscaping, serviced and maintained by the **Owner** of the parcel with the boulevard frontage.
(d) For boulevards where the land use of the adjacent property is one, two or four-family residential, and where the boulevard is accessible for maintenance mowing and watering from the adjacent property, the boulevard treatment shall generally be street trees and turf or xeriscape landscaping, serviced and maintained by the Owner of the parcel with the boulevard frontage.
(e) For boulevards where it is unlikely that the adjacent property owner will be able to adequately maintain the boulevard due to geographical constraints, the **District** may accept ownership and maintenance of the boulevard, subject to the approval of the **District Engineer**.

H.5.3 Median and Roundabout Landscaping:

(a) Landscaped medians are generally discouraged within arterial or collector roads due to difficulty of service and maintenance.

(b) In locations approved by the **District Engineer**, medians shall be vegetated with sodded lawn or densely planted groundcover and irrigated street trees.

(c) The landscaping of roundabouts and cul-de-sac islands shall have a hard surface material or landscaping with low shrubs or groundcovers at the discretion of the **District Engineer**, and should feature:

(i) a single specimen tree;

(ii) a group of like trees; or

(iii) public art if the roundabout or cul-de-sac is in the Town Centre area. The selection, design and placement of public art shall be made in cooperation with the Public Art Advisory Commission.

H.5.4 Utilities Coordination:

(a) Placement of landscape features shall be coordinated with the location of underground utilities and shall be, as much as is practical, aligned and buried to provide a continuous 1.0m deep utility-free trench beneath tree planting locations.

(b) Planting and paving design shall be co-coordinated with the design and construction of surface utility boxes, such that boxes fall entirely within either a paved surface or entirely within a planted surface but not partly in paving and partly in planting and that grades and alignment of boxes match the final design and construction of all elements to create a co-coordinated and orderly appearance, free of trips and hazards.

H.5.5 Plant Materials:

(a) Plants shall have the ability to withstand adverse conditions such as airborne pollutants, maximum sun exposure and reflected heat from pavements, high winds and abrasive forces, occasional snow loading and exposure to salt from road clearing operations, and limited root zone soil volumes.

(b) Plant hardiness requirements vary by elevation. Plants shall be hardy to Canadian Plant Hardiness Zone 5A to 1A as site conditions dictate.

(c) Plants shall be capable of reduced water demand following a one-year establishment period.

(d) Plants shall have relatively low maintenance attributes including: fine to medium leaf size and canopy density; non-fruit bearing or having only berry-sized non-staining and non-toxic fruits; low susceptibility to disfiguring or fatal diseases and infestations; infrequent demands for pruning, fertilizing and other cultural requirements.

(e) Plants shall be of appropriate size and form at maturity to meet criteria listed in this bylaw.

H.5.6 Tree Planting:

(a) Street Tree plantings shall be required on streets and **highways** in all subdivisions where new roads (including culs-de-sac) or road extensions are required.

(b) Minimum number of boulevard trees shall be calculated as follows:

(i) Medium trees (± 10 - 20m ht. at maturity) greater of 1 per lot or 15m.

(ii) Small trees (Under 10m ht. at maturity) greater of 1 per lot or 10m.

(iii) Plantings of trees closer than 6m on centre shall require the written concurrence of the District Engineer.

(iv) Locate trees fronting on single family lots in locations that avoid all utility service alignments and driveways. Generally, this will lead to tree placement in the half of the lot frontage away from the driveway side, and not at either the lot centerline or at a lot line.

(c) Boulevard or 'street' trees shall be of a single species/cultivar on either side of the street within a given block. Centre median tree species may vary.

(d) Street tree species shall vary between intersecting streets. Street tree selection will be made with consideration of maintaining a diverse and varied street tree distribution across a neighbourhood to minimize disease risks.

(e) All street trees shall have:

(i) A compact or upward branching structure.

(ii) Ability to withstand pruning for pedestrian, vehicle and/or building clearance without compromise to tree health or form.

(iii) Absence of species/varietal characteristics of structural weakness, susceptibility to wind damage, or thin, easily damaged bark.

(f) Trees shall be minimum 5 cm caliper measured at 300mm above the root ball at the time of planting, and of uniform size if planted in a boulevard row.

(g) Tree branch clearance requirements are 5m over the traveled portion of road and 2.25m over the sidewalk.

(h) Trees directly under electrical power lines must meet the following selection and soil volume requirements:

i. Minimum allowable soil volume per tree is 4 cu.m. with 1m depth pit.
ii. Mature height not greater than 7.5m.

(i) Trees beside hydro lines must meet the following selection and soil volume requirements:

i. Minimum lateral distance from nearest line 2.75m.
ii. Minimum allowable soil volume per tree is 4 cu.m. with 1m depth pit.
iii. Mature spread not greater than 5m.

(j) Trees with limited available soil volume must meet the following selection and soil volume requirements:

i. Minimum allowable soil volume per tree is 4 cu.m. with 1m depth pit.
ii. Mature height not greater than 10m.

(k) Trees for available soil volumes of 9 cu. m. or greater must meet the following selection and soil volume requirements:

i. 1m pit depth
ii. Mature height not greater than 20m.

(l) Trees for a wide boulevard or wide median use only must meet the following selection and soil volume requirements:

i. Minimum available root zone of 20 cu. m. per tree
ii. Minimum boulevard or median width of 3.5m

(m) Minimum setbacks for trees to objects in new developments shall be as follows:

Underground streetlight conduit or irrigation main	0.6m
Other underground utilities	3.0m
Lamp standards	6.0m
Steel and wooden utility poles	3.0m
Driveways	1.5m
Catch basins	1.5m
Manholes, valve boxes, services	3.0m
Sewer service boxes	3.0m
Fire hydrants	2.0m
Road intersection	7.0m
Curb face (see SS-L3 for Root Barriers required)	0.5m

Sidewalk	0.85m
Curb face and sidewalk with root barrier	0.60m
Buildings - fastigiate (columnar) tree	2.0m
Buildings - regular crown tree	3.0-5.0m

The District Engineer may consider custom setbacks where trees are being installed in existing streets with established utilities.

(n) Lawns/Fine Grass, Rough Grass and Wildflowers:
Sod shall be used on all lawn/fine grass areas. Seeding, as an alternate, shall require approval of the **District Engineer**.

(o) Rough grass and wildflower areas shall be seeded. Seeding method shall be noted on drawings.

(p) Areas to be seeded with grades greater than 3:1 and/or highly erodible soils shall be hydroseeded with a nurse crop seed mix, a hydraulically applied erosion control mulch, or erosion control blanket. Erosion control method to be noted on drawings.

H.5.7 Landscape Maintenance

(a) All landscaping must be actively maintained by the **Owner** for the entire Landscape Maintenance Period as described below. The Landscape Maintenance Period for landscape establishment shall be one year from the date of **Substantial Performance** of the landscape components of the work. All landscape areas shall be provided establishment maintenance which shall include irrigation maintenance and watering, mowing, weeding, pruning and supplemental fertilization until the end of the Landscape Maintenance Period. The Landscape Maintenance Period shall continue until a Certificate of **Total Performance** of all Landscape **Works** is issued by the **District** upon the expiration of the Landscape Maintenance Period.

(b) The Owner's qualified professional shall submit a maintenance schedule with the **Certificate of Substantial Performance**. It shall include timing and arrangements for:
   i. Routine inspection
   ii. Aerating and dethatching turf areas
   iii. Replenishing mulch
   iv. Fertilizing
   v. Pruning
   vi. Weeding

(c) is encouraged to implement sustainable or environmentally-friendly practices for overall landscape maintenance.

H.6 **Irrigation**

H.6.1 Irrigation Plan Requirements

(a) For irrigation **Works** that will be owned and maintained by the **District**, a Qualified Professional with expertise in landscaping, engaged by the **Owner**, is required to submit landscape drawings for review by the **District**.
The following information shall be shown on the Irrigation Drawings:
   i. property lines and easements
   ii. buildings, edge of pavement, curb lines and curbs, sidewalks, lighting fixture locations, surface utilities and related service boxes or other elements that would affect the irrigation system.
   iii. Location of all existing vegetation to remain.
   iv. Location of retaining walls and slopes that exceed 3:1 vertical.

v. Designate the areas irrigated by each valve (irrigation zones) and assign a number to each valve.
vi. Clearly identify any 'temporary zones': those zones which are intended to operate for less than a two (2) year grow in period.
vii. Schematic layout showing all points of connection, backflow prevention, water meters, electrical supply and meters, winterization facilities, timeclocks, heads, valves, piping, sleeves, sensors and other elements critical to construction and maintenance of the irrigation system.
viii. Irrigation legend describing brand, model and size of timeclocks, heads, valves, piping, sleeves, sensors and all other elements shown on the irrigation plan.

H.6.2General Irrigation Requirements

(a) A complete and working automatic irrigation system shall be provided for all landscaped areas within a **highway** boulevard, median or roundabout. Temporary watering provisions
(b) shall also be made for planted areas of a 'non-irrigated' variety – to allow for watering through a maximum 1-year establishment period or in severe drought.
(c) Urban trees in pavement shall be irrigated with an automatic irrigation system that may include bubblers or drip elements.
(d) Sleeves shall be provided under sidewalks and driveways, and to medians / islands, as required for installation and maintenance of the irrigation system without removing surface paving.
(e) Provide a flow sensor and master valve, both connected to the controller, that will stop flow to the system or irrigation circuit in cases of an irrigation water leak. Provide an isolation gate valve upstream of all automatic sprinkler valves.
(f) Design to water plant materials with different watering requirements (e.g. grass vs. shrub areas and high vs medium vs low water use shrub areas) on different valve circuits.
(g) Where surface sprinklers are used, ensure unobstructed sprinkler coverage to tree bases from at least two sides.
(h) Every drip system shall be designed with a filter, pressure regulator, flush valve and air relief valve. The drip component manufacturer's instructions for installation and maintenance shall be included in the project specifications.
(i) The irrigation system shall perform to within 15% of the targeted application efficiency standards for irrigation systems, as determined by the Irrigation Association and the Irrigation Industry Association of British Columbia, as follows:
    i. Spray Zones: 75% or higher;
    ii. Rotor Zones: 80% or higher;
    iii. Microjet Irrigation Zones: 85% or higher.
    iv. Drip Irrigation Zones: 90% or higher.
(j) Sprays and rotors shall be designed with head to head coverage to meet the application efficiency standards.
(k) It is the responsibility of the Certified Irrigation Designer to identify to the **Owner** and to the **District** any landscape impediments, existing or planned, that will impede reaching the targeted efficiencies. At the discretion of the **District**, irrigation system design audits may be performed to ensure design efficiency has been met.
(l) The irrigation system shall be designed with minimal pressure losses where possible. Pressure losses between any two sprinklers on the same zone shall be less than 10%.
(m) Pipes shall be sized to allow for a maximum flow of 1.5m/sec.
(n) The irrigation system shall be sized and designed to 80% of point of connection available flow and pressure; allowing for 20% growth of system or 20% reduction in operating pressure while retaining targeted operational efficiencies.

(o) Locate point of connection or pedestal to meet the following requirements:
   i. No pedestal or point of connection locations will be permitted with medians without the explicit written consent of the **District**.
   ii. No pedestal location shall be subject to application of irrigation watering.
   iii. No point of connections shall be placed within a sidewalk without the explicit written consent of the **District**.

(p) The irrigation design shall include voltage loss calculations to the electrical control valve furthest from the controller. The drawings are to include:
   i. A chart comparing the actual voltage drop to the allowable voltage drop on common and zone signal wires;
   ii. Voltage loss shall not exceed the maximum voltage loss as specified by the manufacturer of the irrigation controller;
   iii. Indicate wire locations, wire gauge required, spare wires and necessary splice box locations on the Contract Drawing.
   iv. Install one spare control wire for every five (5) electric control valves connected to the controller;

(q) Install one spare common wire for every ten (10) electric control valves connected to the controller.

(r) Irrigation sleeves shall be installed to route irrigation lines under hard surfaces and features. Non-metallic CSA approved electrical conduit shall be installed adjacent to irrigation sleeves.

(s) Electric control valves used in the design of the irrigation system are to remain consistent in size and manufacturer, where possible. Renovations or additions to the irrigation system shall use the same manufacturer, model and size that exist on site. It is permissible to use an electric control valve from a different manufacturer for specialized applications. In general:
   i. Electric control valves must be sized to the design flow;
   ii. Drip and micro irrigation zones must include filtration and pressure regulation to manufacturers' specifications. Drip and micro zones must have an isolation valve prior to zone valve for maintenance of filtration.
   iii. Unless it has deemed not possible, valves are to be located on the periphery of green spaces and where available, within planting beds.
   iv. Design approval will be required to insert valve locations within hardscape surfaces.

(t) Sprinklers specified for the irrigation system are to remain consistent in size, nozzling and manufacturer. Modifications or additions to the existing irrigation system shall use the same manufacturer, model and size that exist on site. Sprinkler choice is based upon:
   i. Available operating pressure at the base of the sprinkler;
   ii. Desired radius;
   iii. Type of landscape/plant material to be irrigated.
   iv. Preference will be given to sprinklers incorporating pressure compensating devices.
   v. Preference will be given to sprinklers incorporating check valves to reduce low head drainage.

(u) Sprinkler arcs, radius and alignment are to be designed and capable of adjustment to minimize overspray onto adjacent surfaces outside of landscape areas.

(v) Drip line and emitters must incorporate technology to limit root intrusion.

H.6.3 Irrigation Service Connections

Except as required otherwise all landscaped areas of a **highway** boulevard, median or roundabout shall be serviced with a metered water service (50mm diameter, and a metered electrical service (120/240 volts, 60 amps minimum). Provision of water and electrical services by the Owner shall include the establishment of service accounts with the utility providers, all necessary permits,

testing and certification, and all materials, labour, fees and utility costs necessary to provide the service until the end of the Landscape Maintenance Period.

SCHEDULE I DESIGN AND CONSTRUCTION OF WATER DISTRIBUTION SYSTEMS

I.1 General

I.1.1 If a **water distribution system** is required, **subdivision** or **development** must not be approved until:

(a) the **Owner** provides each **parcel** within the **subdivision** or **development** with a water service connected to a **water distribution system** that is connected by trunk water mains, to an existing **community water system**. All **works** must be installed in accordance with the standards set out in **District** Bylaws and the regulations of the local water authority; and

(b) the proposed **subdivision** or **development** is included within an established water system boundary which is either extended or established pursuant to the local improvement and local service provisions of the *Local Government Act* or *Community Charter*, as required by the authority having jurisdiction.

(c) where the **District** does not own or operate the **community water system,** the **Owner** of the **community water system** has provided the **District Engineer** with a Certificate of Public Convenience and Necessity issued by the Comptroller of Water Rights, together with written confirmation from the water utilities **engineer,** that the system meets the requirements of this Bylaw.

(d) new water mains must be installed and commissioned in accordance with the **District's** "Requirements for New Water Mains" policy.

I.1.2 Where the **District** does not own or operate the **community water system** and the proposed **work**s do not meet the design criteria set out in this Bylaw, the **subdivision** or **development** may be approved provided that:

(a) the **Owner** of the **community water system** has submitted a five-year capital plan prepared by an **engineer**;

(b) the **Owner** of the **community water system** has complied with the conditions set out in the five-year capital plan; and

(c) the subject property for the application is located within the boundaries of the capital improvement area as set out in the approved five-year capital plan submitted by the **Owner** of the **community water system**.

I.2 Capacity of System and Sizing of Water Mains

Subsection 1.2.1 amended by Bylaw 1269, 2025

I.2.1 Water distribution systems must be designed and constructed to accommodate the maximum number of dwelling units permitted on the parcel under the Zoning Bylaw, as amended from time to time.

I.2.2 Mains must be sized using the Hazen Williams formula with the coefficient "C" equal to 120. The maximum flow velocity for peak hourly demand rate must not exceed 2.0 m/s. For maximum daily flow rate plus the fire flow rate, the maximum flow velocity must not exceed 4.0 m/s.

I.3 **Domestic Demand Criteria**

I.3.1 For residential areas, the daily domestic demand criteria for the purposes of designing **water distribution system**s must be as follows:

TABLE I-I-1- DAILY DOMESTIC DEMAND CRITERIA	
Average Daily Flow	= 900 litres/capita/day
Peak Daily Flow	= 1800 litres/capita/day
Peak Hour Flow	= 4000 litres/capita/day

Table I-I-2 added by Bylaw 1269, 2025

TABLE I-I-2- DAILY DOMESTIC DEMAND CRITERIA INFILL HOUSING	
Average Daily Flow	= 600 litres/capita/day
Peak Daily Flow	= 1200 litres/capita/day
Peak Hour Flow	= 1800 litres/capita/day

I.3.2 The demand criteria must be selected to suit the particular circumstances as approved by the **District Engineer**. Densities for specific **zone**s are indicated in TABLE I-2.

TABLE I-2-COMMUNITY WATER SYSTEM DENSITIES		
	People/Ha.	**People/Unit**
Single Family	24-30	3
Multi-family Low	85	2
Multi-family Medium	(3 storey) 120	2
Multi-family High	(4-12 storey) 320-960	2
Mobile Home	45	2
Industrial	50	-
Institutional	50	-
Commercial	75	-

I.4 **Fire Demand Criteria**

I.4.1 Water distribution systems must be designed to ensure that fire flows as required by the most recent Fire Underwriters Survey are available for required durations. Notwithstanding, the provisions of the Fire Underwriter's Survey, fire flows and shall not be less than:

Table 1-3 deleted and replaced by bylaw 1269, 2025

TABLE I-3- REQUIRED FIRE FLOW		
Development	**Minimum Required Fire Flow**	**Duration (hours)**
One or two dwelling unit housing and Infill Housing	60 litres/sec	1.5
Three or four dwelling unit housing	90 litres/sec	2.0
Five or more dwelling unit housing, Row Housing or Mobile Home Parks	150 litres/sec	2.0
Commercial and Institutional	150 litres/sec	2.0
Industrial	225 litres/sec	3.0

I.4.2 Notwithstanding the above table, for all **subdivision** or **development**, with due consideration to anticipated building size, the **Owner's Engineer** must provide, detailed design calculations supporting the amount and duration of the design flows prior to final design.

Subsection I.4.3 added by Bylaw 1269, 2025

I.4.3 Where a proposed **Subdivision** or **Development** has a fire flow requirement greater than what is available from the **Community Water System,** and increasing the fire flow supply or distribution system is not viable, in the opinion of the **District Engineer**, the **District Engineer** may approve the **Subdivision** or **Development**.

I.5 Design Pressures

I.5.1 The **water distribution system**s must be designed to provide domestic water at the probable building main floor elevation on each **parcel** as follows:

Maximum static pressure	827 Kpa	120 psi
Minimum static pressure	275 Kpa	40 psi
Minimum residual pressure at peak hour	250 Kpa	36 psi
Minimum residual pressure at fire flow conditions	140 Kpa	20 psi

I.5.2 Hydraulic Net**work** Considerations

(a) Where there is an existing hydraulic net**work** model in place, the **District** will provide information for design calculations.

(b) Depending on the complexity and extent of the proposed **water distribution system**, the **District** may elect to carry out a hydraulic analysis showing minimum design flows and pressures. The **Owner** will be required to pay for this analysis.

(c) The maximum length of any permanent, non-interconnected water main must be less than 150 m. All mains exceeding 150 m, unless it is a temporary situation, must be looped.

(d) Where the water system network is deficient, installation of supplementary mains may be required and may necessitate the provision of rights of way in favour of the **District** or the agency having jurisdiction.

(e) The minimum pipe size for all water mains shall be 200 mm diameter. The **District Engineer** may require water mains larger than 200 mm diameter if on a distribution or transmission route. The minimum water main size for commercial or industrial areas shall be 200 mm.

(f) In residential areas, fire hydrant leads must be 150 mm diameter minimum. Water mains 100 mm in diameter may be permitted for domestic service on dead-end **roads** where no further extension is planned. Wherever practical, water mains must be looped. Dead-end mains must not be promoted.

I.6 Location and Grade of Water Mains

I.6.1 Water mains must be located in the **road** right of way as shown on Standard Drawing. (e.g. Statutory right of way).

I.6.2 A minimum horizontal clearance of 1 meter between a water main and underground utilities must be provided, except for sanitary and storm sewer mains.

I.6.3 A minimum three-meter clear horizontal distance between a water main and a sanitary or storm sewer main must be maintained.

I.6.4 In special cases such as installations in rock or hardpan and subject to any provincial regulations, the horizontal clearance may be reduced with the approval of the **District Engineer** and the Interior Health Authority, provided the invert of the water main is a minimum of 450 mm above the crown of the sanitary sewer. On side hill streets the water main must be located on the cut side of the centre line of the street.

I.6.5 Water mains must be designed to follow a straight alignment between intersections and at grades parallel to the **road** centerline unless otherwise approved by the **District Engineer**.

I.6.6 Curved alignments may be accepted provided the pipe alignment is at a parallel offset to an established boundary. In no case shall the radius of curvature be less than 300 times the outside diameter of the pipe barrel. The design drawings must indicate the method for achieving the curvature. In no case shall curvature be established in PVC pipelines using joint deflection.

I.6.7 Water mains must be designed at grades that minimize high points in the main. Where a high point is unavoidable, a hydrant, a service, or an air release valve must be installed at the high point as required by the **District Engineer**.

I.6.8 Where the slope of the water main exceeds 20%, anchorage is recommended. Slopes 30% or greater require anchorage and trench dams must be incorporated in the design.

I.6.9 Gas main, electric or telephone duct, or other utility lines may only be installed in the same trench with water mains when horizontal and vertical separation is maintained.

I.6.10 Where it is necessary for a water main to cross other underground services, the crossing must be made at an angle greater than 20 degrees and the vertical clearance between services at the crossing point must be not less than 150 mm except for sanitary sewers where clearance must be in accordance with the *Public Health Act*.

I.6.11 Design drawings must indicate whether the water main passes over or under other underground services which it is crossing.

I.7 **Services**

I.7.1 The diameter of water services must be approved by the **District Engineer**.

I.7.2 The diameter of water services shall be determined considering **water distribution system** pressures, requirements for sprinklers and building size (fixture counts). In no case shall the diameter be less than 19 mm.

I.7.3 The diameter of water services for **District** Parks shall be as required by the **District Engineer**, but in no case shall the diameter be less than 25 mm.

I.7.4 Separate water services installed in accordance with Standard Drawings must be provided to each **parcel** and installed on the same side of the **parcel** as the sanitary sewer service.

I.7.5 Tappings shall be made at an angle of < 30 and > 10 degrees above the horizontal centerline p**lane** of the pipe.

I.7.6 Curb stops must be located 2.0 meters from the property corner pin. Where such location will conflict with other services, alternate alignments may be submitted for approval.

I.7.7 19 mm diameter service connections may be tapped directly into mains 150 mm diameter and greater. 25 mm diameter service connections may be tapped directly into mains 200 mm diameter and greater, except in the use of PVC water mains where all service connections must be made

with double strap service saddles. 40 mm and 50 mm diameter service connections must be made using double strap service saddles. Multiple corporation stops must be staggered.

I.8 **Blow Offs**

I.8.1 Blow offs are required at the end of all dead-end water mains and must be constructed and installed in accordance with Standard Drawings.

I.9 **Water Sampling Stations**

I.9.1 The **District Engineer** may require water sampling stations to be installed. Water sampling stations shall be Kupferle Foundry Eclipse 88.

I.10 Air Valves

I.10.1 The general application of the three types of air valves must be:
(a) air/vacuum valves for filling or discharging mains and preventing negative pressures,
(b) air release valves for small air release during normal operation, and
(c) combination valves for combination of air/vacuum and air release valves.

I.10.2 Air valves are not required on water mains 200 mm diameter and smaller, except as determined by the **Owner's Engineer** or as required by the **District Engineer**.

I.10.3 Combination air valves must be installed at the summit of all mains 250 mm diameter and larger, except where the difference in grade between the summit and valley is less than 600 mm. Where practical, with approval of the **District Engineer**, fire hydrants may be located to facilitate an air release.

I.11 Fire Hydrants

I.11.1 Fire hydrants must be located as specified in the most recent publication of the Fire Underwriter's Survey, "Water Supply for Public Fire Protection".

I.11.2 Where hydrants are located other than at intersections, they must be located on the projection of the property line dividing two lots. In selecting the location of a hydrant, the probable route of the firefighting equipment must be considered in consultation with the Fire Department.

I.11.3 A hydrant must not be located within 3 meters of a utility pole, pad mounted transformer, light standard, or any other obstructions.

I.11.4 Legal access and clearance of 1.3 m must be maintained around the fire hydrant.

I.11.5 Hydrants must be flow tested with results added to the hydrant service card.

I.11.6 All hydrants must be painted in a specific colour (team green) and be colour-coded according to the **District** Fire Department standards utilizing the NFPA standard regarding expected flow rates.

I.11.7 For hydrants located across a rural **road** ditch, provision for access, including a culvert and frost protection must be provided.

I.11.8 All hydrants must be bagged until **substantial performance** is achieved.

I.12 Valving

I.12.1 Valves must be located as follows:
(a) In a cluster at the pipe intersection or at the projected property line, when located in an intersection, to avoid conflicts with curbs and **sidewalks**:
  (i) 3 valves at "X" intersection,
  (ii) 2 valves at "T" intersection,
  (iii) or as required by the **District Engineer** so that specific sections of mains may be isolated.
(b) Not more than 200 m apart for single family residential. All other **zones** require special designs.
(c) Not more than two hydrants are isolated.

I.12.2 Valves must be the same diameter as the main. Gate valves must be used up to and including 300 mm diameter. Gear operated butterfly valves will be allowed in mains larger than 300 mm. Valves must be installed in accordance with Standard Drawings.

I.13 Thrust Blocking

I.13.1 Concrete thrust blocking and/or adequate joint restraining devices must be provided at bends, tees, wyes, reducers, plugs, caps, valves, hydrants and blow-offs.

I.13.2 Thrust blocking and/or adequate joint restraining devices are not required for bends at 5 degrees.

I.13.3 The restraining device system must take into account potential future excavations of the **road** in the vicinity of the water main.

I.13.4 The engineering calculations for the thrust block design, based on fitting type, water pressure and soil conditions shall be provided to the **District Engineer** if requested.

I.14 Reservoirs

I.14.1 All reservoirs require a pre-design report prior to commencing detailed design.

I.14.2 Reservoirs must be designed to suit particular circumstances.

I.14.3 Reservoir designs must include:

(a) structures to be below ground and covered unless specifically approved otherwise;
(b) material must be reinforced concrete designed in accordance with the American Concrete Institute's manual on Environmental Engineering Concrete Structures - ACI 350 R-Current Version;
(c) 2 cells, each containing one half of total required volume and capable of being isolated and drained and filled independently;
(d) two lockable access openings in roof for cleaning and maintenance with easy access to any ladders. Minimum dimension to be 1-meter x 1 meter each. Overflow pipe must be visible from the access hatch;
(e) At all access hatches, a survey mark inlaid inside showing the geodetic elevation is to be provided;
(f) Access hatch(s) to have the following:
  (i) Aluminum cover ¼" tread plate – 300lb/ft^2 ,
  (ii) perimeter drain,
  (iii)perimeter sealing gasket,
  (iv)slam lock with aluminum removable sealing plug and opening tool,
  (v) flush lift handle,
  (vi)gas spring assist cylinder,
  (vii) 90-degree hard open arm;
(g) ventilation pipes or openings sized to handle appropriate intake and exhausting volumes of air for filling and drawing the reservoir;
(h) floor to be sloped to the sump;
(i) sub drain under floor to collect and drain any leakage, connected to overflow pipe;
(j) interior stainless steel wall ladder from roof access to floor. Any exterior ladders must be vandal proof and prohibit unauthorized access;

(k) inlet and outlet pipes to be designed to disperse water throughout the reservoir;
(l) overflow drain to be provided and sized to transmit the maximum reservoir design inflow. The overflow drain must be connected to an acceptable point of discharge; approved by the **District Engineer**;
(m) All entrance doors must be equipped with electric strike and fob reader system as supplied by Chubb Edwards in accordance with **District** standards;
(n) A PLC based control system, instrumentation, and process and SCADA telemetry in accordance with **District** standards, including;
(i) Continuous level measurement of each reservoir cell
(ii) Back up high-level float alarm signals for each reservoir cell;
(iii) Intrusion alarming for each hatch;
(iv) Intrusion alarming for the reservoir valve chamber;
(v) Room temperature monitoring in the valve chamber;
(vi) Flood monitoring in the valve chamber;
(vii) HMI for local monitoring;
(viii) UPS power supply;
(ix) Chlorine residual or other analytical monitoring shall be included.

I.14.4 PLC, HMI, and SCADA programming shall be done by the **District's designated integrator**, in accordance with District standards at the Owner's expense.
(a) equipment and operations manuals;
(b) security against vandalism and theft;
(c) landscaping acceptable to the **District** is to be provided including irrigation; and
(d) a minimum 30 amp, 120 VAC power service

I.14.5 Reservoir capacity must be calculated by the following equation:
Total Storage Requirement = A + B + C
Where: A = Fire Storage
B = Equalization Storage (25% of maximum day demand)
C = Emergency Storage (25% of A + B)

I.14.6 Reservoir capacity must not be less than the greater of the following:
(a) One day average annual consumption for the service area.
(b) The sum of the peak hourly demand flow rate sustained for 6 hours plus the fire flow required to meet Fire Underwriters Survey Guidelines for the specified period of time, less the pump station capacity with the largest capacity pump out of service.

I.14.7 Reservoir valve chamber design must incorporate:
(a) all valves associated with the reservoir;
(b) sump in valve chamber floor, connected to overflow pipe through a check valve;
(c) 50 mm valved outlet off supply line within valve chamber for **water supply** for cleaning reservoir; and
(d) valves must be outside stem and yolk.

I.15 Pump Stations

I.15.1 Pump stations must be designed to meet maximum daily demands with the largest pump out of service with balanced storage online. If equalization storage is not online, pump station capacity must meet peak hour demand with the largest pump out of service.

I.15.2 Pump station design must assess, and where appropriate incorporate, the following features:

(a) ability to handle the ultimate flow requirements;
(b) type of station and impact on neighbours;
(c) construction dewatering requirements;
(d) access for construction;
(e) access for maintenance;
(f) aesthetics, noise, and landscaping acceptable to the **District** is to be provided, including irrigation;
(g) security against vandalism and theft;
(h) proximity and adequacy of power supply;
(i) minimizing energy requirements;
(j) equipment and maintenance requirements (access, lifting equipment, etc.);
(k) standby power and its compatibility;
(l) soil suitability for intended purpose;
(m) convenience of operation and maintenance.
(n) safety for operators and public; and
(o) capital, operation, and maintenance costs.

I.15.3 Pump Station design must include:

(a) A PLC based control system, instrumentation, and process and SCADA telemetry in accordance with **District** standards, including:
    (i) Feedback signals from and control signals to each motor starter;
    (ii) Feedback signals from and control signals to chlorination system (if required);
    (iii) Lead pump selection, including the option to alternate;
    (iv) Continuous Suction Pressure monitoring and alarming;
    (v) Continuous Discharge Pressure monitoring and alarming;
    (vi) Continuous Flow monitoring and alarming;
    (vii) Continuous Room Temperature monitoring and alarming;
    (viii) Flood monitoring;
    (ix) Intrusion monitoring;
    (x) All entrance doors must be equipped with electric strike and fob reader system as supplied by Chubb Edwards in accordance with **District** standards
    (xi) HMI for local monitoring; and
    (xii) UPS power supply
(b) full duplex pump sequencing;
(c) VFDs or electronic soft starters, with ramping, to minimize starting and stopping surges;
(d) starters in individual enclosures for each pump motor in accordance with District standards, including:
    (i) Hand-Off-Auto selectors; Hand-Off-Auto selectors;
    (ii) ii. Keypads mounted in the starter door for VFD's and Soft Starters;
    (iii) iii. Hour Meters;
    (iv) iv. Ammeters (may be part of keypad display);
    (v) v. Phase Loss Protection; and
    (vi) vi. Power Factor Correction to meet electrical supply utility requirements.
(e) low discharge pressure override-start plus alarm;
(f) low pressure or no flow override-start plus alarm;
(g) alarms to be both audible and visible;
(h) control valves to minimize starting and stopping surges;
(i) duplicate control cables, without splices, between pump stations and reservoirs;
(j) security against vandalism and theft;

(k) energy efficient motors;
(l) hour meters, recording flow meter and recording suction and discharge pressure gauges at each pump;
(m) flow metering equipment;
(n) automatic heating, ventilating and dehumidifying systems;
(o) in-station lighting;
(p) telemetry alarm system;
(q) wireless (radio) telemetry between pump station and reservoir;
(r) drainage to be provided for all areas of pump station;
(s) chlorine injection requirements, including safety, storage and handling;
(t) chlorine alert detection;
(u) chlorine weigh scale;
(v) electrical phase loss protection;
(w) electrical drawing schematics for control panel;
(x) reduced pressure backflow preventer;
(y) a minimum 347/600V electrical service; and
(z) pump motors shall operate at 575V, three-phase for motors five horsepower or greater.

I.15.4 For each design submission to the **District**, an extra set of drawings and manuals pertaining to the design of the pump station, key plan, and location plan must be submitted to the **District Engineer**.

I.15.5 PLC, HMI, and SCADA programming shall be done by the **District's designated integrator**, in accordance with District standards at the Owner's expense.

I.15.6 The **Owner** must provide three sealed sets of mechanical shop drawings, three sealed sets of electrical line diagrams, two sealed copies of design calculations for review by the **District Engineer**.

I.15.7 Factory certified pump head/capacity curves must be submitted to the District for review and pumps must not be shipped until the District has reviewed and marked the head/capacity curves as having been reviewed.

I.15.8 The **Owner** must provide two copies of an Operation and Maintenance Manual in a three-ring binder with the name of the facility embossed on the cover, prior to issuance of a **Certificate of Total Performance**. The manual must contain:
(a) Table of contents;
(b) Identified, plasticized, labeled section dividers;
(c) As-constructed shop drawings;
(d) equipment layout drawings;
(e) electrical, control, and alarm wiring diagrams;
(f) operating instructions for all equipment;
(g) maintenance instructions for all equipment, including frequency of maintenance tasks
(h) equipment data sheets;
(i) spare circuit cards for critical components;
(j) certified head/capacity curves for pumps;
(k) equipment part lists; and
(l) emergency operating procedures.

I.16 Pressure reducing valve (PRV) Stations

I.16.1 PRV stations must be designed as above ground facilities in order to avoid "confined space entry" requirements. PRV stations shall be provided with a minimum 30 amp, 120 VAC power service.

(a) PRV station design must include:
- (i) Forced air ventilation, heat and light;
- (ii) External kiosk and antenna;
- (iii) All entrance doors must be equipped with electric strike and fob reader system as supplied by Chubb Edwards in accordance with **District** standards
- (iv) Parallel pressure reducing valves;
- (v) Air release valves;
- (vi) Water quality sample points;
- (vii) Sump drain to storm;
- (viii) Off road vehicle parking;
- (ix) Manuals as per "manual" section;
- (x) landscaping acceptable to the District Engineer; and

(b) A PLC based control system, instrumentation, and process and SCADA telemetry in accordance with **District** standards, including:
- A. Security switches
- B. Discharge and suction pressure transmitters
- C. temperature sensor;
- D. flowmeter;
- E. uninterruptable power supply;
- F. radio or hard wire modem;
- G. external antenna;
- H. operator interface panel.

Where necessary, in the opinion of the **District Engineer**, the criteria of this section may be modified.

I.17 Facility Access

I.17.1 Paved vehicular access with turnaround and parking for up to two vehicles must be provided to all reservoirs and pump stations. The minimum standard shall be shown in the Standard Drawings, for a residential lane with curb, gutter, and drainage provisions to match surrounding neighbourhood.

I.18 Waterworks Approved Materials

I.18.1 Only the materials listed in the approved products list in Schedule E unless otherwise approved by the District Engineer are approved for installation in water systems owned and operated by the **District.**

SCHEDULE J ONSITE WATER SUPPLY

schedule J deleted and replaced by Bylaw 1269, 2025

J.1 General

J.1.1 Where an onsite **Water Supply** is permitted under this bylaw **Subdivision** approval is subject to:

a) receipt of a report from a qualified professional proving all lots created by the **Subdivision** can be serviced with an onsite **Water Supply**, or

b) registration of a restrictive covenant on title pursuant to Section 219 of the Land Title Act stating no building will take place until proof of onsite water supply is provided by a qualified professional.

SCHEDULE K DESIGN AND CONSTRUCTION SANITARY SEWER SYSTEMS

K.1 General

K.1.1 If community sewer is required in accordance with this Bylaw, a **subdivision** or **development** must not be approved unless the **Owner** of the **parcel** being subdivided or **developed**, provides each **parcel** in the **subdivision** or **development** with a sanitary sewer service connected to the **District** Sanitary Sewer System. All **work**s must be constructed and installed in accordance with the standards as set out in this Bylaw.

K.2 Design Flows

Subsection K.2.1 deleted and replaced by Bylaw 1269, 2025

K.2.1 Sanitary sewer facilities must be designed and constructed to accommodate the maximum number of dwelling units permitted on the parcel under the Zoning Bylaw, as amended from time to time.

K.2.2 All **parcel**s must be serviced by gravity flow unless otherwise approved by the **District Engineer**.

K.2.3 The sanitary sewer system must be designed based on the following criteria:

Subsection K.2.3(a) deleted and replaced by Bylaw 1269, 2025

(a) Domestic Flow Rate = 350 litres/capita/day, and **Infill Housing** domestic flow rate = 250 litres/capita/day plus;

(b) Infiltration rates for:

(i) New pipes not in water table	=	5,000 l/ha/day
(ii) New pipes in water table	=	8,000 l/ha/day
(iii) Old pipes	=	10,000 l/ha/day

(c) Densities per **TABLE K-1**

TABLE K-1-SANITARY SEWER SYSTEM DENSITIES

	People/Ha.	People/Unit
Single Family	24-30	3
Multi-family Low	85	2
Multi-family Medium	(3 storey) 120	2
Multi-family High	(4-12 storey) 320-960	2
Mobile Home	45	2
Industrial	50	-
Institutional	50	-
Commercial	75	-

(d) A peaking factor must be applied to the average flow. With this factor being modified to suit the areas served as follows:

Peaking Factor = $f\ (1 + \frac{14}{4 + \sqrt{P}})$

Where: P = Population in thousands
f = Reduction factor, applied as follows:

New residential areas	= 0.75
Old residential areas	= 0.85
Commercial and Industrial area	= 1.00

(e) Peak design flows must be determined by applying the peaking factor to the average daily flow, and adding inflow and infiltration (I & I) flows.

(f) Pipes shall be designed so that the sewer flow does not exceed d/D=0.67 for pipes 250 mm diameter and less, or d/D=0.75 for pipes greater than 250 mm diameter. {d=flow depth and D=pipe diameter.}

K.3 **Pipe Flow Formulas**

K.3.1 Gravity Sewers

(a) Manning's formula must be used for gravity sewers. The roughness coefficients must be:

Concrete	=	0.013
PVC	=	0.011

K.3.2 Force Main Sewers

(a) Hazen-Williams formula must be used. Friction coefficient must be C = 120.

K.3.3 Velocities

(a) The minimum velocity must be 0.6 m/sec. There is no maximum velocity, however, consideration must be given to scour problems where flow exceeds 3.0 m/sec.

K.4 **Minimum Grade**

K.4.1 The grade of any sewer is governed by the minimum velocity required (0.6 m/sec). However, the last section of a main that will not be extended in the future must have a minimum grade of 1.0% where 150 mm diameter pipe is proposed. Notwithstanding the above, the minimum grade for all pipes must be 1.0% unless restricted by topography or other factors approved by the **District Engineer**. There must be no change in grade between manholes.

K.4.2 Where the slope of the sewer main exceeds 20%, anchorage shall be considered by the **Owner's Engineer**. Where slope is 30% or greater, anchorage must be incorporated in the design. Anchorage must be constructed in accordance with Standard Drawings.

K.5 **Alignment of Sewer Mains**

K.5.1 Sewer mains must be designed to follow a straight alignment between manholes unless approved by the **District Engineer**. Where permitted, horizontal curves will require a constant offset and must be uniform throughout the curve. In no case shall the radius of curvature be less than 300 times the outside diameter of the pipe barrel. The design velocity must exceed 0.90 m/sec., the minimum grade must be 1.0%, and the curve midpoint and two l/4 points are to be located by survey and shown on the as-constructed drawings with an elevation and offset of the invert at each point.

K.5.2 Routing of the sewers must be approved by the **District Engineer**.

K.6 **Service Connections**

K.6.1 Separate service connections installed in accordance with Standard Drawings must be provided to each **parcel** and must be installed, wherever possible, in a common trench with the water service. All services must enter the main at a point just above the springline.

K.6.2 Only single connections will be permitted.

K.6.3 Connections to new mains must be made using standard wye fittings; connections to existing mains shall be made using wye saddles or other pre-approved methods.

K.6.4 The minimum grade from the main to the property line shall be 2.0% for a 100 mm service and 1.0% for a 150 mm service.

K.6.5 The diameter of sewer services must be as determined by the **Owner's Engineer** but in no case shall the diameter be less than 100 mm.

K.6.6 The minimum depth of a service at the property line must be 1.2 m within a **highway** right of way and 1.0 m within a statutory right of way.

K.6.7 Inspection chambers are required for all connections and shall be installed in accordance with Standard Drawings.

K.6.8 Service connections must be installed at the downstream corner of the **parcel** at an offset of 3.0 m from the property pin.

K.6.9 Service connections may be permitted into manholes provided that:

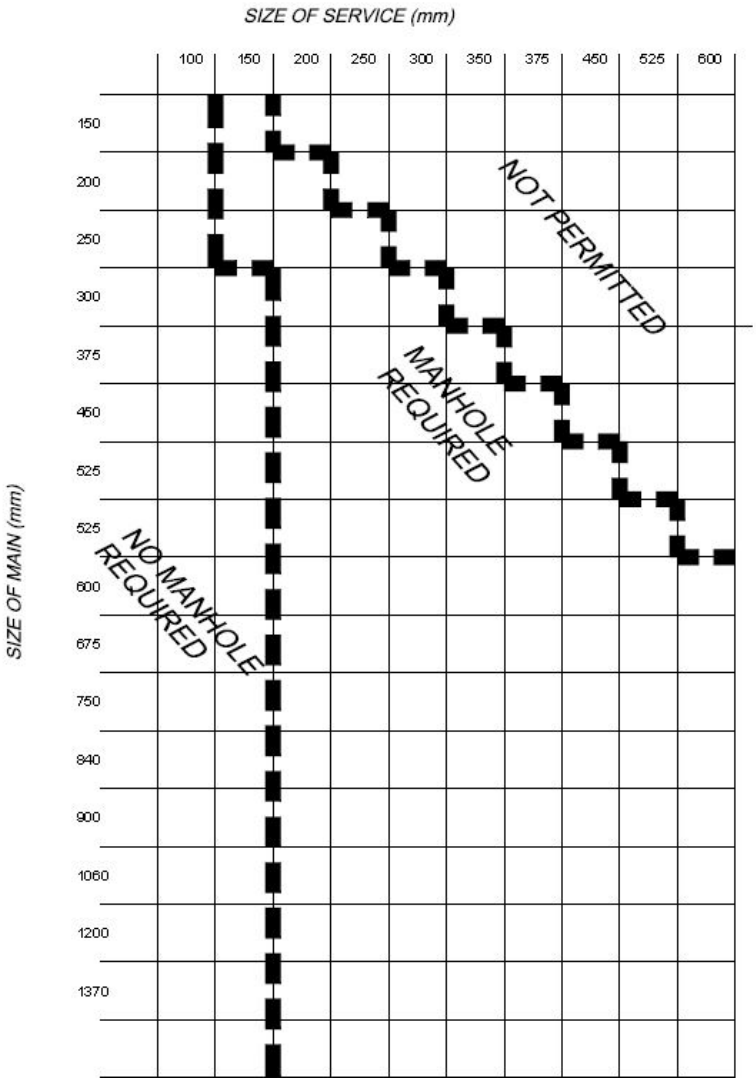
(a) the connection is not in an adverse direction to the flow in the sewer main and
(b) the connection enters the manhole so the service crown matches the sewer main crown.

K.6.10 Manholes are required for services relative to the size of the main as shown in **TABLE K.1**.

K.6.11 Following final grading, Brooks Boxes are to be installed on every inspection chamber.

K.6.12 Manholes are required to be installed at the intersection of the main and the service for non-residential services 150 mm and larger as shown in TABLE K-1.

TABLE K-1



K.7 **Minimum Sewer Main Diameter**

K.7.1 The minimum permitted size of pipe is 200 mm diameter.

K.7.2 Where no further extension is anticipated, the minimum pipe diameter may be reduced to:

(a) For residential lands - 150 mm diameter with minimum 1.0% grade

(b) For commercial and industrial - 200 mm diameter with minimum 0.60% grade

K.8 **Depth of Cover**

K.8.1 The depth of the sewer main must be sufficient to provide “gravity flow” service connections to both sides of the **highway** and must allow for future extension(s) to properly service all of the upstream tributary lands.

K.8.2 The minimum depth of cover shall be 1.2 m.

K.8.3 The maximum depth of cover is 4.5 m unless approved by the **District Engineer**.

K.9 **Manholes**

K.9.1 Manholes must be installed at all:
- (a) changes in grade,
- (b) changes in direction, except for curvilinear sewers,
- (c) changes in pipe sizes,
- (d) intersecting sewers,
- (e) terminal sections, and
- (f) upstream and downstream end of curvilinear sewers.

K.9.2 Manholes must be placed at all locations where future extensions are anticipated and must be spaced no further than 150 m apart.

K.9.3 For sanitary manholes not located within the **road**, the rim elevation must be designed to be above:
- (a) the adjacent storm manhole rim elevation,
- (b) the surrounding ground so that infiltration from ponding will not occur, and
- (c) the 100-year return runoff event.

K.9.4 Manholes must be constructed and installed in accordance with Standard Drawings.

K.9.5 All manhole lids are to be clearly labelled Lake Country Sewer.

K.10 **Hydraulic Losses Across Manholes**

K.10.1 The following criteria must be used:
- (a) The crown of the downstream pipe must not be higher than that of the upstream pipe.
- (b) Minimum drop in invert levels across manholes:
  - (i) Straight run - no extra drop required other than slope of pipe.
  - (ii) Deflections up to 45 degrees- 25 mm drop
  - (iii) Deflections 45 degrees to 90 degrees - 50 mm drop

K.10.2 Drop manholes and outside ramps must be installed in accordance with Standard Drawings. Where provisions are required for a future drop manhole connection, the manhole must be constructed and installed in accordance with Standard Drawings.

K.10.3 Inside ramps will only be permitted where the proposed alignment conflicts with existing utilities or where an inside ramp is required to match upstream and downstream pipe slopes. Inside ramps must not exceed 450 mm.

K.11 **Clean-Outs**

K.11.1 Clean-outs may be provided at terminal sections of a main in lieu of a manhole where:
- (a) future extension of the main is anticipated.
- (b) the length of sewer to the downstream manhole does not exceed 45.0 m.
- (c) the depth of the pipe does not exceed 2.0 meters of cover at the terminal point.
- (d) design of the anticipated extension is completed to the next manhole to ensure the **works** will not require realignment when extended.

K.12 **Sanitary Lift Stations**

K.12.1 The use of sanitary lift stations is discouraged. Any proposed use of lift stations must receive prior approval from the **District Engineer**. Sanitary sewer lift stations should be located within a right of way outside the required **highway** dedication. Siting of lift station must be approved by the **District Engineer**.

K.12.2 The following criteria cover both dry well and submersible sewage lift stations. Larger capacity sewage lift stations or lift stations with special design or siting requirements may require additional assessment and review of criteria including but not limited to:

(a) Pre-design Report

(i) Prior to commencing detailed design of a lift station, the **Owner's Engineer** must submit to the **District Engineer** for approval a pre-design report that addresses all pertinent design considerations, including:

A. The lift station must be designed to handle the ultimate flows of the designated catchment
B. Type of station and impact on neighbours.
C. Access for maintenance.
D. Aesthetics, noise, odour control and landscaping requirements.
E. Security against vandalism and theft.
F. Proximity of receiving sewers, water mains and adequacy of power supply.
G. Soils. Sub-surface investigations must be undertaken prior to site approval.
H. Capital costs and operation and maintenance costs.
I. Corrosion and odour control.

(b) Design Report

(i)The **Owner's Engineer** must provide three sealed sets of mechanical drawings and three sealed sets of electrical line diagrams for review by the **District Engineer**. Two sealed copies of design calculations shall be provided for documentation.

(ii) Lift station design must address the following:

A. Construction dewatering requirements.
B. Access for construction.
C. Station uplift design must be based on minimum load level and maximum flood elevations.
D. Minimizing energy requirements.
E. Standby power and its compatibility.
F. Convenience of operation and maintenance.
G. Safety for operators and public.
H. All entrance doors must be equipped with electric strike and fob reader system as supplied by Chubb Edwards in accordance with **District** standards

K.12.3 Pumps must be:

(a) Gorman-Rupp or pre- approved equivalent
(b) capable of passing solids up to 75 mm in size
(c) equipped with hour meters
(d) easily removed for maintenance
(e) operate on a 347/600 volt electrical source (pump motors over 5 H.P. are to be 600 volt 3 phase type)
(f) able to operate alternately and independently of each other
(g) able to meet maximum flow condition with one pump in failure mode

K.12.4 Factory certified pump head/capacity curves must be submitted to the District for review and pumps must not be shipped until the District has reviewed and marked the head/capacity curves as having been reviewed.

K.12.5 Motor cables, power cables, etc., must be continuous from within the pump station to within the kiosk. In no instance shall a cable be spliced.

K.12.6 The lift station shall include a PLC based control system, instrumentation, SCADA telemetry in accordance with **District** standards, including:

(a) Feedback signals from and control signals to each motor starter;
(b) Lead pump selection, including the option to alternate;
(c) VFDs or electronic soft starters, with ramping, to minimize starting and stopping surges;
(d) Continuous level monitoring for pump control;
(e) Emergency high and low-level switches for back up control, independent of the PLC control system;
(f) Magnetic flow meter, with flood monitoring in flow meter chamber;
(g) Flood monitoring in valve chamber;
(h) Kiosk temperature monitoring;
(i) Power supply status from the automatic transfer switch;
(j) Running and fault feedback signals from the standby generator;
(k) HMI for local monitoring; and
(l) UPS power supply.

K.12.7 Electrical and control equipment must be mounted in a three-compartment kiosk adjacent to the station, in accordance with **District** standards. The kiosk must be located a minimum of 3.0 m from the station lid as follows:

(a) Control Panel, telemetry equipment, instrument displays, and motor starters are to be in the kiosk compartment facing the wet well;
(b) Electrical service and distribution equipment are to be located in the kiosk compartment facing away from the wet well;
(c) All cable entries into the kiosk are to be made through a sealed end compartment; and
(d) The kiosk shall be aluminum, insulated, heated, ventilated, with a powder-coat finish;

K.12.8 Each pump motor shall have a starter in an individual enclosure, in accordance with **District** standards, including:

(a) Hand-Off-Auto selectors;
(b) Keypads mounted in the starter door for VFD's and Soft Starters;
(c) Hour Meters;
(d) Ammeters (may be part of keypad display);
(e) Over temperature and seal leak monitoring relays, to pump manufacturer requirements;
(f) Phase Loss Protection; and
(g) Power Factor Correction to meet electrical supply utility requirements.

K.12.9 Check valves must be ball lift type.

K.12.10 All stations must be equipped with an explosion-proof exhaust fan which can be activated by a manual switch and be of sufficient capacity to exchange the total volume of air inside the station

with fresh air within 3 minutes of activation to meet WorkSafeBC requirements for ventilation in a confined space.

K.12.11 The entrances to all stations must be waterproof and be provided with a suitable lock. The access must be a minimum 900 mm x 900 mm in size. The access hatch must have:

(a) an aluminum 6.4 mm tread plate
(b) a perimeter drain
(c) a perimeter sealing gasket
(d) a slam lock with an aluminum removable sealing plug and opening tool
(e) a flush lift handle
(f) a gas spring assist cylinder
(g) a 90 degree hold open arm
(h) a flush fitting padlock tang
(i) be reinforced for 1465 kgs/m^2. All fasteners to be made of 316 stainless steel.

K.12.12 The entrance must be at ground level where feasible but, in no case, more than 300 mm above the ground. An explosion-proof light with a protective cover should be located in a suitable location in the station and the light should be activated by the entrance cover.

K.12.13 Access into the stations must be by an aluminum ladder. The location of the ladder must not interfere with the removal and installation of the pumps, etc. The ladder must be designed to extend and lock at least 600 mm above the station entrance. A platform is to be provided above the high-water level float to permit wet well access. The platform is to be a fibreglass grating.

All wiring in classified areas, including the wet well, area around the wet well, and the kiosk end compartment, must meet the Canadian Electrical Code requirements for that area classification. Sealing between classified and unclassified areas shall meet the requirements of the Canadian Electrical Code. The electrical design and installation is subject to the acceptance of Technical Safety BC.

K.12.14 All equipment must be CSA approved and have at least a one-year warranty for parts and labour. All pumps must be factory tested prior to installation.

K.12.15 A gate valve is required on the influent line and a plug valve on each pump discharge. The valves must be outside the station and be complete with square operating nut and nelson box.

K.12.16 A 38 mm diameter water connection for cleaning purposes must be provided. A backflow preventer is required for connections in the station.

K.12.17 The roof and cover of the lift station should be designed to withstand a loading of H-20 (Highways Standard).

K.12.18 The lift station electrical system shall include an automatic transfer switch and stationary standby generator set, in accordance with **District** standards.

K.12.19 Subject to the findings of the pre-design report regarding access and landscaping, the area around the station and all associated equipment or building must be asphalted. The size of the area is to be determined by the requirements for maintenance.

K.12.20 A receptacle compatible with the **District**'s removable lifting arm must be incorporated into the design of the pump station to facilitate the removal and installation of the pump(s).

K.12.21 The interior surfaces of all fibreglass stations must receive at least two coats of two component white epoxy enamel.

K.12.22 The wet well bottom must be benched to direct all solids into the pump suction. The influent line must be located tangent to the wet well to encourage scouring of the wet well.

K.12.23 Minimum storage between the high-level alarm and the start of overflow under the more critical of:

(a) Minimum 2 hour in wet well at average wet weather flow.
(b) Minimum 1 hour in wet well and influent pipes at peak wet weather flow.

K.12.24 Station to allow removal of pumps using a hoist truck with a 1.8 m boom.

K.12.25 Security lighting and perimeter fencing is to be provided. The fence must be made of black chain link.

K.12.26 Landscaping acceptable to the **District** is to be provided including irrigation.

K.12.27 Minimum barrel size must be 2440 mm in diameter.

K.12.28 PLC, HMI, and SCADA programming shall be done by the **District**'s **designated integrator**, in accordance with District standards, at the Owner's expense.

K.13 Operation and Maintenance Manual

K.13.1 Before acceptance by the **District** of the completed station, the **Owner** must provide three copies of an Operation and Maintenance Manual to the **District**. The manual must contain:

(a) as constructed shop drawings;
(b) equipment layout drawings;
(c) electrical, control, and alarm wiring diagrams;
(d) operating instructions for all equipment;
(e) maintenance instructions for all equipment, including frequency of maintenance tasks;
(f) equipment data sheets;
(g) spare circuit cards for critical components;
(h) certified head/capacity curves for pumps;
(i) equipment part lists;
(j) emergency operating procedures.

K.13.2 The maintenance manuals must be bound documents with the name of the facility on the cover. Manuals must contain a table of contents with each section identified by a plasticized, labelled divider.

K.14 **Sanitary Force Mains**

K.14.1 In conjunction with sanitary pumping facilities, the following criteria must be noted in the design of force main systems:

(a) At the lowest pump delivery rate anticipated to occur at least once per day, a cleansing velocity of 1.0 m/sec should be maintained. Maximum velocity should not exceed 3.5 m/s.
(b) An automatic air relief valve must be placed at high points in the force main to prevent air locking.
(c) The minimum size for force mains shall be 100 mm diameter.
(d) The material for force mains must be HDPE (high density polyethylene) designed to suit the conditions of use.
(e) All force mains must be designed to prevent damage from transient conditions.

K.15 **Noise Control Criteria**

K.15.1 Noise levels for facilities must not exceed 65 dB at property line or 20 m away whichever is closer.

K.16 **Corrosion and Odour Criteria**

K.16.1 Corrosion and Odour controls must be considered in all design.

K.16.2 Analysis for potential odour and sulfides is required.

K.16.3 Odour Criteria:

(a) at 10 m from any gravity main, force main, manhole and lift station or other sewer facility (summer conditions, winds between 2-10 km/h), 1.0 odour units.
(b) where sewer facilities are close to houses, parks or **walkways**, 0.0 odour units.
(c) Dissolved sulfide maximum limit at any point in the system is to be 0.5 mg/l. However, for new tie-ins to **District** system, the maximum limit is 0.3 mg/l.
(d) Wet well size, force main diameter and length, as well as other pertinent factors must be considered in optimizing system operations to avoid odours.

Schedule L deleted and replaced by Bylaw 1269, 2025

SCHEDULE L SEPTIC SYSTEMS

L.1 General

L.1.1 Where a **septic system** is permitted under this Bylaw, a report from a qualified professional proving an onsite **septic system**, plus sufficient area for a backup disposal field, can be achieved on each parcel to be created by the subdivision, is required prior to subdivision approval.

L.1.2 Subdivision into parcels less than one hectare is only permitted where a connection to sanitary sewer is available.

SCHEDULE M DESIGN AND CONSTRUCTION OF STORM DRAINAGE SYSTEMS

M.1 General

M.1.1 Overview

The purpose of Schedule M is to standardize the procedures for designing common drainage facilities in the District. All drainage works will be designed with considerations for public safety, regulatory requirements, and the natural environment. The Owner's Engineer will consult with the District Engineer to determine what existing information may be of assistance to them.

The determination of the primary method for the management and disposal of stormwater will be at the discretion of the District Engineer. To aid in this determination, the Owner may be required to commission a study by a Qualified Professional to determine the viability of ground disposal for storm water.

The presence of an existing municipal drainage system does not mean, or imply, that the system has adequate capacity to receive the proposed design flows, nor does it indicate that the existing system pattern is acceptable to the District of Lake Country. Existing facilities that are undersized or inadequate to accept additional drainage must be upgraded at the Owner's expense to accommodate the appropriate flows. Alternative drainage proposals may be considered.

Stormwater management designs must conform to local government bylaws, regulations, and policies plus federal and provincial statutes and guidelines. These include, but are not limited to, the following:

- District of Lake Country Stormwater Management Design Guidelines
- Existing Master Drainage Plans, Watershed Plans, or Integrated Stormwater Management Plans
- Local Government Act
- Fisheries Act
- Water Sustainability Act
- Canadian Navigable Waters Act
- Canada Wildlife Act
- Migratory Birds Convention Act
- Dike Maintenance Act
- Land Development Guidelines for the Protection of Aquatic Habitat (Canada/B.C.)
- National Guide to Sustainable Municipal Infrastructure (Canada)
- Best Practices for Protection of Groundwater Resources in British Columbia (BC)
- Standards and Best Practices for Instream Works (Canada/BC)
- Riparian Areas Protection Regulation (BC)
- Canadian Dam Association Dam Safety Guidelines
- Applicable Professional Practice Guidelines provided by Engineers and Geoscientist British Columbia
- MMCD Green Design Guideline Manual

Where there is a discrepancy between this Schedule and any of the above-referenced documents, the more stringent requirements or guideline shall govern. Also note that the design standards in this Schedule set minimum acceptable standards.

M.1.2 **Storm Drainage System Triggers**

If a storm drainage system is required pursuant to this Bylaw, the Owner of the parcel being subdivided or developed must provide the proposed subdivision or the parcel being developed with a storm drainage system constructed and installed in accordance with the provisions of this Bylaw, as amended from time to time.

In addition to the requirements of Schedule C Servicing Requirements, a storm drainage system is required where the subdivision or development is located in an area where drainage studies adopted by Council indicate that drainage work should be constructed.

In addition to the requirements of Schedule C Servicing Requirements, a storm drainage system is required where the development includes or is solely for the alteration of land.

M.1.3 **Georeferenced Data**

It is the Owner's Engineer's responsibility to ensure they obtain true and accurate elevations for the development of the site and to confirm the accuracy of any mapping or information that may be provided by the District.

M.2 **Design Overview**

M.2.1 **General Requirements**

a) The Owner's Engineer must design the storm drainage system so that all downstream drainage facilities are capable of handling the determined, controlled post development flows.

b) All stormwater runoff that is discharged to a receiving water, whether directly or indirectly, must be treated using approved methods and to an approved standard.

c) A Stormwater Management Plan must be prepared by the Owner's Engineer for District review for all phases of the proposed development to ensure required drainage routes and facilities are adequately identified, protected, and sized for ultimate development conditions. The level of detail required is contingent on the size and type of development proposed.

M.2.2 **Dual Drainage System**

Each storm drainage system must consist of a minor and a major drainage system as defined below:

M.2.2.1 **Minor Drainage System**

The minor drainage system is comprised of storm sewers, swales, channels, culverts and flow control facilities designed to prevent flooding and property damage and to minimize public inconvenience caused by frequent storm events. Runoff from the minor storm is referred to as the Minor Flow.

M.2.2.2 **Major Drainage System**

The major drainage system comprises surface flood paths, drainage outlets (i.e., designated storm sewers that convey the major flow), ditches, roadways, watercourses and flow control facilities designed to accommodate the runoff from rare and intense storms. A major drainage system shall be designed to protect the public and prevent significant property damage due to flooding caused by

these rare and significant storm events. Runoff from these storm events is referred to as the Major Flow.

M.2.3 Service Levels

The service level for each of the drainage systems is defined by the capacity required to convey or control runoff from design storm events with return periods specified in Table M-1.

Table M-1: System Service Level Return Periods

Drainage System	Design Return Period
Minor	10 years
Major	100 years
Culverts & Bridges on Streams	200 years

M.2.4 Control Criteria

Stormwater discharge generated by the subdivision or development shall be controlled to reduce downstream impacts and to mimic the pre-development conditions as much as possible. The following level of runoff control shall be provided:

Table M-2: Control Criteria

Control Objective	Criteria
Water Quality Control	Treat 70% of the 2-year/24-hour post-development runoff volume or 90% of the average annual post-development runoff volume, depending on whether the design is based on single-event analysis or continuous simulation. See Section M.3.7
Runoff Rate Reduction	Store runoff from the critical minor-system design rainfall event and release it at a rate that approximates the natural pre-development Minor Flow. See Section M.3.3.
Peak Flow Conveyance	Ensure that the Major Drainage system is able to convey post-development runoff from extreme storm events (up to and including the Major Flow) in accordance with good engineering practice as determined by the District Engineer. If the District Engineer determines that this is not feasible, then Control Criteria for discharge to the Major System shall be provided as specified by the District Engineer.

Offsite discharge rates not based on the above criteria may be allowed at the discretion of the District Engineer based on downstream system capacity and/or ability to convey flows without causing erosion, negative impacts to the Receiving Water, flooding, damage to flood protection works or degraded water quality.

M.3 Runoff Analysis

M.3.1 General

This section describes the rationale, methodology, and parameters for determining the design runoff rates and volumes corresponding to the proposed Development or Subdivision. This includes runoff generated within catchments both tributary to and within the Development or

Subdivision. Where analysis of downstream conveyance systems by the Owner is required, runoff rates and volumes from catchments tributary to these works shall also be determined.

M.3.2 **Upstream Catchments**

The Design shall be sized to safely convey runoff from upstream catchments tributary to the Development or Sub-Division. Design runoff values from upstream catchments shall be determined in consultation with the District Engineer to reflect anticipated future land uses within these drainage catchments.

M.3.3 **Pre-Development Runoff**

In general, and for the purposes of this Schedule, "pre-development" refers to natural land cover prior to any disturbances or alterations by humans – including roads, clearings, agriculture, and buildings. The pre-development flow shall be calculated using Equation M-1.

Equation M-1: $Q_T = A \times URR_T$

Where: Q_T = pre-development runoff rate for a specified return period "T" [m^3/s]

A = drainage area [ha]

URR_T = Unit Runoff Rate for the return period "T" [Lps/ha], as found in the District's *Stormwater Management Design Guidelines*

Alternatively, pre-development runoff may be determined using the Hydrograph Method. In this case, the model must reasonably reflect field hydrology conditions based on flow measurements and/or reliable anecdotal evidence. Modelling results are subject to approval by the District Engineer.

M.3.4 **Climate Change**

To account for a changing climate, the rainfall IDF values presented in the District's Stormwater Management Design Guidelines have been adjusted to reflect projected rainfall intensities to the year 2100. This accommodation is adequate for single-event design storms. However, should continuous modelling be required, appropriate continuous climate values projected to 2100 must be used. These continuous data sets shall be obtained from the District.

M.3.5 **Acceptable Methods**

Storm drainage design shall be carried out using one or more of the following methods.

M.3.5.1. **Rational Method**

The Rational Method is applicable for preliminary design, for detailed design of minor drainage systems in urban areas and for the purposes of computing peak flow rates where no retention or detention features are included. Use of the Rational Method shall be limited to hydrologically simple and uniform catchments with a combined area less than 10 hectares. Its application shall also be limited to sizing conveyance systems only. It shall not be used to establish pre-development hydrology.

M.3.5.2 **Hydrograph Method**

Computer models that generate hydrographs shall be used for hydrologic and hydraulic analysis for all instances where the combined drainage catchment area is larger than 10 hectares, where drainage catchments are hydrologically complex and/or where stormwater management systems require more than basic conveyance (systems include green infrastructure, detention or retention storage, infiltration systems, and/or pump stations for example). This method is also acceptable for developing pre-development runoff rates provided that the model adequately reflects anecdotal or recorded flows using historical rainfall events.

M.3.5.3 **Continuous Simulation**

A continuous simulation model shall be used to design infrastructure where system capacity is based on runoff volumes that must be stored and/or released over extended time periods. Climate data time series may have a duration as short as several days (multi-day storms) or as long as several years or decades – the duration required shall be determined by the District Engineer. The maximum time interval for the rainfall time series shall be 1 hour. Digital files of hourly rainfall and temperature data can be obtained from the District.

M.3.6 **Rational Method**

M.3.6.1. **Formula**

The Rational Formula is expressed as: **Equation M-02:** $Q = CIA/360$

Where: Q_T = peak runoff for a specified return period "T", m^3/s

C = runoff coefficient

A = drainage area, hectares

I_T = rainfall intensity for the return period "T" and storm duration equal to the Time-of-Concentration (T_C), mm/hr

M.3.6.2. **Runoff Coefficients**

Runoff Coefficient (C) values shall be established based on the proposed land uses, proposed **developments,** soils, catchment slopes, and hydrogeological information. Runoff calculations and rationale for the C values selected shall be included in the stormwater management section of the Detailed Design Brief that is part of the Detailed Design Submission.

"Default" C values, as shown on Table M-3 may also be used.

Table M-3: Rational Method Design Runoff Coefficients

Land Use	Minor Storm	Major Storm
Commercial	0.85	0.90
Industrial	0.75	0.80
Institutional	[1]	[1]
Residential - Single-Family areas	0.40	0.50
Residential - Multi-units, detached	0.50	0.60
Residential - Multi-units, attached	0.60	0.70
Apartments	0.75	0.80
Parks / Cemeteries	0.20	0.25
Streets – Asphaltic	0.85	0.95

Streets – Concrete	0.85	0.95
Drives and Walks	0.80	0.90
Roofs	0.80	0.90
Green Space (Lawn)	0.15	0.20
Landscaped (Trees / Shrubs)	0.10	0.15
Orchards / Vineyards (Mature)	0.12	0.18
Natural Areas [2]		
Slope < 2%	0.04	0.09
3% < Slope < 6%	0.09	0.14
Slope > 6%	0.13	0.18

[1] Calculate weighted average value based on site land use composition as per Equation M-03.

[2] Adjust to reflect amount, type, and density of vegetation - subject to approval by District Engineer.

Note: The above table assumes conventional site drainage of directing all surface drainage overland into streets and catch basins. The runoff coefficients account for "wet" antecedent conditions. In a case of applying the Rational Method to a mixed land use in a drainage area, a weighted average C value shall be used and can be calculated from the following equation:

Equation M-03: $C_{avg} = \sum \frac{A_i C_i}{A}$

Where: C_{avg} = the average runoff coefficient for the catchment

A_i = the area of land within the catchment correlated to runoff coefficient C_i, and

A = the total catchment area

M.3.6.3 **Time of the Concentration**

The value of the design rainfall intensity (I_T) for the Rational Method is selected from the appropriate Intensity Duration Frequency (IDF) curve, with a duration chosen to coincide with the Time-of-Concentration (T_C). T_C is the time required for run-off to become established and reach the catchment outlet from the furthest point within the contributing drainage catchment. T_C is the sum of two components, the "inlet time" and the "travel time".

M.3.6.4. **Inlet Time**

The inlet time is the time it takes for overland flow to enter the conveyance system. It varies with size of the catchment area and surface imperviousness. In developed urban areas where paved surfaces drain directly to catch basins, the inlet times provided in Table M-4 shall be used. The minimum inlet times reflect roof leaders and parking lot drainage (hard surface) being discharged directly into a piped storm system. Longer inlet times may be appropriate to reflect roof leaders and parking lot drainage being discharged onto ground (grass, gravel, swales) and to account for travel distances and other variables. When Inlet Times other than those presented in Table M-4 are proposed, it is the Owner's Engineer's responsibility to verify that the selected values are appropriate and provide recommendations to the District Engineer for approval.

Table M–4: Inlet Times for T_C Calculations

Lot Type	Minimum Inlet time	
	10-Year	**100-Year**
Single Family Residential	15	10
Multi Family Residential	10	5
Commercial/Industrial/Institutional	10	5

For inlet times in rural areas, the overland flow time must be calculated using one of the following methodologies.

M.3.6.5. **Travel Time**

The travel time is the length of time required for flow to travel within the conveyance system from the point of inflow to the location being analyzed – typically the catchment or system outfall. When the channel or pipe characteristics and geometry are known, the preferred method of estimating channel flow time is to divide the travel length by the average travel velocity obtained by using the Manning equation. This may require one or two iterations since the flow rate used to calculate the velocity must first be estimated, then calculated using the results based on the initial assumption. Default roughness coefficients for different types of open channel linings and pipe materials are found in Sections M.5.2.1 and M.6.3.2.

M.3.6.5.1. **Developed Areas – Use FAA Airport Equation**

Common time of concentration calculations include the FAA, Kirpich, and Kerby equations. The FAA (U.S. Federal Aviation Administration) equation is the most commonly used of the three because it uses the widely recognized Rational Coefficient to describe watershed ground cover.

Equation M-05: $T_c = 3.26\ (1.1 - C)\ L^{0.5} / (S)^{1/3}$

Where: T_c = Time of concentration (minutes)C = Rational method runoff coefficient
L = Longest watercourse length in the watershed (m)
S = Average slope of the watercourse (m/m)

M.3.6.5.2. **Rural / Undeveloped Areas – Use BC Water Management Method**

This method was developed by the BC Ministry of Environment, Water Management Division, Hydrology Section. It is limited to drainage areas up to 1000 ha and is dependent on the catchment's characteristics. Equation M-06 and corresponding coefficients in Table M-6 reflects curves fitted to the graphical method presented in the BC Supplement to TAC Geometric Design Guide.

Equation M-06: $T_C = aA + bA^{0.5} + c$

Where: T_c = Time of concentration (hours)
A = Catchment area (ha)

Table M-5: Water Management Method Coefficients

Catchment Slope	Coefficients		
	a	b	c
Flat (slope ≈ 0%)	-0.0416	4.5609	0.4984
Rolling (slope ≈ 1%)	0.0488	3.0973	0.3041
Moderate (slope ≈ 2.5% slope)	-0.0113	2.2271	0.0642
Steep (slope > 10%)	0.0233	0.9075	0.0832

Note that for agricultural and rural basins, the curves labeled Flat or Rolling should be used. For forested watersheds, the curves labeled Rolling, Moderate, or Steep should be used.

M.3.6.6. **Rainfall Intensity**

Rainfall intensities shall be determined from the IDF data presented in the most recent version of the District's Stormwater Management Design Guidelines. Values obtained from the Guidelines shall be included in the Owner's Engineer's Design Brief accompanying the Stormwater Management Plan (SWMP).

M.3.7 **Hydrograph Method**

M.3.7.1 **General**

Analysis using the Hydrograph Method requires computer software capable of modelling the hydrologic characteristics of the watershed and generating runoff hydrographs from rainfall hyetographs. The hydrographs are typically routed through a network of open channels, conduits, storage facilities, and other stormwater management infrastructure or components. Hydrographs my be generated from single-event storms as well as from continuous time series covering multiple rainfall events or even years-worth of historical rainfall and climate data. The Hydrograph Method shall be used to analyze non-homogeneous drainage catchments, complex combinations of infrastructure and runoff controls, and/or the effects of timing due to flow routing through the system. Analyses and reporting shall be completed as per the District's Stormwater Management Design Guidelines.

M.4 **Site Design**

M.4.1 **Site and Lot Grading**

A comprehensive lot grading plan shall be prepared by the Owner's Engineer. The plan shall retain as many natural surface drainage features as possible while meeting the grading requirements of all the proposed lots within the Development area. The grading plan shall also mitigate or at least minimize impacts on existing adjacent Development areas.

Grading shall comply with the B.C. Building Code and be prepared as per the District's Stormwater Management Design Guidelines.

M.4.2 **Driveway Rough-In**

Driveways for lots fronting a road serviced by a rural road section (ditches and culverts) shall be roughed-in at the direction of the District Engineer. This shall include a driveway culvert, sized and installed as per Section M.5.8 of this Schedule.

M.4.3 **Minimum Building Elevation (MBE)**

The MBE applies to the elevation of the lowest floor slab in a building or the underside of the floor joists where the lowest floor is constructed over a crawl space. Crawl space is defined as the space between a floor and the underlying ground having a maximum height of 1.2 m to the underside of the joists and is not used for the storage of goods or equipment damageable by flood waters.

The MBE shall be at least 0.60 m above the storm sewer service connection invert and 0.30 m above the Major Drainage System hydraulic grade line (HGL), whichever requires the greater MBE. Establishment of the MBE shall also consider the influence of the groundwater table at its annual peak.

For sites near a watercourse for which a floodplain elevation has been established, the MBE shall be a minimum of 0.30 m above the instantaneous 200-year return period flood elevation or 0.60 m above the maximum daily 200-year return period flood elevation. Where a flood elevation has not been established, setbacks should be as per current Provincial guidelines. Where more than one setback is applicable, the greater distance shall be applied.

M.5 **Minor System**

M.5.1 **Service Level**

The Minor System is considered as a "convenience" system. It is intended to capture and convey runoff from frequent rainfall and typical snowmelt events. For roads with an urban cross section, the minor system may include curbs, gutters, catch-basin inlets, catch-basins, catch-basin leads, maintenance holes, storm sewers, flow-control structures, detention storage, infiltration systems, stormwater quality treatment, and outfalls. For roads with rural cross sections, the Minor System may include ditches, culverts, and vegetated swales. The Minor System may also include green infrastructure and Low Impact Development (LID) Best Management Practices (BMPs).

M.5.2 **Storm Mains**

M.5.2.1 **Sizing**

Storm sewers shall be designed to provide the required capacity in free flow (not surcharged) conditions using Manning's formula. The following Manning's roughness coefficients shall be used:

- 0.011 for smooth-walled PVC or HDPE pipes
- 0.013 for smooth-walled concrete pipes
- 0.024 for corrugated metal pipes

The minimum storm sewer diameter shall be:

- 250 mm for mains within all residential/single family zones
- 300mm for mains within all industrial/commercial/multi-family zones

Downstream pipe sizes shall not to be reduced unless the downstream pipe is 600 mm diameter or larger and increased grade provides adequate hydraulic capacity without exceeding velocity limits. Detailed hydraulic analysis and the District Engineer's approval is required. The maximum reduction is two pipe sizes.

Storm sewers may be sized according to the required capacity taking 50% of the capacity of any upstream infiltration facilities into consideration. The infiltration capacity must be calculated and justified by a Qualified Professional experienced in this field. In no case shall main diameters be less than the specified minimums.

M.5.2.2. **Surcharged Storm Sewers**

Surcharged sewers to convey the design flows are permitted only as exceptions and with completion of a report by the Owner's Engineer and approval of the District Engineer. In all such cases, it must be clearly demonstrated that the projected highest hydraulic grade line has no impact on downstream properties.

M.5.2.3. **Grades and Velocities**

Minimum grades of storm mains, flowing full or half-full, are required to obtain the minimum velocity of 0.6 m/s. Where velocity exceeds 4.5 m/s, or when super-critical flow occurs on steeper slopes, flow throttling or energy dissipation measures to prevent scour or to accommodate the transition back to subcritical flow may be required. Where the slope of the storm sewer main exceeds 10%, but is less than 20%, anchorage shall be considered by the Owner's Engineer. Justification for not including anchorage in the design under these slope conditions shall be included in the Design Brief.

Where slope is 20% or greater, anchorage must be incorporated into the design. Anchorage must be constructed in accordance with Standard Drawings. At the discretion of the District Engineer, the Owner's Engineer shall also determine if special provisions are required to protect against displacement of sewers by erosion or shock. These provisions shall be incorporated into the design and adequately detailed in the design drawings and specifications.

M.5.2.4. **Discharge to Natural Watercourses**

Runoff from developments near Okanagan Lake, Ellison Lake, Kalamalka Lake, and Wood Lake may be discharged directly to the lake provided that the required minor and major systems exist, stormwater quality is addressed, and approval from the appropriate provincial authority is obtained. Developments within the remaining areas of the District are required to attenuate offsite discharge to the appropriate pre-development runoff rate via on-site controls.

Where drainage discharge enters a natural watercourse, maximum discharge velocities shall be less than 1.0 m/s. All proposals for works affecting natural watercourses must be forwarded by the Owner to the appropriate provincial and/or federal authorities for review and approval.

Should siltation or erosion controls be required by the above agencies, details of the proposed works must be included in the engineering drawings and must be installed as part of the works.

M.5.2.5 **Location**

M.5.2.5.1 **Public ROWs**

Storm sewers shall be located as shown on the Standard Drawings within a Subdivision Road right-of-way (ROW) or open lane. Where this is technically impractical, and it is proposed to place storm sewers within private property, the Owner's Engineer shall provide rationale and analysis for consideration by the District Engineer. Works to be owned by the District, and which are on private property, shall be located within a Statutory Right of Way (SROW).

M.5.2.5.2. **Statutory ROW Through Private Land**

The District Engineer may require a statutory right-of-way over a drainage course that crosses private land to allow for future maintenance by the District and to prevent structures in a location where they could be damaged by stormwater. When a storm main is located within a statutory right-of-way (SROW) across private land, and appurtenances which require maintenance are located within the right-of-way, the Property Owner must ensure that maintenance access is available. For large structures or structures requiring an enhanced maintenance level such as oil/sediment chambers, control structures and pond inlet/outlet chambers, an access route adequate to support the maintenance vehicles shall be provided. The surface of the route may be gravel, concrete pavers, or asphalt depending on the location and the context of the site at the discretion of the District Engineer.

SROW requirements are further defined in Schedule B.7 of this bylaw.

M.5.2.6 **Depth and Cover**

Storm sewers should be of sufficient depth to:

- Permit gravity service to all tributary areas, including both sides of the roadway if feasible,
- Prevent freezing,
- Clear other underground utilities, and
- Prevent damage from surface loading.

Storm sewers shall be designed with cover ranging from a minimum of 1.2 m to a maximum of 4.5 m above the crown of the pipe, subject to approval by the District Engineer.

M.5.2.7. **Alignment**

Except as indicated for Curved Sewers, horizontal and vertical alignments shall be straight lines between maintenance holes unless approved by the District Engineer.

M.5.2.8. **Curved Storm Sewers**

Where permitted by the District Engineer, horizontal and vertical curves may be formed using pipe joint deflections as follows:

- Minimum radius shall be 300 times the outside diameter of the pipe barrel (300 x D) or 1.5 times the manufacturer's recommended minimum radius of curvature – whichever is greater.
- Constant radius throughout curve.
- Joint deflection not to exceed 50% of maximum recommended by pipe manufacturer.
- Minimum design velocity = 0.9 m/s.
- Minimum grade = 1.0% (0.01 m/m).

The curve midpoint and two quarter-points shall be located by survey and shown on the as-constructed drawings with corresponding invert elevations and offsets.

Subject to approval by the District Engineer, sewers larger than 600 mm diameter may include deflections formed by mitred bends to a maximum mitre of 45 degrees.

M.5.2.9 **Ditch Inlets**

The minimum pipe diameter for ditch inlets to the storm sewer system shall be 400 mm. All ditch inlets shall be connected to a maintenance hole. All ditch inlets to storm sewers shall be equipped with a headwall, and for large pipes (>600 mm diameter), debris screens. If directed by the District Engineer, the ditch inlet shall include a sedimentation basin or trap.

M.5.2.10. **Temporary Cleanouts**

Temporary clean-outs may be provided at terminal sections of a main provided that:

a) Future extension of the main is proposed or anticipated,
b) The length of storm drain to the downstream maintenance hole does not exceed 45.0 m, and
c) The depth of the pipe does not exceed 2.0 m at the terminal point.

M.5.2.11. **Pipe Joints**

Watertight joints are preferred, but open joints may be used subject to approval by the District Engineer to support groundwater recharge. However, since open joints can increase the risk of erosion within pipe bedding, their use shall be limited to grades less than 5%. Where the use of open joints is approved, clear 19mm crush gravel rather than sand bedding shall be used.

M.5.3 Maintenance Holes

M.5.3.1. **Where Required**

Maintenance holes are required at the following locations:

- Every change of pipe size.
- Every change in grade, except as indicated for curved sewers.
- Every change in direction, except as indicated for curved sewers.
- Upstream end of every sewer line.
- Downstream end of curved sewers.
- Every pipe intersection except for service connections as per **Error! Reference source not found.**
- Every catch basin connection.
- Outfalls to the major system (i.e., creeks, channels, lake) in order to isolate the upstream main to facilitate cleaning. The maintenance hole shall be located as close as possible to the point of discharge.

M.5.3.2. **Spacing**

The maximum distance between maintence holes shall be:

- 150 m for pipes with diameters less than 900 mm, or
- 250 m for pipes with diameters 900 mm and larger.

M.5.3.3. **Hydraulic Considerations**

The crown of the downstream pipe must not be higher than the crown elevation(s) of the upstream pipe(s).

Minimum drop in invert elevations across maintenance holes:

- Straight runs: 5 mm drop

- Deflection up to 45 degrees: 20 mm drop
- Deflection 45 to 90 degrees: 50 mm drop

M.5.3.4. **Hydraulic Losses**

Hydraulic losses shall be calculated for maintenance holes with significant change of grade or alignment. For high velocity flows, particularly for pipes with diameters 600 mm or larger, detailed analysis using the Froude number, or utilizing appropriate computer models is required. The Manning's equation should not be relied on for pipe slopes above 10%. For low to moderate velocities and smaller pipes, use following equation:

Equation M-08: $H_L = k V^2 / 2g$

Where: H_L = head loss (m)
V = flow velocity entering junction (m/s)
g = gravitational acceleration (9.81 m/s2)
k = head loss coefficient (1.0 for channelled 90 degree bends and tees to 1.5 without channelized benching)

Where benching is used, the minimum drops listed in Section M.5.3.3 are applicable for velocities below 1 m/s. Where flows exceed 1 m/s, H_L should be specifically computed - the greater of the two values shall be used as the drop across the junction.

M.5.3.5 **Drop Maintenance Holes**

Drop maintenance holes and outside ramp structures should be avoided where possible by steepening inlet sewers. Where necessary, drop maintenance holes or outside ramps shall be installed as per Table M-6:

Table M-6: Drop Maintenance Holes and Ramps Criteria

Invert Difference	Structure
Up to 0.25 m	Inside Ramp
0.25 to 0.90 m	Outside Ramp
Greater than 0.90 m	Outside Drop*

* Inside ramps may be permitted, but only where the proposed alignment conflicts with existing utilities or where an inside ramp is required to match upstream and downstream pipe slopes. Inside ramps must not exceed 450 mm and must be approved by the District Engineer.

M.5.3.6. **Lid Markings**

All maintenance hole lids shall be clearly labelled Lake Country Storm Sewer.

M.5.4 **Catch Basins**

M.5.4.1. **General**

a) Catch basins are required at regular intervals along roadways, at intersections, and at low points.

b) Side-inlet catch basins are required for all curbed roads. Lawn basins are required on boulevards and private properties where necessary to prevent ponding or flooding of sidewalks, boulevards, driveways, buildings, and yards.

c) Catch basin grates shall be installed as specified in the District's Standard Detail Drawings. Alternate grates may be allowed providing that corresponding rating curves are submitted to and approved by the District Engineer.

d) All catch basins shall discharge to a storm sewer system or approved infiltration system. Direct discharge from catch basins to natural streams or receiving waters shall not be allowed.

M.5.4.2. **Spacing**

Catch basin spacing shall provide sufficient inlet capacity to collect the entire minor flow, or major flow if required as per Section M.6.1 of this Schedule, into the pipe system. To ensure that the capture or inlet capacity matches the storm main capacity, the spacing of catch basins on streets shall, at the minimum, meet the following criteria:

a) Road grades less than or equal to 3% shall have a maximum spacing of 150 m or 675 m2 of paved area, whichever is more stringent.

b) Road grades greater than 3% shall have a maximum spacing of 100 m or 450 m2 of total area.

c) Catch basis will be spaced to ensure no overflows to driveways, boulevards, sidewalks, or private property.

d) Catch basis will be spaced at intersections so as not to interfere with crosswalks.

The Owner's Engineer shall provide confirmation that the above-listed maximums have not been exceeded by the design.

M.5.4.3. **At Low Point**

Double, side-inlet catch basins are required at all low points on a road, including cul-de-sacs. Double catch basins are required on both sides of the road if it is crowned, and only on the lower side of the road if it is cross-falled or super-elevated.

M.5.4.4. **Sediment Trap**

All catch basins shall be equipped with a minimum 0.5 m sump to capture and hold sediment.

M.5.4.5 **CB Leads**

M.5.4.5.1. **Minimum Diameters**

All catch basin leads shall be sized to convey the design inlet capacity, subject to the following minimum diameters:

a) from single, top-inlet catch basin – 200 mm

b) from double top-inlet or side-inlet catch basins – 250 mm

M.5.4.5.2. **Minimum Slope**

The minimum slope of the lead shall be 2.0% unless otherwise specified by the District Engineer.

M.5.4.5.3. **Connections**

All catch basin leads shall discharge into a maintenance hole.

M.5.4.5.4. **Cover**

Catch basin leads shall have a minimum cover of 0.9 m. If this is not feasible, the design shall include traffic load and frost protection. Design calculations must be provided.

M.5.5. **Service Connections**

M.5.5.1. **General**

Every legal lot shall be provided with a separate service connection where disposal to ground of discharge from foundation perimeter drains and/or roof drains is not recommended by a Qualified Professional or at the discretion of the District Engineer. Connections shall drain away from building foundations by gravity, but pumped connections may be permitted if requested prior to design, approved by the District Engineer, and appropriate covenants are provided.

M.5.5.2. **Foundation Drains**

Foundation perimeter drains for buildings are required as per the British Columbia Building Code. Where a hydrogeological study justifies their use, and subject to approval by the District Engineer, dry wells or ground infiltration systems may be used as the storm water disposal method for connection of perimeter drains. These systems shall be designed and supervised by a Qualified Professional.

Foundation perimeter drains are not permitted to be directed to any infiltration device or soak away pit that impacts an engineered retaining wall or reinforced earth structure.

Where infiltration systems are not recommended in the hydrogeological study, foundation perimeter drains may be connected by gravity via a storm service to the storm main provided that:

a) the elevation of the basement/crawlspace floor is at least 600 mm above the elevation of the storm main obvert, or

b) 600 mm above the anticipated or known high ground water table, or

c) 600 mm above the 100 year hydraulic grade line within the main at that point, whichever is higher.

M.5.5.3. **Roof Leaders**

Roof drainage leaders shall be connected to the storm service connection unless geotechnical conditions support use of splash pads for dispersal to the ground. The evaluation of this requirement shall be included in the scope of the study referenced in Section M.1.1. Use of ground disposal for roof leader discharge is subject to approval by the District Engineer.

Roof leaders shall not be directed onto driveways which drain directly onto District right-of-way, including roads, or to areas draining directly onto neighboring properties.

M.5.5.4. **Size**

Service connections shall be sized to accommodate peak design flow, subject to the following minimum pipe diameters:

- from Single Family or Low Density Multi-Family lots – 100 mm
- from Medium or High Density Multi-Family lots – 150 mm
- from Commercial, Industrial, or Institutional lots – 150 mm

M.5.5.5. **Location and Depth**

As a general rule service connections shall be located at the lowest corner of the property and installed at an offset of 4.0 m from the property pin.

Minimum depth will depend on the frost depth, but should be at least 0.9 m where subsurface building floor space is not required. Where basements are proposed, the depths of the storm sewers and services shall be increased to suit.

M.5.5.6. **Grade**

Service connections shall have the following minimum grades:

- 100 mm diameter pipe: 2%
- 150 mm diameter pipe: 1.00%
- Larger sizes: Grade based on minimum velocity of 0.75 m/s.

M.5.5.7. **Connections to Mains**

a) For connections to new mains, use standard wye fittings.

b) For connections to existing mains, use wye saddles or, if approved, insertable tees.

c) Service connections may be permitted into maintenance holes if

d) the connection is not oriented against the flow in the main and

e) maintenance hole hydraulic requirements are met.

f) Storm services to properties shall not be permitted from storm drains located in rights-of-way unless a clean-out is provided and the nature of the development will permit access to the right-of way for inspection, maintenance, and repair.

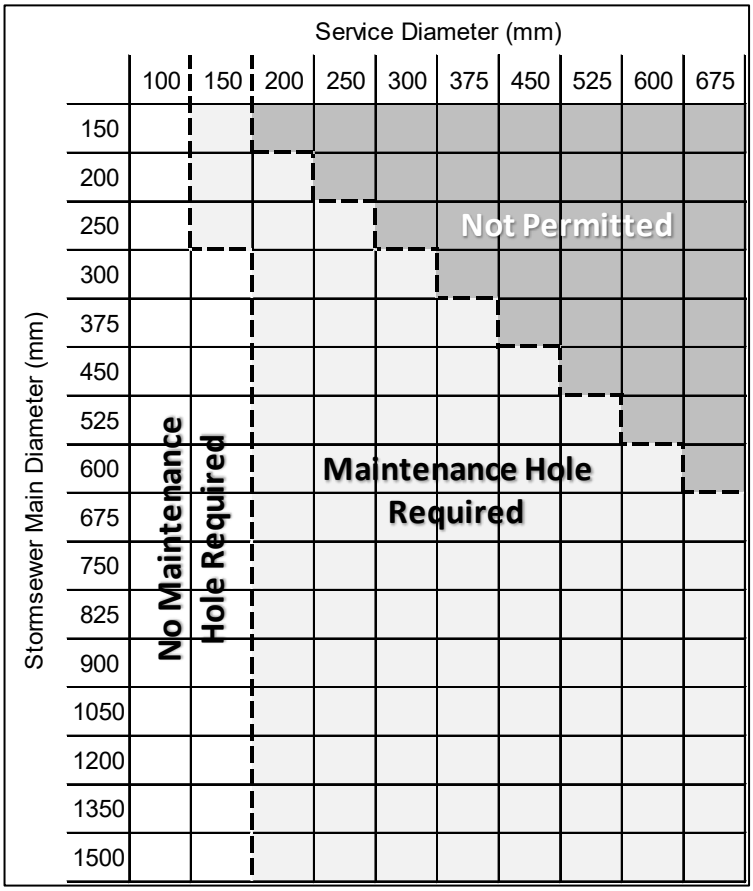
g) Must Include an inspection chamber unless service is less than 2.5 m long and connects to a maintenance hole.

h) Service connections shall be designed as mains if they exceed 30 m in length.

M.5.5.8. **Maintenance Access**

Maintenance holes are required for services relative to the size of the main as shown in **Error! Reference source not found.**

FIGURE M-1



M.5.6. **Sub-Surface Disposal / Infiltration Facilities**

M.5.6.1 **General**

Infiltration facilities are intended to reduce offsite-discharge volumes and rates, and to promote groundwater recharge. They are suitable for high permeability soils with low groundwater elevation, but must be supported by an appropriate study prepared by a Qualified Professional for confirmation and design guidance.

Design details should be in accordance with current technologies as outlined in Infiltration Systems guidelines in Land Development Guidelines for the Protection of Aquatic Habitat (Canada/B.C.), and related documents such as the MMCD Green Design Guideline Manual.

The Owner's Engineer shall submit all sizing assumptions and calculations for review and approval by the District Engineer.

Under no circumstances shall these systems or controls be used in the following conditions:

- Areas within 30 m of a slope that is steeper than 3.0 (horizontal) to 1.0 (vertical) and higher than 6.0 m, or a slope that has been assessed to be unstable or potentially unstable by a Qualified Professional.
- Areas where the post-development wet season groundwater table is less than 0.6 m below the base of proposed infiltration system or infiltrating surface.
- Areas where existing dwellings do not have foundation drains.
- Bedrock or other impermeable layer is located within 1.2 meters of the infiltrating surface.
- The infiltrating surface is located on top of fill material.
- The adjacent or underlying soils have a fully saturated percolation rate of less than 10 mm/hr.
- Site is sensitive to potential groundwater contamination.

M.5.6.2. **Infiltration Rate Correction Factor**

A correction factor, or factor of safety, is commonly applied to measured infiltration rates for design purposes. These correction factors are intended to mitigate the following:

- Long-term silting or "blinding" of the facility.
- Potential variability in the subsurface conditions.
- Type and size of infiltration facility.
- Whether it is public or private.

The correction factor is applied as follows:

Equation M-01: $K_{Design} = K_{Field} / SF$

Where: K_{Design} = the design infiltration rate (mm/hr)
K_{Field} = the infiltration rate as determined by field tests (mm/hr)
SF = the Safety Factor

The Safety Factor shall be recommended by the Qualified Professional, but shall not be less than 2.0.

M.5.6.3 **Drywells**

Where drywalls are deemed suitable by the District Engineer as part of an on-site storm water management plan for the minor system, the minimum number of dry wells must be determined by considering the flow generated from the site in relation to the infiltration capacity of the site soil. Sufficient temporary storage (within the drywell, surrounding drain rock, and potentially on the surface) shall be constructed with sufficient volume to temporarily store generated flows

until such time as they infiltrate into the subsurface. Design shall be in accordance with Standard Detail Drawings.

M.5.6.4. **Perforated Pipes**

Perforated pipes within infiltration trenches are only suitable for undisturbed ground where water can move horizontally out of the trench and where drainage water is free from silts. The system must be designed to function under surcharged conditions, and is therefore more suitable to locations with flatter slopes. Where necessary, this type of infiltration system shall include internal overflows within each maintenance hole. Design shall be subject to approval by the District Engineer.

M.5.6.5. **Infiltration Basins / Manufactured Systems**

Surface infiltration basins shall be designed in accordance with the criteria specified in Section M.5.6. Pre-manufactured modular infiltration chambers shall be designed as per manufacturer's recommendations. Shop drawings for such systems shall be provided, and shall reflect site conditions, including invert elevations and layout dimensions. Details regarding inspection and maintenance access shall also be provided.

The design shall include provision for system failure and overflow under Major Storm conditions.

The design shall include an operations and maintenance manual, along with an estimate of annual O&M costs.

M.5.6.6. **Pre-Treatment**

Particularly in multi-family, commercial, institutional, and industrial developments, all infiltration systems shall include pre-treatment measures to remove sediments, suspended solids, and oils and greases prior to entering the infiltration zone. This is especially a concern in areas with new development until landscape vegetation has matured. Pre-treatment design shall be in accordance with Section M.9 of this Schedule.

M.5.7. **Outfalls**

Outfalls of a storm sewer system into watercourses shall be designed recognizing aesthetics and erosion control. All new all storm water outfalls to natural watercourses or water bodies must be approved by the appropriate provincial and federal authorities. In cases where the receiving water is classified as a navigable water way, approval may also be required from the Canadian Coast Guard.

Outfalls into lakes shall be submerged, extended from shore, and constructed according to the following:

- soft bottom, 0.6 metres minimum bury to allow for seasonal sand erosion and deposition
- rock bottom, criteria to be confirmed by Canadian Coast Guard
- exposed pipes must be a minimum of 2.4 metres deep during lake "low water" level

Where a storm sewer discharges into a natural watercourse or open channel, riprap bank protection will be provided and, if necessary, energy dissipation facilities. Discharge perpendicular to stream flow will be avoided.

M.5.8. **Culverts**

M.5.8.1. **General**

Culvert design shall be in accordance with the procedures outlined in the most current edition of a generally accepted design manual including, but not limited to:

- American Concrete Pipe Association – Concrete Pipe Design Manual
- Corrugated Steel Pipe Institute – Handbook of Steel Drainage and Highway Construction Products
- BC Supplement to TAC Geometric Design Guide.

Where the design guideline referenced above in section M.5.8.1 contradicts the requirements of this Schedule, the more conservative requirement shall govern.

M.5.8.2. **Minimum Diameters**

The minimum diameter for culverts will be:

- crossing residential driveways – 400 mm
- crossing commercial, industrial, or institutional driveways – 450 mm
- crossing public roads – 600 mm
- on a stream, regardless of road or driveway classification – 600 mm

M.5.8.3. **Hydraulic Design**

Culverts shall be sized to convey the design flow with a maximum headwater depth to culvert diameter ratio (Hw/D) of 1.0 measured from the culvert invert at the inlet. Analysis shall consider both inlet and outlet control and the design shall be based on the condition requiring the larger diameter.

- The following Manning's roughness coefficients shall be used for circular culverts:
  - 0.011 for smooth-walled PVC or HDPE
  - 0.013 for smooth-walled concrete
  - 0.023 for corrugated HDPE
  - 0.024 for corrugated metal
- Manufacturer's recommended roughness coefficients shall be used for non-circular culverts.
- Driveway culverts that form part of the Minor system shall be designed to convey runoff from the Minor Storm with a maximum headwater to diameter ratio (Hw/D) of 0.5 – measured from the culvert invert at the inlet.
- Culverts crossing roads shall be sized to convey the design flow with a maximum headwater to diameter ratio (Hw/D) of 1.0 measured from the culvert invert at the inlet.
- The design shall consider both inlet and outlet control and shall be based on the condition requiring the larger diameter.
- All culverts shall be constructed with inlet and outlet structures approved by the District Engineer. Exceptions may be granted at the discretion of the District Engineer.

- When culverts or storm pipes are greater than 600 mm, the outfall pipe or structure shall be protected against entry by a free swinging, lockable, weighted grating which will allow passage of materials on discharge.
- Energy dissipation and erosion control at culvert outfalls shall be considered in the design.

M.5.8.4 **Depth and Cover**

- The minimum depth of cover over culverts is 0.3 metres, subject to the manufacturer's loading criteria.
- Culvert invert elevations shall be no lower than the corresponding design elevation of the ditch bottom. Where there is insufficient depth to maintain minimum cover, two or more culvert barrels may be installed to convey the design flow.

M.6 **Major System**

M.6.1 **General**

Storm runoff generated by less frequent, higher intensity rainstorms may exceed the capacity of the Minor System. Runoff from these events will pond in depressions and follow whatever overflow route is available. This network of ponding and overland flows is called the "Major System." It may be comprised of some, or all, of the components found in the Minor System but sized to convey or otherwise accommodate the Major Flow. The Major System may also include road surfaces, overland drainage routes, and surface ponding. If the Major System is properly planned, it can minimize or even eliminate the potential inconvenience and property damage caused by large rainfall events or when inlets to the minor system become blocked by debris.

Even though storm sewers can function as part of the Major System, this is not encouraged. Using pipes to convey Major Flows may be implemented in special circumstances, but only with the approval of the District Engineer.

M.6.2 **Surface Flow Routing**

Roadways with curbs and gutters may be designed as wide channels to convey major surface flow. In this case, the Owner's Engineer will consider the impact of surface routing on the major flow hydraulic grade line (HGL) of adjacent lateral roads. Existing lateral roads designed with the major HGL below surface may preclude using surface flow routing on the road being designed. Use of barrier curbs for major surface flows on roads is preferred, but rollover curbs may be used with approval of the District Engineer.

The design of the intersections will ensure that the surface flow can continue along the designated path crossing over lateral roads. Similar considerations are required if a change of surface flow direction is required at an intersection.

Calculations to verify that the surface flow is maintained within the road right-of-way and that the water elevation at maximum ponding/flow is at least 0.30 metres below the lowest Minimum Building Elevation (MBE) of adjacent buildings shall be provided with the design.

The following criteria for routing major design flows on road surfaces with an urban cross section shall be met:

- For all classes of roads, the flow/ponding depth shall not exceed 0.150 m above gutter line nor overtop the curb, whichever governs.
- Flow velocities greater than 2.5 m/s must be approved by the District Engineer.
- On local roads, the flow may spread to the crown.
- On collector roads, the flow spread must leave one lane or a road surface equivalent free of water to ensure access for emergency vehicles (fire, ambulance).
- On arterial roads, the flow spread must leave one lane in each direction free of water.
- Flooding is not permitted on private property except in flow channels within dedicated rights-of-way.

M.6.3 **Ditches**

M.6.3.1. **General**

Roads with rural cross-sections shall be constructed with ditches that ensure adequate road subgrade drainage (in compliance with standard road design). Ditch design shall conform to the criteria specified below. Variations may be implemented with appropriate justification by the Owner's Engineer and approval of the District Engineer.

- Minimum slope: 0.5% (0.005 m/m)
- Minimum depth: 0.3 m below road sub-grade
- Minimum freeboard: 0.3 m
- Maximum flow depth: 0.6 m
- Minimum bottom width: 1 m
- Maximum side slopes: 2:1 (H:V)

M.6.3.2. **Sizing**

Table M-7 provides acceptable Manning's "n" values for road surfaces, ditches, and swales, which shall be used with the Manning Formula for design and assessment of these structures.

Table M-7: Open Channel Roughness Coefficients

Condition	Manning's "n"	
	Minimum	Maximum
Concrete curb and gutter	0.012	0.016
Asphalt roadway	0.013	0.018
Grassed boulevards and swales	0.035	0.050
Ditches – gravel / small cobbles	0.025	0.030
Ditches – vegetated	0.030	0.035
Ditches - Rip-Rap (Class 10 kg / D_{50} 200mm)	0.068	0.072
Ditches - Rip-Rap (Class 25 kg / D_{50} 300mm)	0.071	0.076
Ditches - Rip-Rap (Class 50 kg / D_{50} 350mm)	0.073	0.078
Ditches - Rip-Rap (Class 100 kg / D_{50} 450mm)	0.075	0.080

Roughness coefficients for conditions not listed in Table M-9 shall be determined by the Owner's Engineer and submitted for approval by the District Engineer.

M.6.4. **Swales**

Swales shall be lined with turf on a minimum of 100mm of topsoil or lined with an erosion protection system approved by the District Engineer. All such swales serving two or more parcels of property shall be sized to accommodate the Major Design flow, and shall meet the following criteria:

- Minimum slope: 1.0% (0.01 m/m)
- Minimum freeboard: 0.15 m
- Maximum flow depth: 0.3 m
- Maximum side slopes: 4:1 (H:V)

All swales that are to be owned and operated by the District shall be located within a Statutory Right of Way (SROW).

M.6.5. **Culverts**

M.6.5.1. General

In addition to the design requirements presented in Section M.5.8, Major System culverts shall also be designed according to the following:

All culverts shall be installed with inlet and outlet structures.

Trash racks and/or debris barriers may be required upstream of culvert installations, as directed by the District Engineer.

M.6.5.2. **On Streams**

In addition to the design requirements presented in Section M.5.8, culverts on streams shall also be designed according to the following:

- All culverts shall be designed to convey the instantaneous 200-year return period flow or greater.
- Inlet and outlet structures are required for all culverts on streams, unless otherwise directed by the District Engineer.
- Culverts on fish-bearing streams shall meet conditions as specified by municipal, provincial, and federal authorities. Such culverts will be required to allow safe fish passage, and habitat restoration works will generally be required. The Owner's Engineer shall confirm and implement these requirements with the appropriate agencies.

M.6.6. **Piped Systems**

In special circumstances, or to accommodate lower building elevations, Minor System storm sewers may be enlarged or supplemented to accommodate major flows. System details shall be indicated in the Storm Water Management Plan and approved by the District Engineer. Design shall include:

- Provision of adequate inlets to accommodate major flows – including flows carrying suspended sediment and debris
- Surface overflow routes at potential surface ponding locations
- Compliance with minor drainage system guidelines.

M.6.7. **Overflow Routes**

Sags or low points in roads and cul-de-sacs must be designed with a safe overflow route to an approved receiving water or to adequately sized drainage infrastructure. These overflow routes may be ditches or swales and shall be designed as per Sections M.6.3 and M.6.4 respectively. The overflow route shall also be located within a right-of-way in favour of the District, with a minimum width of 4.5 m.

Where a ditch crosses private property, the ditch shall be offset in the right-of-way to permit a 3.0-metre-wide access for maintenance vehicles. Additional right-of-way may be required to facilitate the ditch construction and access. The top of the ditch adjacent to the property line shall be a minimum 0.5 metres away from that property line, and the design HGL shall be at least 0.6 m below the MBE of adjacent buildings. Ditches shall be designed to maximize infiltration where infiltration is appropriate as per Section M.5.6.

M.6.8. **Discharge to Natural Watercourses**

Storm discharge rates and volumes to natural watercourses shall be controlled to prevent damage to the natural channel and harm to the ecological system. Consideration must be given to fish bearing streams and to streams presently at capacity.

Designs must conform to all applicable federal, provincial, and municipal laws and regulations. The Owner shall submit the designs to, and obtain comments and approvals from, the appropriate provincial and/or federal agencies.

M.6.9. **Surface Disposal / Infiltration Systems**

If the study referenced in Section M.1.1 indicates that soil conditions are suitable to support infiltration-based disposal of Major System flows, then the system shall be designed in accordance with Section M.5.6.

M.7 **Detention Facilities**

M.7.1 **General**

It is usual to provide detention storage facilities in conjunction with flow control. Such facilities temporarily store the volume of runoff corresponding to the condition where the inflow rate exceeds the controlled discharge rate.

Storage facilities may be surface or underground and may be “online” or “offline”. Storage facility selection shall be subject to approval by the District Engineer and shall include

consideration of ownership and operation & maintenance requirements. The number of storage facilities shall be minimized.

Design details, other than discharge rates, should be in accordance with current technologies as outlined in Land Development Guidelines for Protection of Aquatic Habitat (Canada/B.C.), and related documents. Design for specific types of detention storage shall also reflect the following requirements.

M.7.1.1. **Parking Lot Storage**

a) Requires detailed lot grading design to ensure proper drainage, pedestrian safety and convenience, and major flow paths.
b) Maximum ponding depth: 300 mm outside vehicle stalls, 150 mm within vehicle stalls, however, also with consideration to frequency of ponding and impact to users of the parking lot.

M.7.1.2. **Underground Storage**

a) Facilities include tanks and oversized pipes, with outlet controls.
b) Cross sections and inlet and outlet locations shall be designed to minimize maintenance requirements.
c) Structural design to accommodate traffic loads and groundwater pressure.
d) Maintenance access provisions required.

M.7.1.3. **Dry Detention Ponds**

a) An off-line pond is preferred, but an on-line facility may be considered at the discretion of the District Engineer.
b) Fencing and graded slopes required as per referenced design guidelines.
c) May accommodate active recreational uses.
d) Overflow elevations to be coordinated with MBEs.
e) Provide warning signage indicating facility is a stormwater detention structure subject to flooding or rapid water level changes. Signs to be posted at all public access points or road frontages.

M.7.1.4. **Wet Detention Ponds**

a) Intention is to provide on-line detention storage and maintain a permanent minimum water levels.
b) Catchment area must be large enough to provide sufficient base flow to ensure wet storage and is sustained without becoming stagnant (based on local hydrologic characteristics).
c) Fencing and graded slopes required as per referenced design guidelines.
d) Can provide a public amenity within a passive park.

e) Overflow elevations to be coordinated with MBEs.

f) Provide warning signage indicating facility is a stormwater detention structure subject to flooding or rapid water level changes. Signs to be posted at all public access points or road frontages.

M.7.2 **Flow Controls**

Control structures shall be used to provide consistent flow control as specified in Section M.2.4. These structures shall be designed to include multi-stage controls. For example, two or more orifices located vertically on a control structure can be designed to provide increasing discharge rates as the water level rises. Safe overflow must be provided for conditions that exceed the maximum design flows.

Flow controls may be designed using the standard orifice and weir equations:

Equation M-09: Orifice Equation: $Q = CA(2gh)^{0.5}$

Where: Q = release rate (m^3/s)
C = orifice coefficient (0.62 for sharp or square edge)
A = area of orifice (m^2)
g = gravitational acceleration (9.81 m/s^2)
h = net head on orifice (m)

Equation M-10: Weir Equation: $Q = CLH^{1.5}$

Where: Q = release rate (m^3/s)
C = weir coefficient (to be determined by the Owner's Engineer, subject to approval)
L = effective length of weir crest (m)
H = net head on weir crest (m)

Release rates which do not reflect the criteria specified in Section M.2.4 may be allowed or required by the District Engineer, depending on downstream conveyance system capacity, stream protection, flood protection, and/or water quality issues.

M.7.3 **Sizing**

The design volume for detention facilities shall be determined using the Hydrograph Method and shall be the largest peak storage volume required to control flows as per the criteria specified in Section M.2.4. The District Engineer may require a 10% volumetric safety factor be applied to the calculated maximum volume. Rooftop or parking lot storage may be included in storage sizing calculations with the approval of the District Engineer. All sizing assumptions and results shall be provided as part of the design submission.

M.7.4 **Inlet /Outlet Considerations**

Design of inlet and outlet structures shall include consideration of energy dissipation and erosion control. Safety grates are required over all inlet and outlet openings larger than 500 mm diameter. Locks for access hatches are required.

M.7.5 **Geotechnical Considerations**

Geotechnical investigations by a Qualified Professional to address issues related to the design of all stormwater detention facilities shall be completed as part of the planning and design studies, and are a prerequisite to the final design of such facilities.
Wherever possible, the stormwater storage facility shall be excavated in natural, stable ground. Should topography dictate that a berm be constructed along one or more sides of a surface facility (dry or wet pond), the berm shall be designed by a Qualified Professional.

When the storm main is required to cross private land(s), the right-of-way must be a minimum of 4.5 m wide, however, the width must be suitable to accommodate excavations based on WorkSafeBC regulations for trench side slopes.

M.7.6 **Ownership**

For storage not under private ownership, all accesses to inlets/outlets, any structures and maintenance access routes to the facility shall be dedicated to the District. Land that is adjacent to a storage facility which is subject to flooding as per the design standard established, but which is part of the privately-owned parcel being developed, will be required to dedicate rights-of-way, to allow for encroachment of water onto the affected land. The right-of-way documents shall be prepared by the Owner, naming the District as grantee.

A restrictive covenant shall be placed on lots abutting the facility to control lot development so as not to compromise design requirements at the high-water level for major runoff events. This is to ensure an adequate freeboard is maintained.

The Owner shall confirm the need for an operational license for any wetland style storage or treatment facility with the appropriate municipal, provincial, or federal agency, and shall apply for and secure such license.

M.7.7 **Operations & Maintenance**

An Operations & Maintenance Manual for each type of detention storage facility shall be provided to the District. This shall include details of the system components and inspection and maintenance requirements in terms of tasks and frequencies.

For detention facilities that will be owned and operated by the District, suitable maintenance vehicle access from a public road to the detention facility shall be provided and protected by a right-of-way in favour of the District.

- For surface facilities (dry ponds), access shall include provisions for maintenance vehicles to access the pond.
- For buried facilities, access shall include adequate provisions to inspect and maintain the facility as per the required Operations & Maintenance Manual.

M.7.8 **Emergency Overflow Provisions**

If overflow is not provided as part of the flow control structure, then an adequate emergency overflow must be provided as part of the detention facility design. An adequate surface flow

route from the overflow structure to the designated Major Drainage route must be provided and must be located within a public or District-owned right-of-way.

M.7.9 Rapid Drawdown

The ability to discharge from storage facilities at the maximum flowrate that the downstream system can accommodate after storm runoff peak flows have passed, and the flows from other contributing areas have decreased or ended, shall be provided. The discharge rate for drawdown purposes shall be sufficient to restore available storage capacity in the facility to sufficiently control runoff from subsequent storm events within a reasonable time frame as per TABLE M-1.

TABLE M-1: Drawdown Provisions

Time After Commencing Drawdown From Full Level	Available Volume Required Below Design Full Level
24 hours	Volume equivalent of 1 in 10-year, 24-hour run-off
72 hours	100% of total storage volume

M.7.10 Temporary Conditions

Where land developments occur in advance of permanent detention facilities, the District may consider temporary storage facilities on an individual basis. Maintenance charges and responsibility for temporary storage facilities will be borne by the developer.

M.8 Erosions Control

M.8.1 General

Erosion and sediment control shall be incorporated into the design of all open channel conveyance routes and at all outfall / discharge locations. Typical erosion control methods include, but are not limited to vegetation, root-reinforced vegetation, manufactured materials and systems, rip rap, and velocity control.

M.8.2 Open Channels

Earthen open channels such as ditches and swales shall be designed to prevent incising, erosion, and movement of sediment. Such design is dependent on soil characteristics, channel lining, channel slope, flow depth, and flow velocity. Generally, open channels shall be designed to meet the maximum velocities specified in Table M-8.

Table M-8: Permissible Open Channel Velocities (Fully Vegetated / Grass-Lined)

Earth – Soil Type	Permissible Velocity (m/sec)		
Longitudinal Channel Slope	<0.5%	5-10%	>10%
Erosion Resistant Soils	1.2	0.9	0.7
Highly Erodible Soils	0.9	0.7	0.5

- Highly erodible soils include Fine Sand (non-colloidal), Sandy Loam (non-colloidal), Silt Loam (non-colloidal), and Ordinary Firm Loam.
- Erosion resistant soils include Fine Gravel, Stiff Clay (very Colloidal), Graded Loam to Cobbles (non-colloidal), Graded, Silt to Cobbles (colloidal), Alluvial Silts (non-colloidal), Alluvial Sites (colloidal), Coarse Gravel (non-colloidal), Cobbles, and Shales and Hard Pans.

At the discretion of the District Engineer, a more rigorous analysis using shear stress and soil characteristics supported by a study by a Qualified Professional, based on field investigation, may be required to establish the safe discharge rate for an open channel.

Bare-earth open channels will not be permitted, and must be vegetated or otherwise protected from erosion using rip-rap lined bottoms and sides, erosion control structures, geo-fabrics, or other methods approved by the District Engineer.

Erosion control calculations shall be submitted with the design. Rip rap design shall be conducted using methods presented in the most current edition of the BC Supplement to TAC Geometric Design Guide.

M.8.3 **Sediment and Erosion Control**

Given that disturbed soils are highly vulnerable to erosion and subsequent sediment transport during rainfall events, sediment and erosion control (SEC) measures as specified in Schedule N of this bylaw shall be implemented to protect stormwater management facilities and receiving waters. This applies, but is not limited to, areas that are cleared and grubbed, slope cuts, fills, and stockpiled materials such as sand, gravel, native soils, and topsoil.

M.9 **Stormwater Quality**

M.9.1 **General**

Several potential organic and inorganic substances can be found in rainwater runoff and are referred to as “non-point source” (NPS) pollution because the sources tend to be highly dispersed across the landscape. The ones of greatest relevance and which are targeted for treatment are:

- Total suspended solids (TSS)
- Oil and grease (O&G)
- Trace metals, typically represented by copper and zinc

Focusing on the removal of these constituents is expected to yield adequate removal of other associated constituents.

M.9.2 **Sizing**

All developments shall incorporate water quality treatment provisions into the design to meet the performance targets provided in this section. The targets are expected to be met for every new development and redevelopment site by implementing Best Management Practices (BMPs). Facilities shall be sized to adequately treat the following:

- 70% of the 2-year/24-hour post-development runoff volume when using a single-event design approach, or

- 90% of the average annual post-development runoff volume when using continuous simulation for design.

M.9.3 **Performance Targets**

The performance targets are classified as “Basic Control”, which address suspended solids, and “Hydrocarbon Control”, which addresses oils and grease. These targets shall apply to all stormwater discharges from the subdivision or development, including offsite discharges and discharges to a receiving water.

M.9.3.1. **Basic Control**

Basic treatment focuses on removal of TSS along with associated pollutants attached to those sediments, including low levels of petroleum hydrocarbons (oil and grease). Basic control is applicable to all non-agricultural lands within the District and must provide treatment for:

- 80% removal of TSS.

Discharge from the treatment system must meet the BC Recreational Water Quality Guidelines for turbidity.

M.9.3.2. **Hydrocarbon Control**

Hydrocarbon (oil and grease) removal is specifically required for sites where there is significant likelihood that higher concentrations of petroleum hydrocarbons will be released; in general, this includes sites with significant presence or use of vehicles. The performance target is:

- No on-going or recurring visible sheen in receiving watercourse(s), and
- 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/L with a maximum discrete (grab sample) concentration no greater than 15 mg/L.

The catchment area to the treatment system may be restricted to drives, roads, and parking areas.

M.9.4 **Best Management Practices**

Table M-9 shows how the performance targets are to be applied to various land uses. Best Management Practices (BMPs) presumed to achieve the performance targets if properly designed, installed, and maintained are presented as follows:

M.9.4.1. **Basic Control**

- Rain Gardens / Vegetated Bioswales
- Porous Asphalt Drives, Sidewalks, Parking Areas
- Sand Filters / Filter Strips
- Stormwater Treatment Wet Ponds / Wetlands
- Manufactured TSS Removal Systems[1]

M.9.4.2. **Hydrocarbon Control – Level 1**

- Oil/water separator (API or coalescing plate type)[2]

M.9.4.3. **Hydrocarbon Control – Level 2**

- Stormwater Treatment Wetlands / Wet Ponds
- Subsurface Infiltration (requires pre-treatment)
- Sand Filters / Amended Sand Filters

Rainwater source controls and landscape-based, surface-oriented BMPs are encouraged over below-ground, manufactured (or engineered) devices. This list is not exhaustive, and alternative BMPs may be used subject to approval by the District Engineer.

Proposed use of manufactured devices must be accompanied by documentation of performance from a reputable testing or certification program[3]. Performance testing and/or monitoring may be required during the Maintenance Period at the discretion of the District Engineer.

[1] Including media filter and membrane filter systems as well as manufactured biofiltration systems, at the District's discretion.

[2] Requirement for an oil/water separator at multi-family residential sites may be waived at the discretion of the District Engineer if a development or redevelopment proponent can show that the site design has minimized impermeable surfaces and arranged buildings, roads, and parking elements in a manner similar to single-family residential areas. Typically, this will mean that total impermeable surfaces constitute less than 50% of the site and, more specifically, that large open parking lot areas must not be present. For purposes of rainwater management, impermeable surfaces includes all buildings, patios, decks, driveways, sidewalks, and parking areas on a single property; note that this is different than "parcel coverage" as defined in the District's Zoning Bylaw.

[3] These programs include, in order of preference, (1) Canadian Environmental Technology (ETV) Program; (2) State of Washington (USA) Technology Assessment Protocol – Ecology (TAPE) program; and (3) Technology Acceptance and Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations. Other testing or certification programs administered by third parties, such a universities or independent testing labs, may also be acceptable, at the discretion of the District Engineer.

M.9.5 **Additional Requirements**

All stormwater quality installations shall:

a) Provide a high flow bypass that regulates the flow rate into the treatment unit and conveys high flows directly to the outlet such that scour and re-suspension of material previously collected does not occur.

b) Provide maintenance access both to the structure and within the structure so that accumulated debris, oils, and sediments can be readily removed with a vacuum truck.

c) Meet H-20 loading criteria when located where vehicles can pass over the structure.

d) Joints and fittings shall be oil resistant and watertight.

M.10 **Pumping Systems**

M.10.1 **Lift Stations**

Where possible, drainage pump stations are not to be used within the District and gravity systems utilized instead. Where drainage pumping is required, however, the Owner's Engineer must review the proposed concept and design criteria with the District Engineer, submit a pre-design report, and obtain approval from the District Engineer before proceeding with design. At a minimum, the pre-design report should include the following:

a) Delineated catchment area map

b) Estimated flows and operating head / HGL

c) Pump station location

d) Connection point to existing infrastructure.

Stormwater lift stations shall be designed as per the requirements for sanitary lift stations (except where not applicable to stormwater) as presented in Schedule K of this bylaw.

M.10.2 **Sump Pumps**

In general, design that allows for the potential of ongoing ground water issues should be avoided. In special cases, where groundwater seepage is seasonal, the District Engineer may allow a sump pump system inside the building which will discharge to the storm main via a storm service. A backwater or check valve and a siphon break must be installed in the sump pump discharge line to prevent backflow into the building. Discharge may be to the surface or a soak away pit, if geotechnical conditions, reviewed by a Qualified Professional, permit.

Note that permanent groundwater pumping is not permitted to District storm sewers.

SCHEDULE N DESIGN AND CONSTRUCTION OF SEDIMENT AND EROSION CONTROL SYSTEMS

N.1 General

N.1.1 Where the provisions of this Bylaw require a sedimentation and erosion control system, the design and construction of such services must be in accordance with the provisions of this Bylaw.

N.2 Design Criteria

N.2.1 The **Owner** must ensure that no silt, gravel or debris resulting from construction activity in the **subdivision** or **development** is allowed to discharge into existing drainage systems, natural drainage courses, water courses, or onto **highway**s or adjoining properties.

N.2.2 All proposed **subdivision** or **development** projects must provide erosion and sedimentation controls to prevent the displacement of soil and the transport of sediment from the project site resulting from land disturbing activities. In order to prevent the displacement of soil and the sediment transport during land disturbing activities, erosion and sedimentation control measures are required and shall be performed as described below. Both temporary and permanent erosion and sedimentation controls both during construction and post-construction shall be implemented.

N.2.3 The objective of erosion and sedimentation control is to prevent the displacement of soil and the transport of sediment to streams, wetlands, lakes, drainage systems, **highway**s and adjacent properties. Erosion on construction sites can result in excessive sediment transport to adjacent properties and to surface waters. Sediment transport can result in adverse impacts such as flooding due to obstructed drainage systems, smothering of aquatic habitat and the creation of algae blooms in lakes, among others.

N.3 Clearing Limits

N.3.1 Prior to any site clearing or grading, areas to remain undisturbed during project construction shall be delineated and marked on-site by flagging or other method. At a minimum, clearing limit delineation shall be installed at the edges of all sensitive area buffers. Retain existing vegetation, where possible.

N.4 Cover Measures

N.4.1 Temporary and permanent cover measures shall be provided when necessary to protect disturbed areas as detailed in the erosion and sedimentation control documents.

N.5 Perimeter Protection

N.5.1 Perimeter protection to contain sediment from sheet flow shall be provided downslope of all disturbed areas where necessary as detailed in the erosion and sedimentation control documents. Such protection shall be installed prior to upslope grading. Perimeter protection includes the use of vegetated strips, as well as more conventional constructed measures such as silt fences.

N.6 **Traffic Area Stabilization**

N.6.1 Unsurfaced entrances, **road**s, and parking areas used by construction traffic shall be stabilized to minimize erosion and tracking of sediment off site as detailed in the erosion and sedimentation control documents.

N.7 **Sediment Retention**

N.7.1 Surface water collected from disturbed areas of the site shall be routed through a sediment pond or trap prior to release from the site as detailed in the erosion and sedimentation control documents, except areas at the perimeter of the site small enough to be treated solely with perimeter protection. Sediment retention facilities shall be installed prior to grading of any contributing area.

N.8 **Surface Water Controls**

N.8.1 Surface water controls shall be installed to intercept and convey all surface water from disturbed areas to a sediment pond or trap and discharge it downslope of any disturbed areas as detailed in the erosion control documents, except areas at the perimeter of the site small enough to be treated solely with perimeter protection. Significant sources of upslope surface water that drain onto disturbed areas shall be intercepted and conveyed to a stabilized discharge point downslope of the disturbed areas.

N.9 **Drainage, Sediment and Erosion Control Plan**

Section N.9 deleted and replaced by Bylaw 1161, 2021

N.9.1 The **Owner's Engineer** must submit Drainage, Sediment and Erosion Control Plan detailing drainage, erosion and sedimentation control measures. All drainage, erosion and sedimentation control measures shall conform to the details and specifications in District Bylaws and policies unless an alternative is approved by the District.

N.10 **Construction within sensitive areas and buffers**

N.10.1 Unless a higher standard is required by a senior level of government, any construction that will result in disturbed areas on or within a stream or associated buffer, within a wetland or associated buffer, or within 15 metres of a lake or other water way shall be subject to "best management practices" including but not limited to "Urban Runoff Quality Control Guidelines for the Province of British Columbia from the Municipal Waste Branch Environmental Protection Division BC Environment" (June 1992) for erosion and sediment control. These provisions include phasing the project whenever possible so that construction in these areas is limited to the dry season.

N.11 **Maintenance**

N.11.1 All erosion and sedimentation control measures shall be maintained as per the erosion and sedimentation control plans submitted by the **Owner's Engineer**. The **Owner's Engineer** shall be responsible for ensuring maintenance and review of erosion and sedimentation control and for compliance with all conditions relating to erosion and sedimentation control.

N.12 **Final Stabilization**

N.12.1 Prior to obtaining **total performance**, the site shall be stabilized and the structural erosion and sedimentation control measures (such as silt fences and sediment traps) shall be removed and drainage facilities cleaned as specified.

SCHEDULE O DESIGN AND CONSTRUCTION OF STREET LIGHTING

O.1 General

O.1.1 The **Owner** must provide **street lighting** designed and constructed in accordance with this Bylaw.

O.1.2 The **District Engineer** may require additional **street lighting** be installed in locations where **street lighting** will improve public safety.

O.2 Design Criteria

O.2.1 Lighting is generally required in all urban and suburban areas. In other areas, lighting requirements shall be in accordance with warrants as indicated in the Transportation Association of Canada Guide for the Design of Roadway Lighting.

O.3 Decorative Street lighting

O.3.1 Additional requirements for decorative **street lighting** shall apply to areas identified in the Town Centre Road and Bottom Wood Lake/Woodsdale Roads areas.

FIGURE O-1 Bottom Wood Lake/Woodsdale Roads

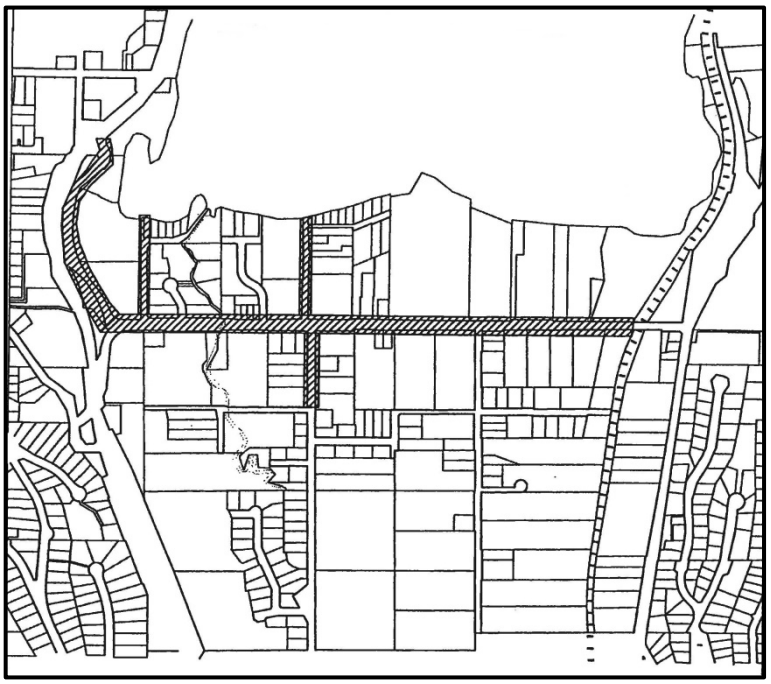
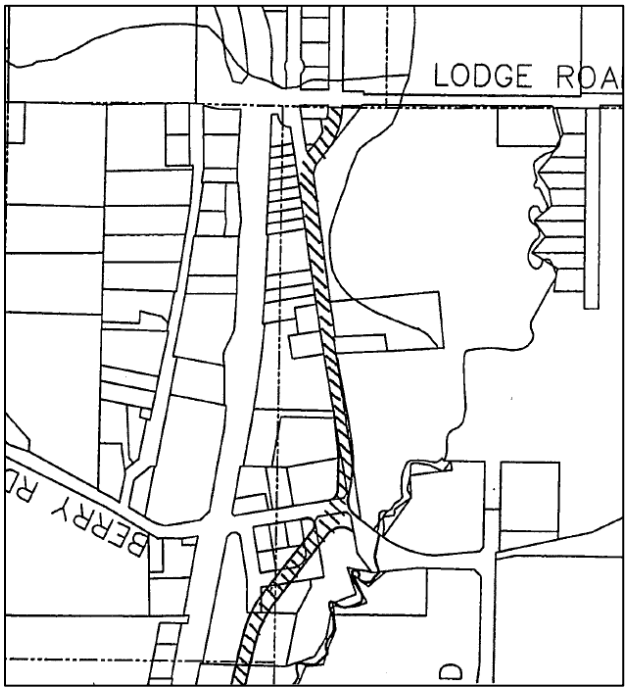


FIGURE O-2 Town Centre Road



O.3.2 Where decorative lighting is required, the following shall apply:

Decorative Luminaire
– King Luminaire K124 Paragon Series

Decorative |Pole
– West Coast Engineering #23300-15FT-Rayleigh Series7

Pole Shall include:
– 15 Foot tapered steel shaft;
- Baseplate on pole shall be supplied with a 297 mm. bolt circle diameter (197 mm. bolt square) that will accept 1”’ diameter galvanized bolts;
– Handhole cover shall be 102 mm. x 178 mm. mounted 222 mm. up from the pole baseplate; and
– Decorative cast aluminum base shall be the two-piece wraparound Raleigh Series.

O.3.3 Fixtures shall be approved by the **District Engineer.**

O.4 **Codes and Standards**

O.4.1 Streetlight designs shall be performed to the latest edition of:
(a) IRDMA/AMSO RP-8 Design Guidelines for Roadway Lighting
(b) IESNA DG-19-08 Design Guidelines for Roadway Lighting
(c) IESNA DG-5 Recommendations for Walkways and Class 1 Bikeways
(d) CSA C653 Energy Efficiency
(e) **MMCD**, Specifications, and Standard Drawings
(f) BC Electrical Code
(g) Transportation Association of Canada Guide for the Design of Roadway Lighting
(h) WorkSafe BC
(i) BC Hydro and FortisBC Design Guidelines

O.5 **Permits**

O.5.1 It is the **Owner**s sole responsibility to obtain all required electrical permits and inspections. A copy of the permits shall be submitted to the **District** upon application for **final approval**.

O.6 **Levels of Illumination**

O.6.1 The average levels of illumination in lux must be as shown in TABLE O-1

TABLE O-1 LEVELS OF ILLUMINATION		
ROAD CLASSIFICATION	**RESIDENTIAL AREAS**	**COMMERCIAL AND INDUSTRIAL AREAS**
Arterial **Highway**	9.0 lx	17.0 lx
Collector **Highway**	6.0 lx	12.0 lx
Local **Highway**	4.0 lx	9.0 lx
Walkways	5.0 lx	5.0 lx

Note: The maximum uniformity ratio for local residential **roads** and **walkways** shall be 5:1 and for all other **roads**, be 3:1. The uniformity ratio is expressed as the average horizontal lux divided by the minimum horizontal lux.

O.7 **Light Loss Factor**

O.7.1 Designs shall be performed using a light loss factor (LLF) per **MMCD** and IESNA design guidelines. The light loss factor shall take into account both lamp lumen depreciation (LLD), lamp dirt depreciation (LDD), and ballast factor (BF).

O.8 **Pole Specifications**

O.8.1 In general, poles must be installed as follows:

(a) **Arterial highways** - staggered spacing.

(b) **Collector highways** - staggered spacing.

(c) **Local highways** - spaced one side of street behind **sidewalk** if **sidewalk** required, otherwise staggered spacing.

(d) **Walkways** - one at every entrance to a **walkway** and additional lighting where required to meeting illumination requirements. Design of the light distribution pattern must minimize light spill into adjoining properties.

O.8.2 Poles must be located within 0.6 metres of the property corners and must not conflict with driveways, underground services and fire hydrants. Street lighting poles shall be installed in accordance with Standard Drawings.

O.8.3 Pole heights shall be 6.7 metres for **local highways** and 9.0 metres for **collector highways**.

O.8.4 Luminaire poles shall be per MMCD standard drawings E4.1 and E.4.2. Concrete bases shall be Type C trapezoidal concrete per MMCD standard drawing CE1.3.

O.8.5 Poles shall black powder coat finish.

O.9 **Products**

O.9.1 Unless otherwise approved by the **District Engineer**, LED fixtures shall be used for the streetlights. Fixtures shall be full cut-off fixtures with the exception of some decorative lighting fixtures for the purpose of matching decorative styles in existing areas. For every 10 fixtures, 1 spare luminaire and pole shall be provided.

O.9.2 All luminaires shall be Phillips Roadstar series or equivalent as approved by the **District Engineer**.

O.10 **Scheduling**

O.10.1 Scheduling of **work** with the governing electrical authority is the **Owner**'s responsibility. Where costs are incurred with B.C. Hydro or FortisBC in installing the light system, these costs shall be considered as part of the cost of the system and shall be at the expense of the **Owner**.

O.11 **Approval**

O.11.1 Prior to issuance of a **Certificate of Total Performance**:

(a) the **Owner** must submit a copy of the Certificate of Inspection by the governing electrical authority showing that the installation is unconditionally approved.

(b) If the **subdivision** or **development** is not located in an existing streetlight local service area, the **Owner** must submit a letter formally requesting that the local service area boundary be expanded to include the **subdivision** or **development**.

O.12 **Connection to Utility**

O.12.1 An allowance for a minimum of eight streetlights per electrical connection must be made and future extension of the **street lighting** system should be accommodated in this requirement.

O.12.2 Connection shall be made in accordance with Standard Drawings.

O.12.3 All **street lighting** in public right of ways must be provided with electrical metering equipment in accordance with standards of the appropriate electrical utility.

O.12.4 All **street lighting** kiosks must have a test switch.

O.12.5 Single service bases shall be per MMCD standard drawing E4.21. Where required, an aluminum single sided, single door, CSA type R3 rated kiosk may be used for meter installation.

SCHEDULE P DESIGN AND CONSTRUCTION OF ELECTRICAL AND COMMUNICATIONS WIRING AND GAS DISTRIBUTION SYSTEMS

P.1 General

P.1.1 Power supply, communication wiring, and gas service for each **parcel** must be designed and constructed in accordance with this Bylaw.

P.1.2 The **Owner** must obtain a letter of confirmation from the applicable utility that electrical, communication, and gas distribution infrastructure have been installed to their satisfaction.

P.1.3 Kiosks/Laminate Wrapping Requirements – All kiosks must be wrapped with anti-graffiti vinyl wrapping. Wrap material must be a cast vinyl with a high gloss laminated surface. The wrap is to be visually pleasing and compliment the area surrounding the installation location considering landscape, geography, and general theme of the area. Artwork must have a high degree of contrast so as to maximize resistance to graffiti vandalism. Artwork must not be for commercial advertising. All artwork must be approved by the **District Engineer** prior to installation.

P.2 Utility Locations

P.2.1 Systems of **work**s for electrical and communications wiring and gas distribution systems must be installed in accordance with the standards required by the particular utility and any applicable federal and provincial codes.

P.2.2 All utility **work** must be installed in alignments as generally indicated on Standard Drawings. It is the responsibility of the **Owner**s Engineer to coordinate with each utility the actual offsets required prior to a drawing submission to the **District**.

P.2.3 All systems must be designed and constructed so as to fully service all **parcel**s in a **subdivision** or **development**.

SCHEDULE Q DESIGN AND CONSTRUCTION OF HILLSIDE DEVELOPMENT AREAS

Q.1 General

Q.1.1 In steep slope areas where it is impractical to conform to technical requirements of this Bylaw and a Hillside **Development** permit has been issued by the **District**, the **District Engineer** may approve **work**s which comply with the criteria set out in this schedule.

Q.1.2 Use of this schedule is required in steep slope development areas. **Steep slopes** means lands in their natural state that have a slope angle of 20% or greater for a minimum horizontal distance of 10 meters, or adjacent areas where existing or potential sloughing or stability warrants concerns. The definition applies to all properties which are 0.5 hectares or greater in size, and where 10% or greater of the parent property contains slope of more than 20%.

Q.1.3 Before agreeing to the use of this Schedule, the District Engineer must be satisfied that use is warranted due to the topographical constraint involved and that the varied criteria are presented and accepted as good engineering practice and that the varied criteria are environmentally sound and do not adversely affect transportation or public safety.

Section Q.1.4 added by Bylaw 1161, 2021

Q.1.4 Engineering designs under this schedule shall conform to the specifications contained within TABLE Q-1 and Table Q-2.

Q.2 Pre-design Report – *deleted by Bylaw 1161, 2021*

Q.3 Detailed Design

Q.3.1 Detailed design must also consider the following:

(a) Underground infrastructure pipe bedding, trench backfill, and mechanical restraints.
(b) Road**work** structure, barrier curb, and the requirements for safety barriers.
(c) Driveway access concerns.
(d) Building code structural or foundation requirements.
(e) Environmental impact assessment.
(f) A list of requirements on a lot by lot basis pertaining to covenants that may be required.
(g) Each **parcel** created by **subdivision** must have a buildable site with building envelope setbacks and driveways shown on the design drawing.
(h) **Boulevard** grades in excess of 2% may be designed with the following conditions:
  (i) to a point 1.0 m from the back of **sidewalk** or curb (where no **sidewalk** present) where on street parking is provided and to a point 2.4 m back where parking is adjacent to the street, behind the curb, as long as it can be demonstrated that the depth of bury on underground utilities will not be negatively impacted and there is sufficient space for snow storage.
  (ii) In areas where the **boulevard** grade exceeds 2%, the **Approving Officer** may require the developer to undertake **boulevard** slope stabilization and planting.
(i) In no case shall the grade from the property line to back of **sidewalk**, back of curb, or back of ditch be less than 1%.
(j) Level access and clearance of 1.3m around fire hydrants, transformers, and vaults must be established.

(k) Centre median cross-section slope protection from erosion. Centre medians must be designed to be maintenance free.
(l) Alternate utility offsets.
(m) Down slope **road** section with storm mains and sanitary mains in common trench.
(n) Cut/fill slopes, vegetation planting, retaining wall structures, and parking and associated sight distances shall be designed to protect all site distances.
(o) Side yard and rear yard utility corridors shall only be approved if they are included in a right-of-way that restricts the construction of permanent structures (excluding fences).
(p) Utility service and transformer boxes, which need to be at **road** grade, require suitable grading and retaining structures.
(q) Disturbed areas within the **road** right-of-way or on disturbed areas of the site that are not within formal landscaped areas or building envelopes shall be restored to a natural condition or to a condition that will prevent erosion prior to **substantial performance** being issued or final occupancy in the case of a Building Permit application.
(r) *Deleted by Bylaw 1193, 2022*

TABLE Q-1 -HILLSIDE DEVELOPMENT STANDARDS									
STREET TYPE	**CONDITION [1]**	**DESIGN SPEED**	**MAX. GRADE**	**ROW WIDTH [5]**	**PAVEMENT WIDTH (M) [2]**	**PARKING [5, 6]**	**CURB & GUTTER**	**SIDEWALK [3, 4]**	**STREET TREES**
HILLSIDE LOCAL ROAD									
Development fronts both sides	A	40	12	14	6.4	Both sides	Barrier	1	Optional
Development fronts one side	B	40	12	12	6.0	Both sides	Barrier	1	Optional
No **Development** fronting	C	40	12	10	6.0	Where Required [8]	Barrier	1	Optional
HILLSIDE COLLECTOR ROAD									
Development fronts both sides	A	50	10 [7,9]	18	9.4	Above curb Both sides	Rollover[10]	2	2 Sides
Development fronts one side	B	50	10 [7,9]	15	9.4	Above curb Both sides	Rollover[10]	1	2 Sides
No **Development** fronting	C	50	10 [7,9]	14	9.4	Where Required [8]	Barrier	1	2 Sides
HILLSIDE EMERGENCY VEHICLE ACCESS									
		20	15	4.5	4.6				

1 Condition refers to Standard Drawings SD-HS1, SD-HS2 and SD-HS3.

2 Pavement width measured from back of curb.

3 **Sidewalks** shall terminate at a destination or connect with another **sidewalk** or pathway. The numbers indicate whether **sidewalk** is required on either one or both sides of the street.

4 **Sidewalks** are not required on local streets in steep slope areas unless they are required to provide connectivity to schools, parks, commercial areas or lands beyond.

5 Roadway cross sections may be further reduced in width if parking is to be established at strategic locations.

6 Split **road** section **lane** widths require 3.0 m traveled **lane** plus 2.5 m parking or cycling width.

7 Collector Streets maximum grades may be increased to 12% where necessary due to topographic constraints. Where approved, grades exceeding 10% shall be topographically surveyed at the developers' expense, to verify final **road** grades, prior to final **subdivision** approval.

8 Required adjacent to parks, green space and /or trail access points.

9 Except for the 100-metre portion of Chase Road intersecting with Glenmore Road as shown on Standard Drawing SD-HS4 attached to the Administrative Subdivision and Development Standard Forms Policy 155, 2017, as amended from time to time, and generally fronting portions of the following properties:

- 5000 Chase Road, Lot 2 Plan KAP81535, PID 026-759-900, Roll 02121.002
- 5474 Chase Road, Lot C Plan KAP87779, PID 027-694-968, Roll 02118.003; and
- 5235 Chase Road, Lot A Plan KAP35082, PID 002-897-687, Roll 02173.372,

maximum grades may be increased to 15% where necessary due to topographic constraints.

10 to act as gutter pan

TABLE Q-2-HILLSIDE ALIGNMENT DESIGN CRITERIA				
Criteria	**Design Speed**			
1. Horizontal Curve Radii				
Roadway	**60 km/h**	**50 km/h**	**40 km/h**	**30 km/h**
normal crown (-2%)	260m	165m	90m	45m
2% superelevation	205m	120m	65m	30m
4% superelevation	150m	80m	45m	22m
6% superelevation	120m	-	-	-
Through Intersections	200m	120m	70m	40m
2. Superelevation				
Maximum Superelevation	6%	4%	4%	4%
Maximum Superelevation at Intersection	4%	4%	4%	4%
3. Superelevation Transition Lengths				
Transition Lengths (2/4 lane roadways)[1]				
normal crown to +2%	24m/36m	22m/34m	20m	20m
normal crown to +4%	38m/54m	33m/50m	30m	30m
normal crown to + 6%	48m/72m	-	-	-
Min. Tangent Length between reversing				
2% superelevation (2/4 lane roadways)[2]	15m/22m	13m/20m	12m	12m
4% superelevation	28m/42m	26m/40m	24m	22m
6% superelevation	42m/64m			
4. Gradients				
Minimum Grade	0.50%	0.50%	0.50%	0.50%
Maximum Grades				
on horizontal tangents	8%[3]	10%[4]	12%	12%
on minimum radius horizontal curves[5]	8%	9%	10%	10%
Grades Through Intersections				
with design speed on major road	8%	8%	8%	-
approach distance for major road[6]	15/5m[7]	5m	0m	-
with design speed on minor road	5%[8]	5%	6%	6%
approach distance for minor road[9]	20m	15m	5m	5m
5. Vertical Curve K Values				
Criteria				
Minimum Crest	15	8	4	2
Minimum Sag	10	7	4	2
Crest/Sag on approach to stop condition	4	3	2	2
K values listed assume that new **road**ways will be illuminated				
6. Stopping Sight Distances				
Down grades: 12%	109m	78m	52m	34m
9%	101m	73m	50m	32m
6%	94m	69m	48m	31m
3%	89m	66m	46m	30m
0%	85m	63m	45m	30m
Up grades: 3%	81m	61m	44m	29m
6%	78m	59m	42m	29m
9%	76m	57m	41m	28m
12%	73m	56m	40m	28m
7. Decision Sight Distance				
Minimum decision sight distance for 60km/h: 175m-235m.				

[1] Values for transition lengths include tangent runout applied at the same rate as superelevation runoff.
[2] 60% of superelevation runoff occurs on the tangent approach and 40% on the curve, resulting in a minimum length of tangent between reversing curves of 120% of the superelevation length.
[3] Under special circumstances, grades up to 10% may be permitted.
[4] Under special circumstances, grades up to 12% may be permitted.
[5] Applies where radius is less than 1.5 times minimum allowable radius.
[6] Minimum distance back from the gutter line of the minor **road** that the specified grade may not be exceeded.
[7] Distances for design **road** approach to intersection with collector **road**/local **road**.
[8] 4% desirable.
[9] Minimum distance back from the gutter line of the major **road** that the specified grade may not be exceeded.
[10] Note that decision sight distance applies only to multi-**lane roads** at intersections.
[11] The range of values recognizes the variation in complexity that occurs at various sites. For less complex situation, values towards the lower end of the range are appropriate and for more complexity, values at the upper end are used.

SCHEDULE R DRAWINGS

R.1 General

R.1.1 Where **work**s are required to be constructed to service a **subdivision** or **development**, the **Owner's Engineer** must prepare engineering design drawings in accordance with the provisions of this Bylaw.

R.1.2 Drawings submitted to the District for review subsequent to the initial drawing submission, must clearly identify any revisions using a "revision cloud".

R.1.3 When required, the **District Engineer** may request that the **Owner's Engineer** provide 3-dimensional renderings of the proposed **subdivision** or **development**.

R.2 MMCD

R.2.1 **MMCD** Standard Detail Drawings must be referenced to and interpreted simultaneously with the pertinent sections of this Bylaw.

R.2.2 AutoCad Standard border and blocks shall be as per **MMCD**.

R.3 As-Constructed Drawings

R.3.1 Prior to the issuance of a **Certificate of Total Performance** the **Owner** must deposit with the **District**:

(a) one complete set of original as-constructed drawings; and
(b) electronic copies of the drawings in a format acceptable to the **District Engineer**.
(c) one set of Service Cards in the prescribed format for:
  (i) Water
  (ii) sanitary sewer
  (iii) storm sewer
  (iv) fire hydrants

R.3.2 As-constructed drawings must be prepared in accordance with the provisions set out in this Bylaw.

R.4 Design Drawings

R.4.1 In simple servicing cases where a standard drawing contained in this Bylaw is deemed by the **District Engineer** to be sufficient for construction purposes, the **District Engineer** may, in their sole discretion, waive the requirement for design drawings where a **District** approved **contractor** is being used

R.5 Standard Drawings

R.5.1 Existing **work**s refers to previously constructed **work**s.

R.5.2 Proposed **work**s refers to **work**s to be constructed and installed during the current **subdivision** or **development** phase.

R.5.3 Future **work**s refers to any **work**s that will be constructed or installed in future phases or as a part of a **District** construction project.

R.5.4 Where no standard is defined in this Bylaw for the preparation of a drawing to portray a particular service, structure, or other item, instructions and requirements shall be obtained from the **District Engineer**.

R.5.5 The drawings must include a title page, key plan, building envelope plan, composite utility plan, plan profile, details, cross sections, and any other related drawings.

R.6 **Preparation**

R.6.1 Drawings must be prepared:

(a) Using the **District** standard border, title block, drawing symbols and material symbols in accordance with **District** Standard Drawings. The drawings are available from the **District Engineer** in electronic format.

(b) using a cadastral base that matches the legal plan upon which a building permit application is based or on the legal plan which will be sent to the Land Titles Office for registration of the proposed **subdivision**.

(c) in accordance with the sample engineering drawings.

R.7 **Sheet Layout**

R.7.1 Sheet layout shall conform to the following standards:

(a) Sheet size to be A1.

(b) All information shall be completely contained with the drawing borders and shall not encroach on the title block.

(c) Place north arrow close to the top right-hand side of the sheet. For fragmented plan views, place north arrow at the top right-hand side of each fragment.

(d) North arrow must point towards the top of the page or towards the left-hand edge of the page.

(e) In all cases the title page, key plan, location plan and composite utility plan must be oriented in the same direction.

(f) Matchlines must be drawn and reference the appropriate sheet showing the continuation if the size of the **subdivision** or **development** makes it necessary to place the key plan or composite utility plan onto two or more sheets.

R.8 **Dimensions and Units**

R.8.1 The following conventions must be used:

(a) Dimensions and units must be shown in metric. No imperial units are permitted.

(b) Distances must be in meters and grade in percent to an accuracy of 2 decimal places.

(c) Elevations to an accuracy of 3 decimal places.

(d) Areas must be in square meters rounded to the nearest square meter.

(e) Pipe sizes must be in millimeters as per ASTM specifications using 1" = 25 mm.

(f) Existing imperial dimensions, except for pipe sizes, are to be soft converted using the factors of 1 inch = 25.4 millimeters or 1 foot = 0.3048 meters.

R.9 **Lettering**

R.9.1 Lettering must conform to the following:

(a) All lettering to be upper case AutoCAD - Romans.
(b) All lettering to maintain a 1:10 ratio between plotted text height and plotted pen thickness.
(c) The minimum plotted text height shall be 1.5 mm.
(d) The maximum plotted text height shall be 5.0 mm.
(e) Use black ink on all as-constructed drawings except that green ink may be used on the plan profile grid lines.

R.10 **Scales**

R.10.1 The following scales must be used:

(a) Plan View Drawings 1:500
(b) Plan and Profile Drawings Horizontal 1:500 Vertical 1:50
(c) Scales for location plans, key plans, cross-sections, and details shall be chosen as deemed suitable for the application.

R.11 **Title Page**

R.11.1 Title Pages shall contain the following information:

(a) Name of **development**
(b) Name and address of **development**
(c) Name and address of **Engineer**
(d) Site plan of **subdivision** or **development**
(e) Overall plan with lot numbers, plan numbers and street names for the subject **development** and adjoining properties.
(f) For phased **development** all phases must be shown with the current phase outlined darker than future or existing phases.
(g) File numbers of approving authorities, (i.e. **District** and the Ministry of Transportation and **Highways**).
(h) Complete list of drawings belonging to the set.
(i) Legal description of subject properties.
(j) North Arrow
(k) The lettering used on this page is not required to conform to R.9.1 in respect to text styles and text height.

R.12 **Key Plans**

R.12.1 Key Plans shall contain the following information:

(a) Lot numbers, plan numbers, and **road** names of the subject **development** and adjoining properties.
(b) Cross reference of the detailed drawings by outlining the area contained in each drawing and referencing that drawing by drawing number.
(c) North Arrow.

R.13 **Building Envelope Plan**

R.13.1 Building Envelope Plan shall contain the following information:
(a) Overall plan of current phase
(b) Lot numbers
(c) **Roads**, curbs, gutters and **sidewalks**
(d) Rights of way and easements
(e) Offset lines from all property boundaries indicating required building setbacks
(f) 10 meter by 10 meter square on each **parcel** indicating the required minimum building envelope
(g) Notes that indicate the required setbacks from all property boundaries pursuant to the Zoning Bylaw
(h) North arrow
(i) Minimum building elevation

R.14 **Composite Utility Plan**

R.14.1 Composite Utility Plans shall contain the following information:
(a) All existing and proposed utilities, **roads**, **walkways**, and **sidewalk**s.
(b) All rights of way and easements including widths.
(c) Control station monuments with identification number.
(d) All legal information, including bearings, dimensions, lot numbers, block numbers, legal plan numbers, and street names. All lots must be numbered.
(e) Show all BC and EC locations on curved lot lines.
(f) Dimensions for curved lot lines shall include radius and arc length.
(g) All **road**way dimensions including width of right of way, BOC to BOC and BOC to edge of right of way.
(h) Area of each **parcel**.
(i) Lots with curved **frontage** that do not meet the minimum **frontage** requirement, show arc length and radius at property line and at 6.0 meter offset.
(j) North Arrow.

R.15 **Plan and Profile Drawings**

R.15.1 The plan and profile drawings shall be prepared in accordance with this section and shall be divided into two parts: plan view on the top half of the page and profile view on the bottom half of the page.

R.15.2 For complex servicing with multiple utilities located within the same corridor or alignment, each utility shall be shown on a separate plan and profile drawing in addition to composite plan and profile drawings.

R.15.3 Plan Views must be divided into two views as follows:
(a) Above Ground View, must include the following:
(i) All features and utility installations visible above ground
(ii) Lot numbers
(iii) Dimensions establishing location of all surface **works** constructed within statutory rights of way and easements.
(iv) Horizontal curve data for **road** centerlines including radius, arc length, tangent length, and delta angle.

(v) Curb, gutter, and **sidewalk** information including type of curb, width of **sidewalk**, location of letdowns for driveways, wheelchair ramps, etc.

(b) Below Ground View, must include the following:
- (i) Lot numbers
- (ii) All underground utilities such as sanitary and storm sewers, water, electrical and communication wiring, gas and all applicable appurtenances.
- (iii) Utility alignment referenced to the nearest property line or right of way boundary.
- (iv) Size of all pipes and direction of flow for sewers.
- (v) Specifications for all fittings, valves, and hydrants.
- (vi) Geodetic invert elevations at property line for all sewer services connected directly into manhole.
- (vii) Lot services (sanitary, storm, water) referenced to the nearest legal pin.

R.15.4 Profile View

(a) Profiles shall be drawn on a grid that has horizontal lines with 2 mm spacing and vertical lines with 20 mm spacing. Horizontal lines must be accented every 20 mm. All vertical lines must be accented. All elevations shall be relative to a geodetic datum.

R.15.5 Plan and profile drawings must include the following:

(a) Continuous stationing on the accented vertical grid line.

(b) Pre-construction ground profile along the centerlines of proposed **roads**. In statutory rights of way or easements, show pre-construction ground profile for each utility. Include any related data or date surveyed.

(c) Profile shown at true centerline length and projected above to the plan view in as close a relationship as possible.

(d) **Road** centerline profile including the following information:
- (i) percent grade
- (ii) chainage and elevations of BVC, EVC, and PVI
- (iii) external "e" value
- (iv) “K” value
- (v) “A.D.” value
- (vi) length of vertical curve
- (vii) station and elevation of low point or high point vertical curves
- (viii) on super elevated curves and crossfall sections, show percent crossfall and transition length and crown

(e) Profiles of invert and crown of pipes for sanitary sewer, storm sewer, and water mains as well as length, size, type, grade, and class of pipe (i.e. 75 m 200 mm SAN SDR 35 PVC at 2.38 %).

(f) Manhole rim elevations and invert elevations at all inlets and outlets.

(g) Top and bottom inverts on manhole drop structures.

(h) Location type, and elevation of all crossing utilities.

(i) Gutterline and grate elevations for catch basins.

(j) Elevations at the right- and left-hand side of the profile and repeated at breaks in the profile.

(k) Elevations at every even metre graduation on the horizontal accented line.

R.16 **Electronic Drawings**

R.16.1 General Requirements

(a) The **Owner** must submit to the **District Engineer** a complete set of electronic drawings of the **subdivision** or **development** in DWG format compatible with the current version of AutoCAD being used by the **District**.

The electronic drawing must be prepared in accordance with this Bylaw.

R.16.2 Conventions

(a) Drawing symbols must be in accordance with Standard Drawings.

(b) Material symbols must be in accordance with Standard Drawings.

(c) No drawing shall be submitted that contains any external references (xrefs).

(d) All as-constructed drawings must be purged of all unnecessary information prior to submission to the **District**.

R.16.3 Prototype Drawings

(a) An electronic copy of the **District** prototype drawing is available from the **District.** The prototype drawing contains the **District** standard border, titleblock, layers, blocks and linetypes to be used in all submissions of design or as-constructed drawings.

Standard Detail Drawings are provided in Subdivision Standard Forms Policy 155, 2017. Where not superseded by a **District** drawing, the relevant **MMCD** Standard Detail Drawings must be referenced and interpreted simultaneously with this bylaw.

SCHEDULE S FORMS, AGREEMENTS, AND CERTIFICATES

S.1 Subdivision and Development Servicing Agreement

S.1.1 Prior to **work**s being carried out:

(a) on a **District highway** or

(b) in a statutory right of way in favour of the **District**

for the servicing of a **subdivision** or **development**, the **Owner** must:

(i) enter into a **subdivision** and **development** servicing agreement; and

(ii) provide a security deposit in accordance with this Bylaw.

S.1.2 Prior to entering into, and as a condition of a Servicing Agreement, the District Engineer may require the Owner's Engineer to provide a plan demonstrating constructability of the works.

Section S.1.3 deleted and replaced by Bylaw 1161, 2021

S.1.3 All **work**s required to be constructed and installed at the expense of the **Owner** of the land being subdivided or **developed** shall be constructed and installed in accordance with the provisions of the Bylaw before the **Approving Officer** approves the **subdivision** or the **Building Inspector** issues the building permit. At the District Engineer's discretion, the approval may be given or the permit issued if the owner of the land:

(a) Enters into a **Subdivision** and **Development** Servicing Agreement with the **District** accepting the terms and conditions in that agreement, and undertaking to construct and install the required **works** within one year from the date of executing the agreement; and

(b) The **Owner** deposits with the **District** security in the form of cash, a bank draft or an irrevocable letter of credit in a form acceptable to the Chief Financial Officer in the amount of:

(i) One hundred and twenty five percent (125%) of the awarded tender value for the construction and installation of the **work**s: plus

(ii) One hundred and twenty five percent (125%) of the **Owner's Engineer's** fee for the design and inspection of the **work**s as estimated by the **Owner's Engineer**; plus

(iii) enter into a Maintenance Security Agreement to warrant for the maintenance of the **work**s for a period of eighteen (18) months after the date of **substantial performance**; and

(iv) provide a Maintenance Security deposit in accordance with this Bylaw;

(c) The **Owner's Engineer** certifies that the tender has been awarded and that a contract has been executed between the **Owner** and the **contractor**; and

(d) The **Applicant** complies with the provisions of Schedule S, Section 4, Certificate to Commence Construction; and

(e) The **Applicant** provides written proof that all the requirements of the Ministry of Transportation and Infrastructure and other agencies having jurisdiction have been met, if applicable.

S.1.4 The **Owner** will not be required to enter into a Maintenance Security Agreement, nor be required to provide a security deposit when:

(a) There are no **works** required under the provisions of this Bylaw or

(b) Those **works** are not required as a result of a **development** variance permit granted by **Council**.

S.2 **Commitment by Owner and Engineer**

S.2.1 A Commitment by **Owner** and Engineer must be submitted to the **District Engineer** prior to review of design drawings.

S.2.2 A Commitment by **Owner** and Engineer shall be signed by the **Owner** and **Owner's Engineer** certifying that:
the **Owner's Engineer** has been contracted by the **Owner** for the design of all **works**, reviews and designs associated with the **subdivision** or **development**;

(a) the **Owner's Engineer** shall adhere to all Provincial Statute for their profession;
(b) the **Owner's Engineer** shall ensure that the **works** comply with the provisions of all **District** Bylaws, permits, policies, and applicable legislation and regulations;
(c) the **Owner's Engineer** shall ensure that only qualified personnel are retained to carry out tests, inspect or carry out design **work**, detailing, or **field reviews**;
(d) the **Owner's Engineer** has been given contractual mandate by the **Owner** for the purposes of **subdivision** or **development**;
(e) the **Owner's Engineer** shall submit summary reports to the **District Engineer** on request;
(f) the **Owner's Engineer** shall submit letters of Certification of Bylaw Compliance as required;
(g) the **Owner's Engineer** is licensed to practice as an **engineer** in the Province of British Columbia;
(h) the **Owner's Engineer** covenants that their firm presently carries, and will continue to carry for the duration of the project, liability insurance in the amount of five million dollars ($5,000,000).

S.2.3 Notification of termination of the **Owner's Engineer** shall be provided to the **District Engineer** in writing thirty (30) days prior to any intended termination;

S.2.4 Where the **Owner's Engineer** ceases to be retained at any time during construction of the **work**s, **work** on shall cease until:
a new **Engineer** has been retained; and

(a) an updated Commitment by **Owner** and **Engineer** and Commitment to Design and **Field review** have been submitted to the **District Engineer**.

S.3 **Commitment to Design and Field review**

S.3.1 A Commitment to Design and Field Review from the Engineer representing each engineering specialty shall be submitted to the **District Engineer** prior to issuance of a Certificate to Commence Construction.

S.3.2 A Commitment to Design and Field Review shall be signed by the **Owner's Engineer** and each Engineering Specialist certifying that:

(a) the **works** identified by the **Engineer**'s initial, will be designed, constructed and installed in accordance with all applicable **District** Bylaws, permits and policies and legislation and regulations;
(b) **Field reviews** shall be completed and provided to the **District Engineer** during construction.
(c) The **District** shall be notified immediately in writing if the contract for **field reviews** is terminated at any time during construction.
(d) the **Engineer** is licensed to practice as an **engineer** in the Province of British Columbia;
(e) the **Owner's Engineer** covenants that their firm presently carries, and will continue to carry for the duration of the project, liability insurance in the amount of five million dollars ($5,000,000).

S.4 **Certificate to Commence Construction**

S.4.1 No person shall excavate or fill land for the purpose of constructing **work**s, nor shall any person construct or install any of the **work**s until a Certificate to Commence Construction has been issued.

S.4.2 The **District Engineer** shall not issue a Certificate to Commence Construction until the **Owner** submits the following information:

(a) three complete paper copy sets and one electronic copy in pdf format of design drawings showing all pertinent information as required by this Bylaw and prepared in accordance with this Bylaw;
(b) detailed design calculations in support of the **street lighting** layout.
(c) detailed design calculations in support of the fire flows and storage required in the design of a **community water system**.
(d) detailed design calculations in support of a **storm drainage system**.
(e) detailed design calculations in support of a **community sewer system**.
(f) plans and documentation in support of a Drainage, Sediment and Erosion Control Plan.
(g) Letter of Commitment by **Owner** and **Engineer**;
(h) Quality assurance/quality control documentation
(i) Letter of Commitment to Design and **field review**;
(j) If required, letters approving design from the Ministry of Transportation and Infrastructure, and other agencies having jurisdiction.

S.5 **Certification of Bylaw Compliance**

S.5.1 A Certificate of Bylaw Compliance from each Engineer shall be submitted to the **District Engineer** prior to the issuance of a **Certificate of Total Performance**.

S.5.2 A Certificate of Bylaw Compliance may not be submitted until after Substantial Performance of the **work**s.

S.5.3 After submission of Certification of Bylaw Compliance, each Engineer must arrange and conduct a final inspection with the **District Engineer** to determine the acceptability of the Certification of Bylaw Compliance.

S.5.4 A Certification of Bylaw Compliance shall be signed by the **Owner's Engineer** and the **engineer** representing each engineering specialty certifying that:

(a) all obligations for **field reviews** pursuant to this Bylaw have been met;
(b) all obligations pursuant to the previously submitted Commitment to Design and Field Review have been met;
(c) **works** identified in the signed Commitment to Design and Field Review comply in all materials respects with the provisions of this Bylaw and the design drawings and supporting documentation submitted in support of the **subdivision** or **development** application;
(d) the final as-constructed drawings and supporting documents prepared have been submitted;
(e) the **Owner's Engineer** is licensed to practice as an **engineer** in the Province of British Columbia;
(f) the **Owner's Engineer** covenants that their firm presently carries, and will continue to carry for the duration of the project, comprehensive general liability insurance in the amount of two million dollars ($2,000,000);
(g) the **Owner's Engineer** covenants that their firm presently carries, and will continue to carry for the duration of the project, automobile liability insurance in the amount of two million dollars ($2,000,000);
(h) the **Owner's Engineer** covenants that their firm presently carries, and will continue to carry for the duration of the project, errors and omissions insurance in the amount of five hundred thousand dollars ($500,000)

S.6 **Certification of Slope Stability**

S.6.1 A Certification of Slope Stability from the geotechnical Engineer shall be submitted to the **District Engineer** prior to the issuance of **Certificate of Total Performance**.

S.6.2 A Certificate of Slope Stability may not be submitted until after Substantial performance of the **work**s.

S.6.3 A Certification of Slope Stability shall be submitted by a geotechnical Engineer certifying that:

(a) all obligations for slope stability review pursuant to this Bylaw have been met;
(b) all issues related to safety and slope stability have been addressed;
(c) In consideration of slope stability matters due consideration has been given to, "Guidelines for Legislated Landslide Assessments for Proposed Residential **Developments** in BC", Association of Professional Engineers of British Columbia, Revised May, 2010;
(d) **works** identified in the signed Commitment to Design and Field Review comply in all materials respects with the provisions of this Bylaw and the design drawings and supporting documentation submitted in support of the **subdivision** or **development** application;
(e) the final as-constructed drawings and supporting documents prepared have been submitted;
(f) the **Engineer** is licensed to practice as an **engineer** in the Province of British Columbia;
(g) A report confirming slope stability on the lots created as required in Schedule D of this Bylaw.

S.7 **Certification of Total Performance**

S.7.1 A **Certificate of Total Performance** will be issued by the **District Engineer** indicating that **total performance** of the **work**s has been achieved, once the **Owner** has complied with the provisions of this Bylaw.

S.7.2 The **District Engineer** must not issue a **Certificate of substantial performance** until the following has been submitted:

(a) as-constructed drawings;
(b) Utility Service Cards;
(c) Maintenance Security Agreement;
(d) Certification of Bylaw Compliance;
(e) three copies of the plan of **subdivision** which have been executed by all required parties and are ready for registration;
(f) executed copies of all Statutory Right of Way plans and agreements, if applicable and which are ready for registration;
(g) all applicable fees, charges and security deposits;
(h) video reports and air testing results;
(i) confirmation that a final inspection has been conducted by the **District Engineer** and **Owner's Engineer**;
(j) a letter from the governing electrical authority approving the **street lighting** installation;
(k) a letter from communication, gas, and electrical utilities as applicable and Ministry of Transportation and Infrastructure as applicable, confirming that their requirements have been met;
(l) a letter from the applicable **private water utility** approving the **water distribution system**; and
(m) confirmation that **substantial performance** of the **work** has been achieved.

S.8 **Maintenance Security Agreement**

S.8.1 Upon Substantial performance of the **subdivision** or **development** and prior to issuance of a **Certificate of Total Performance** the **Owner** must:

(a) Enter into a Maintenance Security Agreement to warrant for the maintenance of the **works** for a period of eighteen (18) months after the date of **Substantial performance;** and

(b) Provide a maintenance security deposit in accordance with this Bylaw.

S.8.2 The **Owner** will not be required to enter into a Maintenance Security Agreement, nor be required to provide a security deposit when:

(a) There are no **works** required under the provisions of this Bylaw or

(b) **Council** grants a **Development** Variance Permit exempting the **Owner** from some or all of the **works** required under this Bylaw.

SCHEDULE T FEES AND SECURITY

T.1 Fees and Deposits

(a) The **Owner** shall provide all security deposits and pay all fees required under any applicable **District** bylaws, including but not limited to, this bylaw and the **District**'s Fees Bylaw, as amended from time to time.

T.1.2 Security Deposits

(a) Security deposits must be provided to the **District** in the form of cash, bank draft, irrevocable letter of credit, or another form acceptable to the **District,** as follows:

(i) 125% of the awarded tender value (or the **Owner's Engineer**'s estimate if the project has not been tendered) for the engineering, design, quality assurance, contingency, construction and installation of the **work**s; plus

(ii) 150% of the **Owner's Engineer**'s fee for the design and inspection of the **work**s as estimated by the **Owner's Engineer**; plus

(iii) the value calculated and in a form acceptable to the **District** to warrant for the maintenance in accordance with **TABLE** T-1 Maintenance Security Table; plus

(iv) $2000 per sheet for drafting deficiencies.

T.1.3 Maintenance Security Deposit

(a) A maintenance security deposit must be provided to the **District** in the form of cash, bank draft, Irrevocable Letter of Credit or another form acceptable to the **District**, in accordance with the following table:

TABLE T-1-MAINTENANCE SECURITY TABLE [1]	
Description	**Maintenance Security**
Fee Simple Subdivisions (on site **work**s)	$580 per **parcel** or 5% of value of **work**s whichever is greater
Bare Land Strata **development**s	5% of the value of **offsite work**s 2
Offsite **work**s for **subdivision** or **development**	5% of value of capital costs [2]
Deficiencies and/or defects	200% of the estimated cost to **repair** [3]
Building Permits	5% of value of capital costs

[1] more than one of the items contained in the Maintenance Security Table may apply to any **subdivision** or **development**.

[2] five percent (5%) or one thousand dollars ($1,000.00), whichever is greater, of the cost of designing, constructing and installing the **works** required under this Bylaw, as submitted by the **Owner's Engineer** and as approved by the **District Engineer**.

[3] two hundred percent (200%) of the cost to **repair** deficiencies and defects as estimated by the **Owner's Engineer** and as approved by the **District Engineer**.

Deleted and replaced by Bylaw 1262, 2024

T.1.4 Cash in Lieu

(a) Notwithstanding Schedule S-Forms, Agreements and Certificates, subsection S.1.3 ,the District Engineer may require an Owner to provide a non-refundable payment in lieu (cash-in lieu) of constructing or installing all, or a portion of, works and services required under the provisions of this bylaw where, as determined by the District Engineer, such works may be undertaken at a future date or concurrently with other works and services in connection with the development of land.

(b) Cash-in-lieu payments:

(i) will be established through a Subdivision and Development Servicing Agreement between the Owner and District;

(ii) will be deposited into a reserve fund for the future construction or installation of works and services;

(iii) are due before the approving officer approves of the subdivision or the building inspector issues the building permit;

(iv) will not exceed an amount greater that 125% of the costs of design and construction at the time of entering into an agreement, plus any required land acquisition costs.

(v) will be determined by the District Engineer using sound engineering principles and will be based on cost estimates prepared by the Owners Engineer submitted to the District Engineer for acceptance.

T.1.5 Excess or Extended Capacity (Latecomer)

(a) Pursuant to the *Local Government Act*, the **District Engineer** may require the **Owner** to provide excess or extended services to provide access to or to service land other than the **parce**l being **subdivided** or **developed**. Where excess or extended services are required, the **Owner** shall provide additional documentation as requested by the **District Engineer** to assist in making a determination. Such information may include, but is not limited to, drawings that define catchment areas, design drawings, a traffic impact analysis and **onsite** utilities impact analysis.

(b) Where the **Owner** is required to provide excess or extended services, the **Owner** shall be entitled to receive latecomer payments in accordance with the **District's** Latecomer Policy.

Section T.2 deleted and replaced by Bylaw 1161, 2021

T.2 **Fees**

T.2.1 Fees shall be applicable as per the **District** Fees Bylaw as amended from time to time.

SCHEDULE 7
CIVIL INFRASTRUCTURE

GENERAL POLICY

A. This section describes how the remaining parts of the Proposed Development will be serviced.
B. Major access and storm obligations are detailed in section 7.1.
C. The onsite servicing concept plans are detailed in section 7.2.

KEY INFRASTRUTURE ITEMS

7.1 – Major and offsite works 2
7.1.1 - Spine Road 3
7.1.2 - OK Centre Road West 5
7.1.3 – Reserved Section 7
7.1.4 – 10080 Chase Road access 8
(Eastern Access) 8
7.1.5 – Permanent Emergency access 10
(Eastern Access) 10
7.1.6 – Glenmore Residential access 12
7.1.7 - Eastern storm route 15
7.1.8 – Southern storm route 17
7.2 – Concept servicing plan 19
7.2.1 – Water servicing 20
7.2.2 – Sanitary servicing 21
7.2.3 – Storm servicing 22

7.1 – MAJOR AND OFFSITE WORKS

GENERAL POLICY

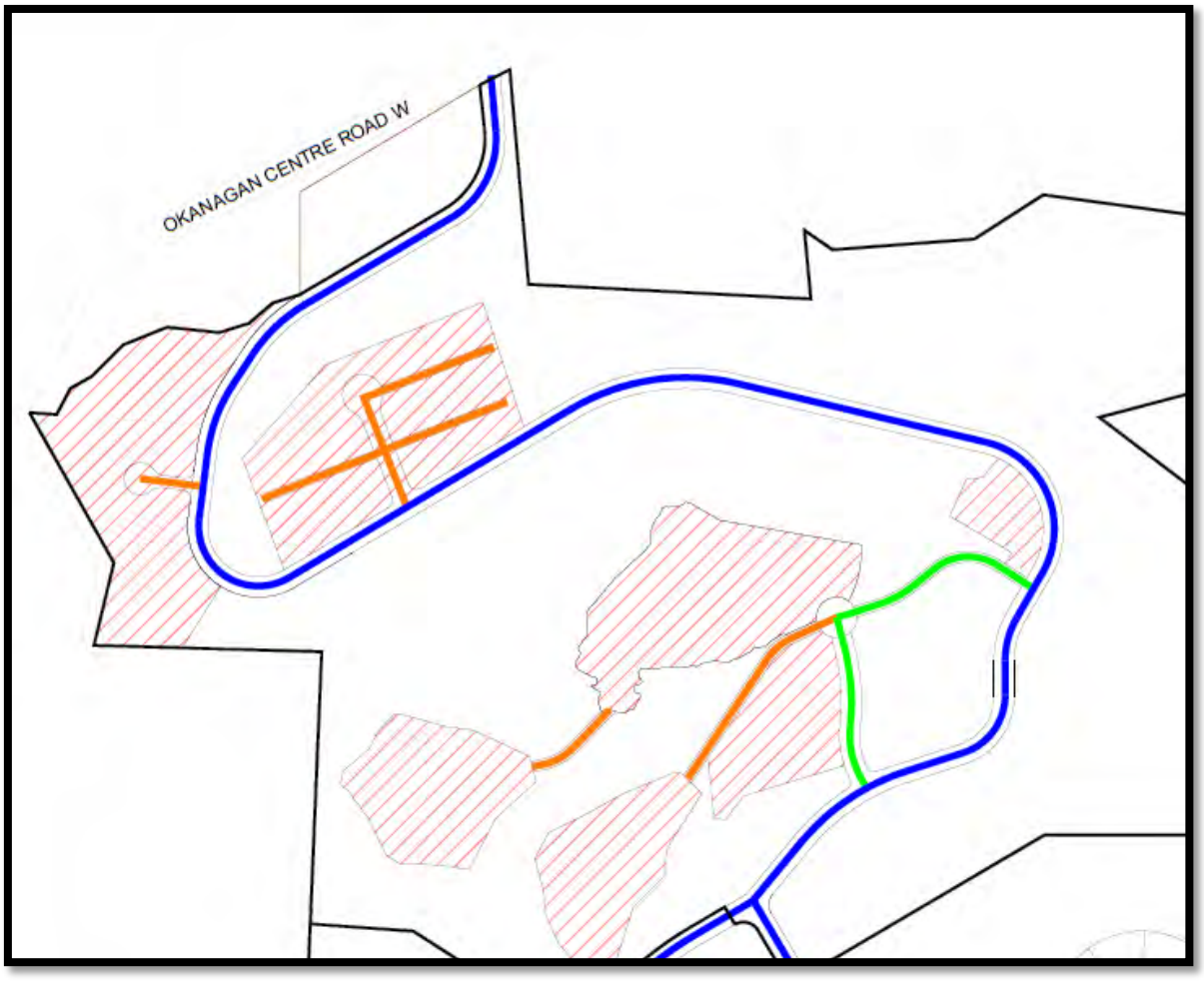
A. The Proposed Development requires several necessary major pieces of infrastructure ("Major Works")which will integrate with the District's existing infrastructure.
B. If the obligation to construct Major Works is triggered by development of a Phase in the Proposed Development, completion of these Works will be written as a condition in the PLR for the applicable Subdivision.
C. Construction of these Major Works may happen concurrently with the construction of development within Phases.
D. The Developer MAY complete the Major Works described in this schedule at any time prior to them being required.
E. Concept designs are shown throughout; detailed designs will be completed in accordance with the Servicing Bylaw supplied in Schedule 6 except for the noted attributes in the unique specifications / variances section below or varied by Schedule 8.
F. Any deviation from the specifications shown in this Agreement would require the mutual agreement of the Developer and the District Engineer.

7.1.1 - SPINE ROAD

GENERAL CRITERIA

1. The southern access road or “Spine Road” is the road connection between the upper Phases of the Proposed Development down the southern slope of the property to Okanagan Centre Road West (shown as a blue line below).

OVERVIEW IMAGE



UNIQUE SPECIFICATIONS / VARIANCES

HIGHWAYS AND WALKWAYS

Cross section:

The applicable cross section is the "Lakestone Collector Road x-sec" defined in **Schedule 8.2 "Road Cross Sections"**.

Intersections:

Due to hillside constraints, all intersections will be standard four way or three-way intersections (not roundabouts).

Landscaping

Affecting: Schedule H.1.5, H.5.2(b), H.5.2(d), H.5.6 and H.6 of the Servicing Bylaw

The spine road is expected to be built largely out of rocky terrain where space will be limited for street trees, and the rocky ground is not conducive to trees surviving.

The Developer will be required to plant street trees only in areas where soil conditions are conducive to the survival of trees and where there is at least 2.5m of width between retaining walls and the road curb, and at a distance of 5m of utility lines. When planting trees is possible pursuant to the above, street trees will be planted at a minimum of 10 meters and a maximum of 15 meters from each other. No automated irrigation lines will be required to be installed.

DRAWINGS

Drawing number. Drawing name

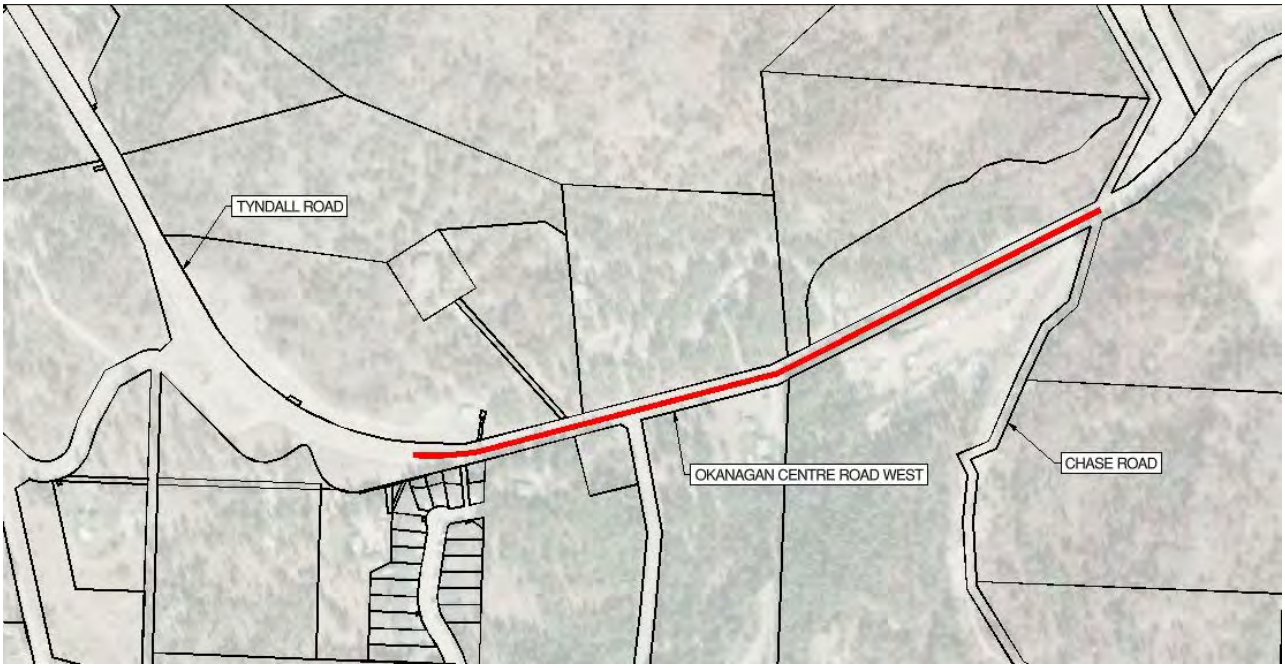
- 07.01.01 - Spine Plan View
- 07.01.02 - Intersection - Southern Access & OKCRW
- 07.01.03 - Intersection Beacon Hill Spine Road
- 07.01.04 - Spine Road - Profile View
- 07.01.05 - Spine Road - Walls and rock cuts – Highlands South

7.1.2 - OK CENTRE ROAD WEST

GENERAL CRITERIA

1. OK Centre Road West upgrades are a DCC project and will be built to the cross section shown in Schedule 8.2 (Okanagan Centre Road West – Typical Section). Components of the upgraded road that intersect with roads the Developer is responsible for (Spine Road to Highlands, and Chase Road East to the Glenmore Residential phase) are shown in the referenced appendix drawings.
2. The intersection at OK Centre Road and the Spine Road is to be sign controlled. This is in agreement with the direction from the District consultant, Align Engineering and is designed to accommodate the traffic loads.
3. The Intersection at OK Centre Road and Chase Road East (pending any renaming) is to be sign controlled. This is in agreement with the direction from the District consultant, Align and is designed to accommodate the traffic loads.

OVERVIEW IMAGE



UNIQUE SPECIFICATIONS / VARIANCES

HIGHWAYS AND WALKWAYS

OK Center Road and Southern access / Spine Road intersection.

Per Align Engineering report, though not likely, there may be the need for a left-hand turning lane from OK Center Road eastbound into the Spine Road of the Proposed Development. Both options (with and without the turning lane) are shown in the attachments. The choice of options is the District's, and any additional cost to build the turning lane will be part of the DCC refunded cost.

STORM DRAINAGE

The storm drainage flows under this road are described in their own sub section (7.1.8)

DRAWINGS

Drawing number. Drawing name

- 07.02.01 - OKCRW Alignment
- 07.02.02 – Chase Road & OKCRW Intersection Overview
- 07.02.03 - Intersection - Spine and OKCRW

7.1.3 – RESERVED SECTION

This section is intentionally left blank

7.1.4 – 10080 CHASE ROAD ACCESS

(EASTERN ACCESS)

GENERAL CRITERIA

1. One of the permanent road connections identified in the 2022 District of Lake Country Mobility Improvement Program is a proposed minor collector street linking Beacon Hill Drive to Chase Road, traversing the parcel located at 10080 Chase Road. The construction of this connection will be a condition of any future redevelopment of that parcel.
2. Completion of this road would provide an additional access point for the Proposed Development. However, as 10080 Chase Road is privately owned and not under the control of the Developer, this road connection shall be considered a beneficial future option only, and its construction is not an explicit requirement of the Proposed Development.

OVERVIEW IMAGE



UNIQUE SPECIFICATIONS / VARIANCES

No unique specification or variances are applicable to this item.

DRAWINGS

No detailed drawings are applicable to this item.

The rest of this page is intentionally left blank

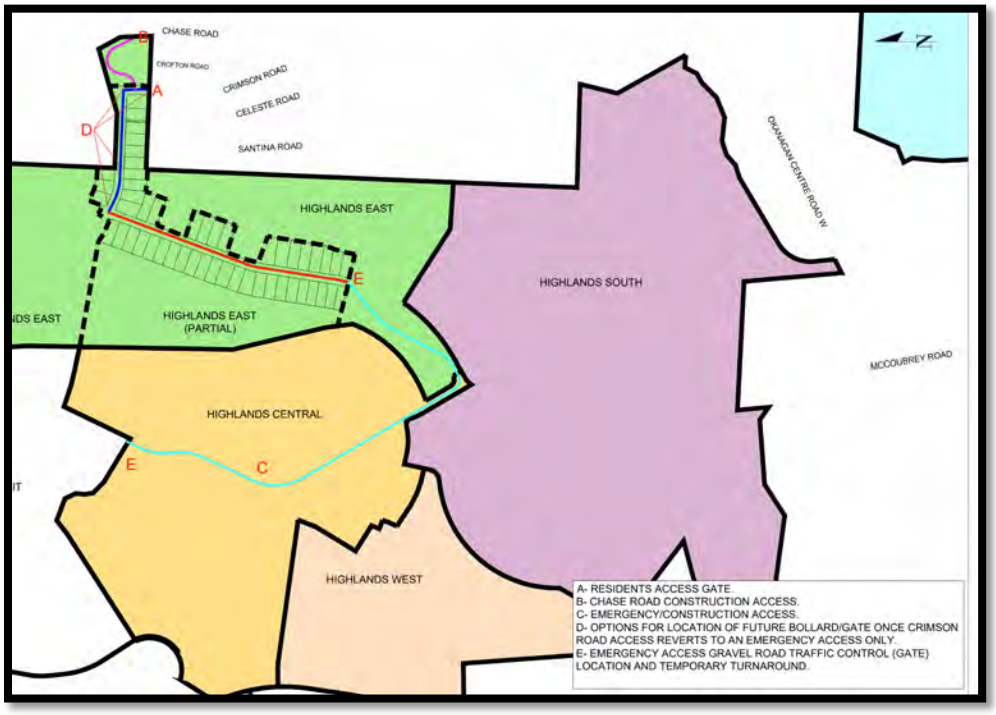
7.1.5 – PERMANENT EMERGENCY ACCESS

(EASTERN ACCESS)

GENERAL CRITERIA

1. The 2012 Masterplan gives the Proposed Development the right and obligation to construct an emergency access to Sage Glenn via the northwest corner of that subdivision (Santina Park). This connection currently exists.
2. Road access will be constructed connecting the Proposed Development to Crimson Road as part of the temporary access described in Section 5.2. Once complete the Lakestone Emergency Access Road connection to Sage Glenn via Santina Park will be phased out.
3. Once a second full road access connection is made (Section 7.1.1 or Section 7.1.4), the temporary access as described in Section 5.2 will be blocked off with a gate or bollard. This access location will then be assigned as emergency access, creating a second emergency egress option.
4. Road construction must be completed in a way that provides adequate access for emergency response and minimizes disturbance and delays to the public and District operational staff. The Developer must ensure that its contractors follow the Servicing Bylaw and all applicable Council policies.

OVERVIEW IMAGE



10/22

UNIQUE SPECIFICATIONS / VARIANCES

No unique specification or variances are applicable to this item.

DRAWINGS

Drawing number. Drawing name

- 05.03A.01 - Roads Phasing – Highlands East (Partial)

The rest of this page is intentionally left blank

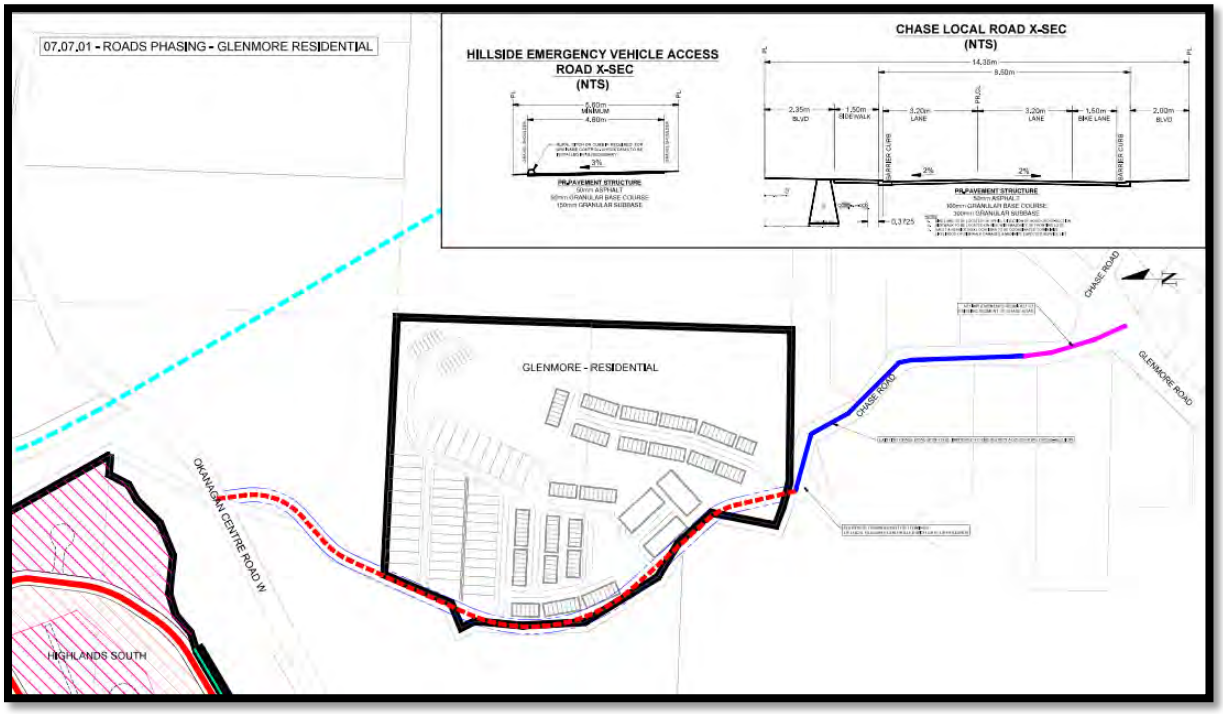
7.1.6 – GLENMORE RESIDENTIAL ACCESS

GENERAL CRITERIA

1. Chase Road (which may be renamed in the future) will connect OK Centre Road West to the Glenmore Residential Phase and must be upgraded to provide access to this phase.
2. Completion of these works is a prerequisite to subdivision of the Glenmore Residential phase, but also will benefit other land owners as well as be an improvement to the overall District transportation network.
3. The work itself could be conducted and paid for by the Developer (and other benefiting parcels would owe latecomers), neighbouring parcel owners (in which case the Developer would owe latecomers), the District (in which case the Developer would owe latecomers or DCCs), or some combination of contributors.
4. The "Chase Local Road X-Section" (Schedule 8.2) upgrade will extend from OK Centre Road to the southern edge of the property boundary of Glenmore Residential at the current local road cul-de-sac (dashed red line).
5. Chase Road from Glenmore Road to the southern boundary of Glenmore Residential will be upgraded to Hillside Emergency Vehicle Access Road standards as shown in Appendix 07.07.01 – Roads Phasing – Glenmore Residential (solid blue).

The rest of this page is intentionally left blank

OVERVIEW IMAGE



Appendix 07.07.01 Roads Phasing – Glenmore Residential

UNIQUE SPECIFICATIONS / VARIANCES

HIGHWAYS AND WALKWAYS

1. Lakestone Local Road cross section (Sched. 8.2) will be applicable from OK Centre Road up to the entrance of this Phase.
2. The Developer is required to provide an emergency egress (with gate) road connection to the existing Chase Road.
3. The Developer is required to improve the existing Chase Road from the emergency access road to the 5474 Chase Road property driveway to the south.

DRAWINGS

Drawing number. Drawing name

- 07.07.01 Roads Phasing - Glenmore Residential

- 07.07.02 - Chase Road ROW - Existing and Proposed
- 07.02.02 - Chase OKCRW Intersection Overview

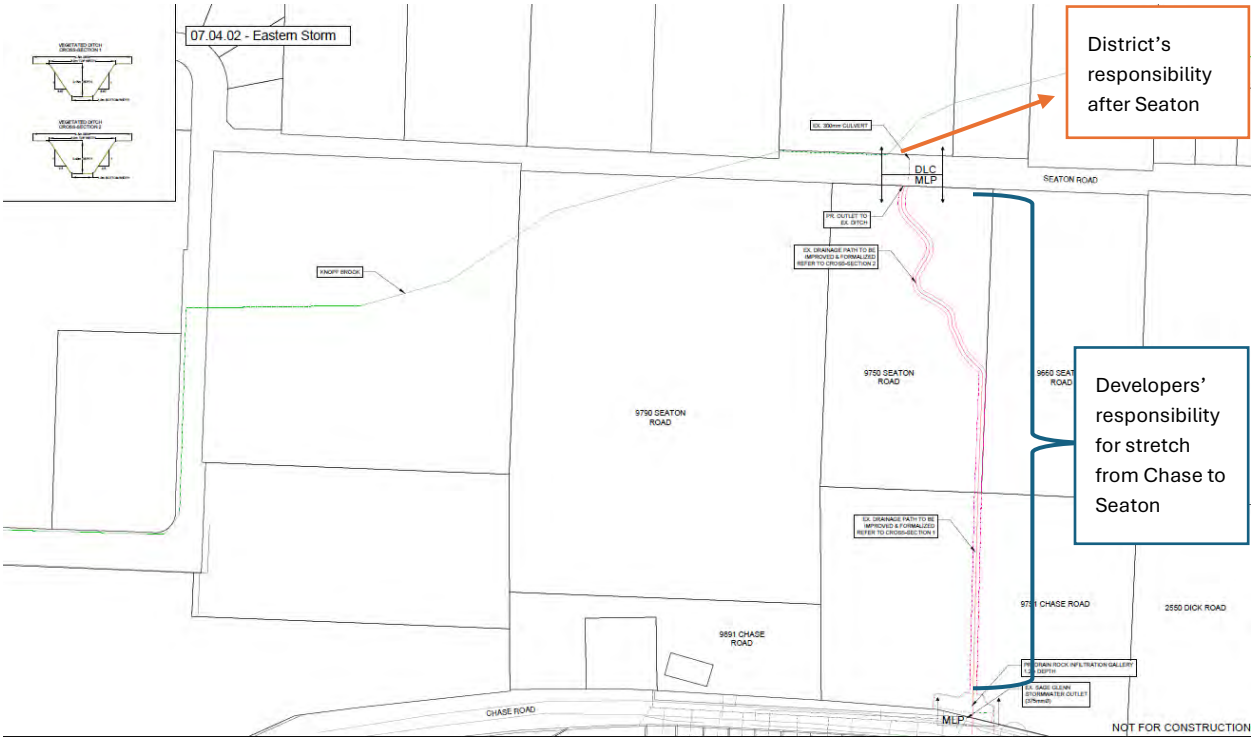
The rest of this page is intentionally left blank

7.1.7 - EASTERN STORM ROUTE

GENERAL CRITERIA

1. Stormwater runoff from the Highlands Central and Highlands East Phases will be directed east to the Sage Glenn subdivision. Water will convey through the Sage Glenn storm system and daylight at Chase Road via existing piping.
2. The District will formalize their access and rights to the existing flow path of water through the two private parcels from Chase Road to Seaton Road.
3. The Developer will improve the existing flow path of water (generally speaking, deepening) to channel flow from Chase Road to Seaton Road. The Developer will also create opportunities for infiltration.

OVERVIEW IMAGE



UNIQUE SPECIFICATIONS / VARIANCES

M – STORM DRAINAGE

The solutions described in this subsection and the servicing brief (Appendix 07.04.01 – Eastern Storm routing brief) is accepted as the pre-design step of the approval procedure of the Servicing Bylaw as related to storm water requirements. Associated detailed design drawing will still need to be submitted by the Developer for the District's review to assure the construction plans represent the pre-design concept described here.

The overland flow route will be built to accommodate a flow rate of 1.5L/second per hectare which is derived from the Urban Systems prescribed Unit Runoff rate ("URR").

In the current undeveloped condition, most of the storm water is infiltrating. Storm water flowing from Highlands Central and Highlands East will be infiltrated into the ground as much as is practical to mimic the predevelopment condition. This will be done with the use of perforated storm water pipes and drywells in multiple locations that are shown to be amenable to infiltration based on geotechnical investigations.

The outlet from the Proposed Development will be into the existing Chase Road storm system either through new pipes directly into it or via pipes in the existing Sage Glenn subdivision.

The Developer will be further responsible for constructing an overland flow route to convey flows from the Chase Road outlet to Seaton Road per Table 2.4.1. (Schedule 2, p. 9,10). The overland flow route will incorporate ditches or swales along with infiltration and outlet/flow control protection as necessary to minimize downstream flows and manage erosion. This is the limit of the Developer's offsite obligations for storm water.

DRAWINGS

Drawing number. Drawing name

- 07.04.01 Eastern Storm Routing Brief
- 07.04.02 – Eastern Storm Routing and Swale Cross Section

7.1.8 – SOUTHERN STORM ROUTE

GENERAL CRITERIA

1. Topographical restrictions with specific highpoints dictate that the storm flows from the Highlands South phase will, in all likelihood, be routed with the southern access road (Spine Road) to OK Centre Road. Storm water may be directed either west on OK Centre Road to existing infrastructure or alternatively storm water may be directed east on OK Centre Road to connect with future District planned stormwater system. Stormwater system design will be in alignment with the Servicing Bylaw.

OVERVIEW IMAGE



Appendix 07.05.01 Southern Storm Overview

UNIQUE SPECIFICATIONS / VARIANCES

STORM DRAINAGE

Direction of flows

The future Spine Road and its storm piping will meet OK Centre Road West at its high point, allowing storm water to gravity flow east or west. The District and the Developer agree that both directions are acceptable provided that the downstream infrastructure can accommodate storm water flows to either Middle Vernon Creek (east) or Okanagan Lake (west).

The District is working on stormwater upgrades of known existing downstream deficiencies in both directions. The expectation is that the Developer will connect into one of these upgraded systems. This work is expected to be paid for via DCC contributions. Expected flows into the storm network are based on the Districts consultant Urban Systems report Titled “TECHNICAL MEMORANDUM - LAKESTONE AREA STORMWATER SERVICING PLAN dated: Dec 16, 2024.

DRAWINGS

Drawing number. Drawing name

- 07.05.01 - Southern Storm – Overview

7.2 – CONCEPT SERVICING PLAN

GENERAL POLICY

A. The Proposed Development consists of onsite servicing. The concept design for water, sanitary and storm services are described in this section.

The rest of this page is intentionally left blank

7.2.1 – WATER SERVICING

GENERAL POLICY

1. The Developer constructed a reservoir in the Summit Phase that will ultimately be interconnected to the Chase Road and Okanagan Centre Road West water networks and will service Highlands Central, Highlands South, and Highlands East. This results in sufficient water servicing for a total anticipated 229 single family residences and 329 multifamily residences.
2. All water services constructed on the Lands will be constructed pursuant to the Servicing Bylaw.



Appendix 07.06.01 - Water Overview

7.2.2 – SANITARY SERVICING

GENERAL POLICY

1. The District will receive sanitary from the Proposed Development to the east, anticipated to be 213 single family residences and 62 multifamily residences.
2. The District will receive sanitary from the Proposed Development to the south, anticipated to be 59 single family residences and 536 multifamily residences.
3. All offsite Works and Services related to sanitary services are not at the Developers expense other than what is stated in this Agreement. All onsite sanitary flows have been calculated in accordance with Schedule K of the frozen Servicing Bylaw.

SANITARY SERVICE ROUTING OVERVIEW



Appendix 07.06.02 – Sanitary - Overview

7.2.3 – STORM SERVICING

GENERAL POLICY

4. The District will receive storm water to the east in a manner described in Section 7.1.7
5. The District will receive storm water to the south in a manner described in Section 7.1.8

STORM WATER ROUTING OVERVIEW



Appendix 07.05.01 Southern Storm - Overview

SCHEDULE 8
LAKESTONE SPECIFIC DESIGN STANDARDS

GENERAL POLICY

1. This section provides standards specific to the Proposed Development which will supersede those standards laid out in the Servicing Bylaw and Zoning Bylaw. In other words, Works and Services built to the variance standards set out in this Schedule will, notwithstanding the provisions of the Servicing Bylaw and Zoning Bylaw, be judged by the District to be Acceptable, subject to the requirements of this Agreement.
2. The discretion that currently exists in the Servicing Bylaw in Schedule 6 for the District Engineer to approve alternative design standards is embedded into this Agreement.

LIST OF LAKESTONE SPECIFIC DESIGN STANDARDS

8.1 – Variances From Bylaws 2
8.2 - Road Cross Sections 4
8.3 - Street Lighting Standards 7
8.4 - Retaining Walls 8
8.5 - Rock Cut Catchment 11

8.1 – Variances From Bylaws

GENERAL POLICY

1. The following variances will be approved as part of this Agreement and do not need to be re-applied for during the duration of this Agreement unless this Agreement expressly contemplates otherwise.
2. Any lengths or height beyond the numbers below would require a new variance to be applied for and obtained in the ordinary process and procedure of applicable bylaws.

LIST OF VARIANCES

	Highlands (partial)	Highlands East	Highlands Central	Highlands West	Highlands South	Glenmore Residential
Cul-de-sac (no emergency egress)[1]		530m		225m	450m	350m
Cul -de-sac (with emergency egress at terminus)[1]	975m		2700m			650m
Retaining wall height (Subdivision related)[3]	10.3m	10.3m	10.3m	10.3m	15m	
Retaining wall height (Private lot owners)	2m					
Design speed (Schedule Q)	30kph standards contained in Servicing Bylaw Schedule Q will be the default road parameters to meet unless otherwise stated in Schedule 7.					
Maximum depth of cover for sanitary (Schedule K) [2]	4.5m	4.5m	7m	7m	4.5m	4.5m
Maximum depth of cover for Storm Water [2]	4.5	4.5m	7m	7m	4.5m	4.5m
Maximum grade at cul-de-sac (entry downhill, entry uphill, and bulbs)	10%.					
Street tree requirements (Schedule H)	The Developer will ensure that a minimum of one tree will be planted in one corner of each lot that has a fronting sidewalk, and that it will be in a position that will allow for that tree to provide shade to pedestrians. This will replace the requirement for boulevard street trees.					

(1) If the Servicing Bylaw is amended to extend the minimum cul-de-sac lengths, then the cul-de-sac lengths shall be the greater of the current bylaw values, the amended bylaw values, and the values outlined in the table above.

(2) For sanitary sewer installations at depths between 4.5 m and 7.0 m, the District Engineer, in their sole discretion, may require additional measures to mitigate operational risks, including, but not limited to the following:

a. **Manhole Protection** – All manhole barrels shall be lined with a protective coating or HDPE liner to resist H_2S-induced corrosion.

b. **Bedding and Compaction** – Provide granular bedding and submit compaction test reports to minimize structural load on the pipe.

c. **Pipe Material and Joints** – Select pipe material and joint type to provide additional protection against buckling and deflection under deep burial conditions.
d. **Service Connections** – Service connections shall enter through manholes or connect to shallower parallel service lines that are connected into a common manhole, rather than individually connecting directly to the deep main sewer line.
e. **Geotechnical Assessment** – Submit geotechnical reports confirming soil conditions and providing recommendations for safe excavation and any required remediation works.

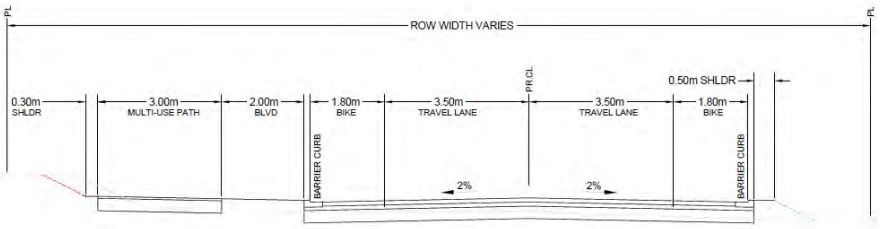
(3) Refer to Section 8.4

DRAWINGS:

Drawing Number. Drawing Name

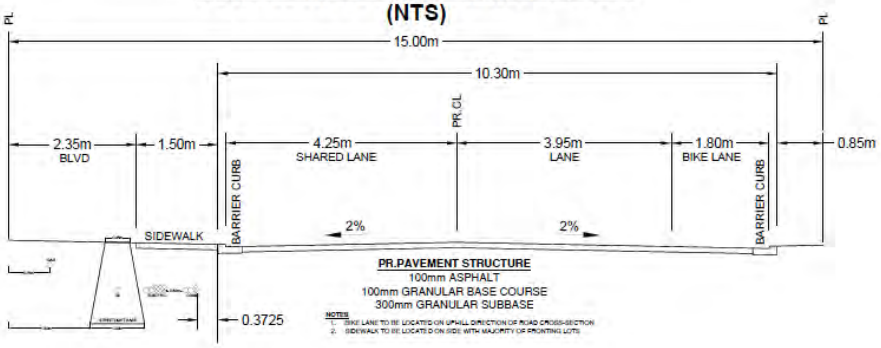
- 07.06.02 Sanitary Overview (Areas where sanitary depth requires variance labeled with bubbles and numbers)

8.2 - Road Cross Sections

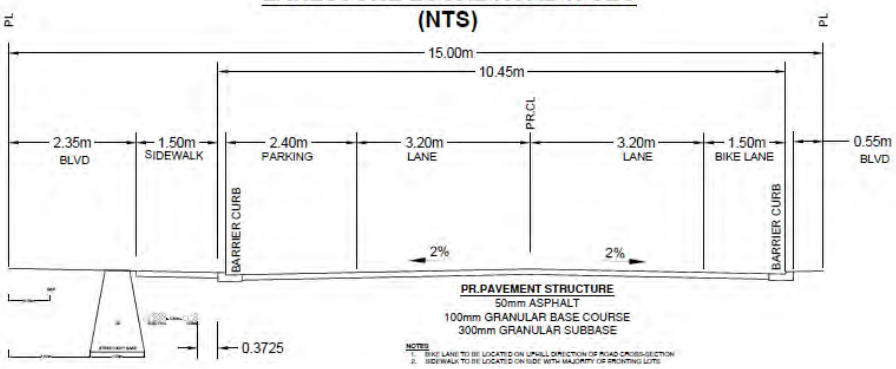


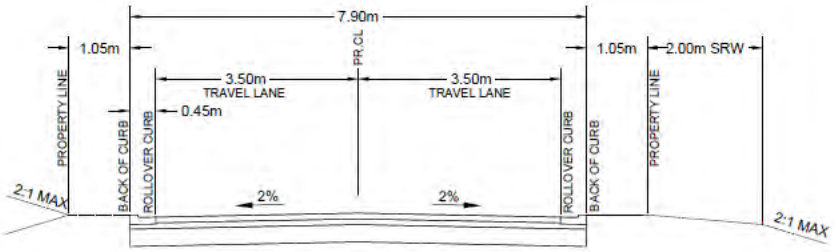
OKANAGAN CENTRE ROAD WEST TYPICAL SECTION
LAKE COUNTRY BUSINESS PARK
(NTS)

LAKESTONE COLLECTOR ROAD X-SEC
(NTS)

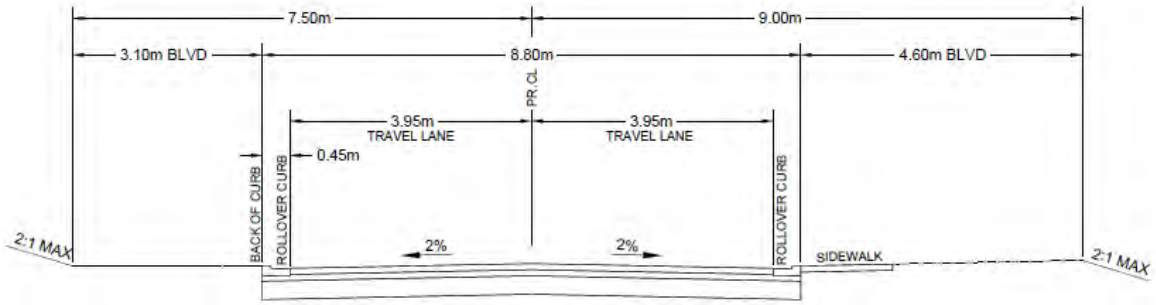


LAKESTONE LOCAL ROAD X-SEC
(NTS)



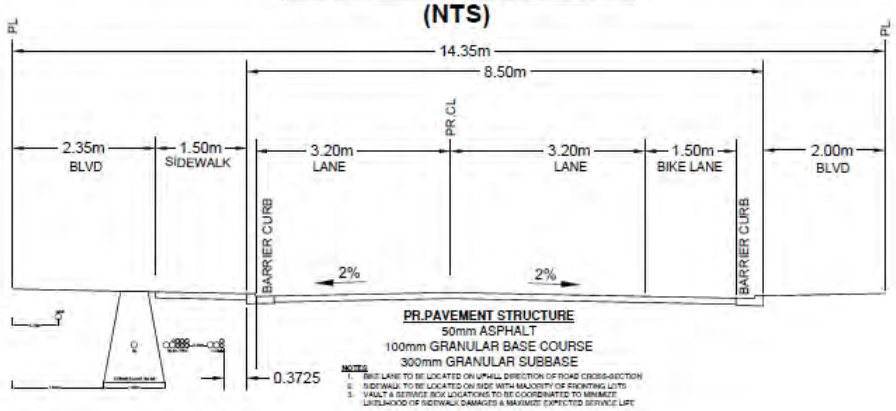


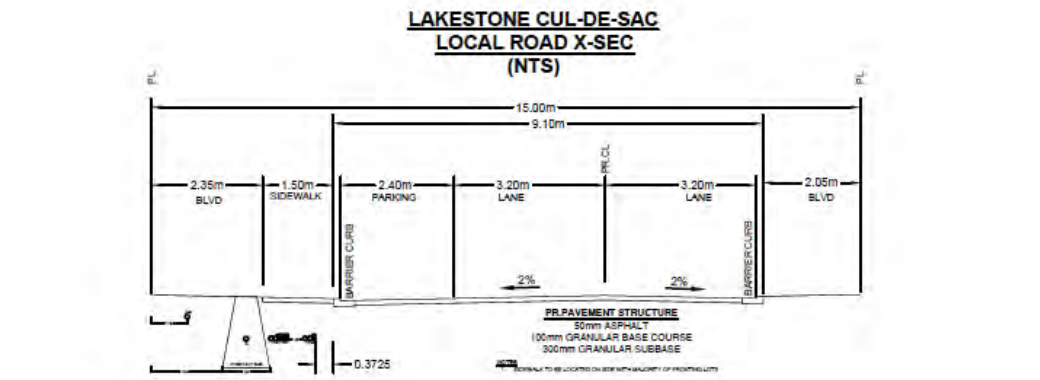
CROFTON RD. TYPICAL ROAD CROSS-SECTION
(NTS)



CRIMSON RD. TYPICAL ROAD CROSS-SECTION
(NTS)

CHASE LOCAL ROAD X-SEC
(NTS)





The District Engineer may approve revision to the road cross-sections if the Developer can show that doing so would assist in the preservation of the natural environment. Final approval of a deviation from the plans shown here would be at the sole discretion of the District Engineer.

DRAWINGS:

Drawing Number. Drawing Name

- 08.01.01 – Roads Overview

8.3 - Street Lighting Standards

Lumenpulse

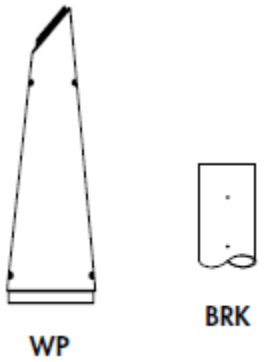
PUR100-120-CSL-M80-40K-CRI80-3-BKTX-DIM-SMG



Arm - PU4-S1E-BKTX



Pole - PPL-S-5-STL-R-24-M-BXTX-WP-BRK-AB



MOBB8-R-12-FR-RO-30K-CRI80-5-BKTX-NO-AB-SPL (021274)

8.4 - Retaining Walls

GENERAL POLICY

1. The Developer will be permitted to build retaining walls up to the heights outlined in the table of Section 8.1 without the need for a Development Variance Permit.
2. The "Subdivision related" walls (row 3 in the table in 8.1) are needed for the development of the various subdivisions of Lakestone. If the Developer sells off a parcel of land within Lakestone to another developer, that developer will be allowed to construct walls in the locations and at the listed heights per the attached appendixes without the need for a Development Variance Permit.
3. Private lot owners in Lakestone may build engineered walls up to 2m without the need for a Development Variance Permit.
4. The anticipated location of future public walls in noted in Appendix 04.04.01, 08.04.02 and 07.01.05. This is provided for District planning purposes only as exact wall locations and configurations will be determined at the detailed engineering design stage.
5. Engineering required for all walls over 1.22 m in height, and not for walls under that height.

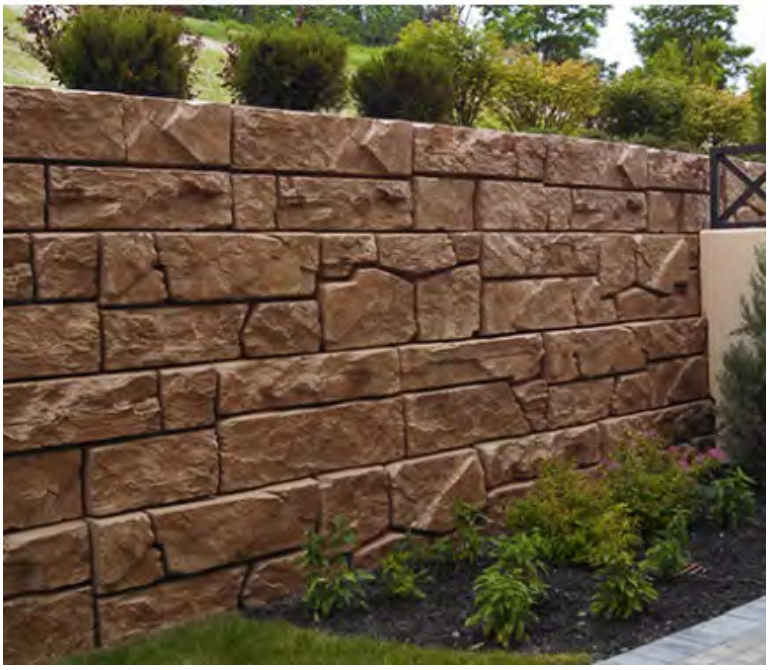
Allowable engineered materials (Developer or private land owner):
A. Magnum Stone (Barkman)



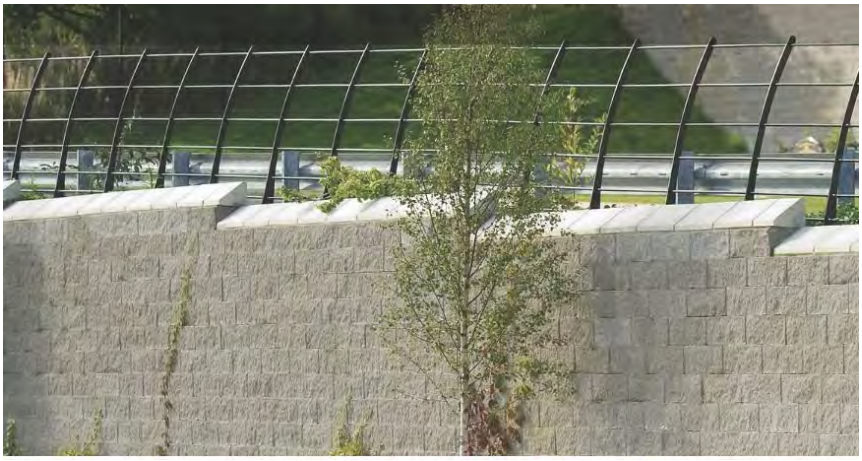
B. Keystone (Barman)



C. Verti Block



D. Maccaferri



DRAWINGS

Drawing number. Drawing name

- 08.04.01 – Wall and Rock Cuts – Highlands Central
- 08.04.02 - Wall and Rock Cuts – Highlands East
- 08.04.03 - Highlands South - Walls – Private
- 08.04.04 - Highlands South - Walls - Private

8.5 - Rock Cut Catchment

GENERAL POLICY

1. The Developer will be permitted to create cut slopes up to 10 meters high without the need for a Development Variance Permit.
2. Developer may extend its right to build up to 10-meter rock cuts to a sub-developer provided the limitations of the extent of that right are put in writing addressed to the District.
3. Any rock cut slopes must include a catchment ditch per the table below:

ROCKFALL CATCHMENT DITCH (VALLEY GEOTECHNICAL)

ROCK CUT SLOPE HEIGHT	CATCHMENT WIDTH	CATCHMENT DEPTH
(m)	(m)	(m)
1.5 - 3.0	1	0.25
3.0 - 4.0	2	0.5
4.0 - 6.0	2.5	0.75
6.0 - 8.0	3	0.75
8.0 - 10.0	4	1
> 10	4[1]	1

SCHEDULE 9
AMENITIES AND PARKS

GENERAL POLICY

1. The Lakestone Masterplan section 2H outlined the obligations and intentions of the parks and trails to be built as part of the Proposed Development. The interpretation of these obligations has evolved over the course of the project, though the delivered parks to date have been substantially in line with such Masterplan and have been accepted by the District.
2. The District separates its park development planning and developer contributions into three components. Future parks to be provided by the Developer are broken down in the same way in this Schedule.
    a. Neighborhood parks
    b. Community parks
    c. Park Improvements.

AMENITY AND PARK ITEMS

9.1 - Land dedication....2
9.2 – Neighbourhood parks....4
9.3 – Community parks....5
9.4 – Park Improvements....6
9.5 - Cost of parks and DCCs....10
9.6 – Past parks....13
9.7 - Private amenities....14

9.1 - LAND DEDICATION

GENERAL POLICY

The plan for the Proposed Development attempts to cluster development to create a community that will incorporate substantial open space in the form of existing forest conservation, parks, trails and community amenities. The Lakestone Masterplan committed to dedicating 52% of the Proposed Development site's 201.23 HA to the District to be public open space. This PDA excludes the 3.3 HA industrial site that was part of the Masterplan, so the total area is now 197.9 HA, 52% of which is 102.9HA.

LAND DEDICATION

The following parcels were dedication to the District in November 2025 and will be added to the Summit's dedication number in the chart below once the additional dedication to be part of that subdivision is complete.

PID 012-274-364 - 4.96 Acres

PID 012-274-305 – 2.8 Acres

PID-012-274-283– 1.195 Acres

PID – 012-274-267 – 0.06 Acres

The land dedication for the Tyndall Lot, current PID 028-363-965, is still in process as of the ratification of the Agreement and is counted in the table below, but the areas are to be confirmed after transfer is completed. The parcel to be transferred are listed below:

PID 028-363-965 – 8.57 Acres/3.6 HA (the lot line adjustment from 11.04 Acres less 2.47 Acres)

LAND DEDICATION TRACKING CHART

The chart below tracks the lands dedicated in previous phases under the Masterplan's land dedication obligation. At the conclusion of each Subdivision, this chart will be updated with the amount of land dedicated as part of that Subdivision. The District shall not approve a Subdivision where the remaining land to be dedicated exceeds 100% of the remaining land required to be dedicated. In other words, "D" must not exceed "C".

	A	B	C = (Prior C) - A	D = (Prior D) - B	E = D / C
Subdivision	Phase size	Amount of which is dedicated	Land remaining	Land remaining to dedicate	% of remaining land to dedicate
Start			197.9	102.9	52%
School site / Community park	8.9	8.9	189.0	94.0	50%
Waterside	13.5	1.0	175.5	93.0	53%
Benchlands	28.0	20.8	147.6	72.2	49%
Highlands *	18.0	13.72	129.6	58.48	45%
Tyndall lot	4.5	3.6	125.1	54.88	44%
Summit**					
Highlands East (Partial)					
Highlands East					
Highlands Central					
Highlands South					
Highlands West					
Glenmore Residential					

*Approximate amounts, to be confirmed. ** To be finalized at subdivision registration

Note: Area's noted above are pulled from the District's public GIS system and are substantially accurate. The parties to this agreement agree to deem the District's GIS map viewer information to be accurate and to be relied upon for this calculation.

9.2 – NEIGHBOURHOOD PARKS

GENERAL POLICY

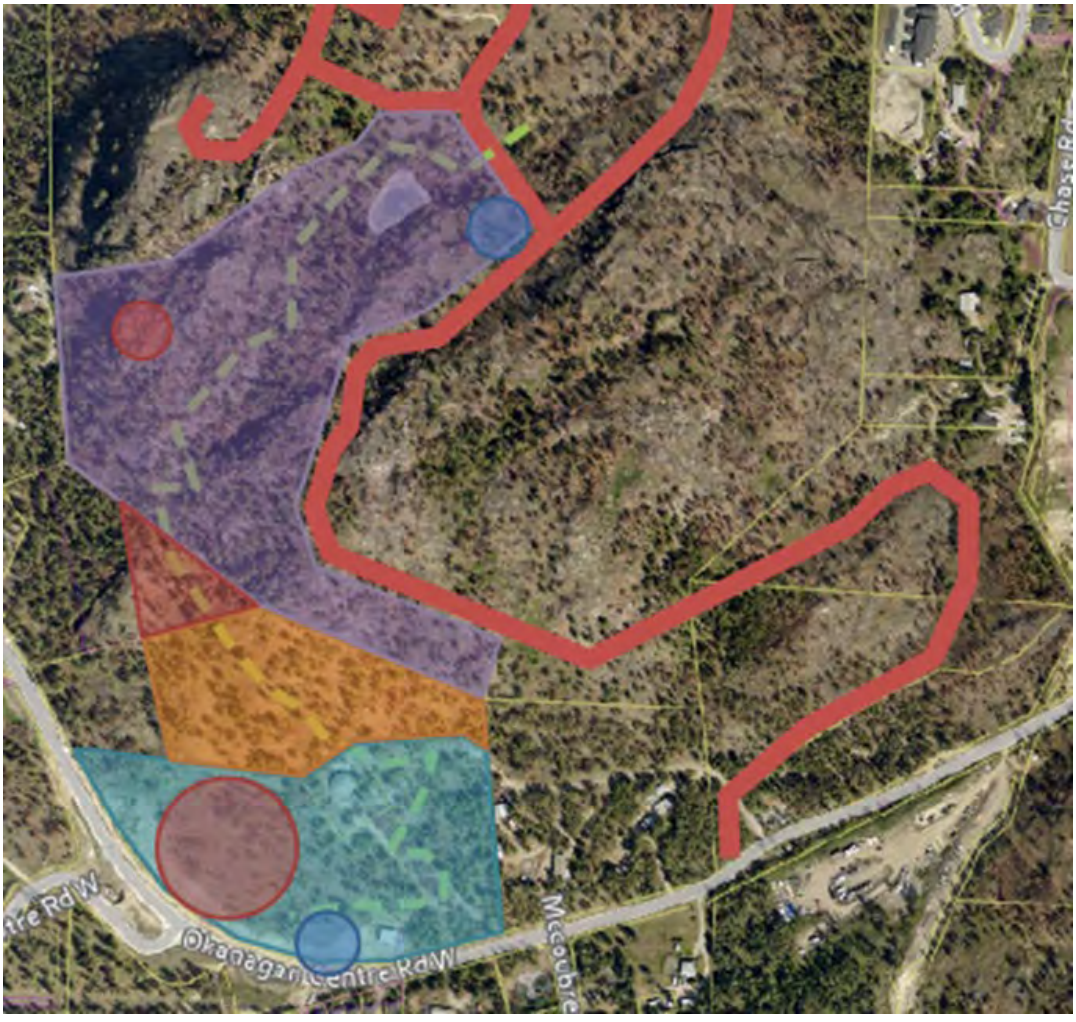
1. Local Government Act policy requires the dedication of land (up to 5% of a subdivision) or cash in leu set at the rate prescribed in the DCC bylaw.
2. All of the future park land to be dedicated will be considered Neighborhood park except for those areas explicitly outlined in Schedule 9.3.
3. The planned land dedication will far exceed the 5% required by statute, and by meeting the requirements of Schedule 9.1, the Developer will have met the requirements of the Neighbourhood park obligations.

The remainder of this page is left intentionally blank

9.3 – COMMUNITY PARKS

GENERAL POLICY

1. Community parks are sometimes referred to as Destination Parks
2. A community park is to be located in Highlands Central (see below image to include dedication of purple and orange shaded areas).
3. Any of the land dedicated in this area will be considered as a contribution to the Community park obligations



9.4 – PARK IMPROVEMENTS

GENERAL POLICY

1. The Developer also intends to create concentrated improvements in two specific locations detailed in 9.4.1 and 9.4.2.
2. The Developer intends to improve the rest of the park land dedication with walking trails and pocket parks.

9.4.1 - HIGHLANDS COMMUNITY PARK

The amenities expected to be included in this community park are: vehicle parking, washrooms, drinking water fountain and/or bottle filler, pathways for pedestrian and/or bicycle circulation, a children's playground, and viewpoint structures.

TRIGGER

Any development in Highlands Central will trigger the obligations to provide the amenity described above.

9.4.2 – SANTINA PARK

1. The Lakestone Masterplan 2012 noted that park land was to be provided adjacent to the existing Santina Park along with the planned emergency access route to be built through the park.
2. The Developer will contribute the applicable lands to the District that are connected to current Santina Park lands, with the emergency access re-routed as described in section 5.2.
3. The Park is to be in conformity with the District's Parks and Recreation Master Plan 2018 which calls for a play area, bike skills, and a half court.[1]
4. The District and the Developer will collaborate (both financially, land consolidation and design/delivery) on the park when the Developer is ready to develop in the Highlands East Phase.

TRIGGER

Any development in Highlands East will trigger the obligations to provide the amenity described above.

[1] Page 71, section N-4, District of Lake Country 2018 Parks and Recreation Master Plan, Revised December 2019

9.4.3 – TRAILS AND POCKET PARKS

GENERAL POLICY

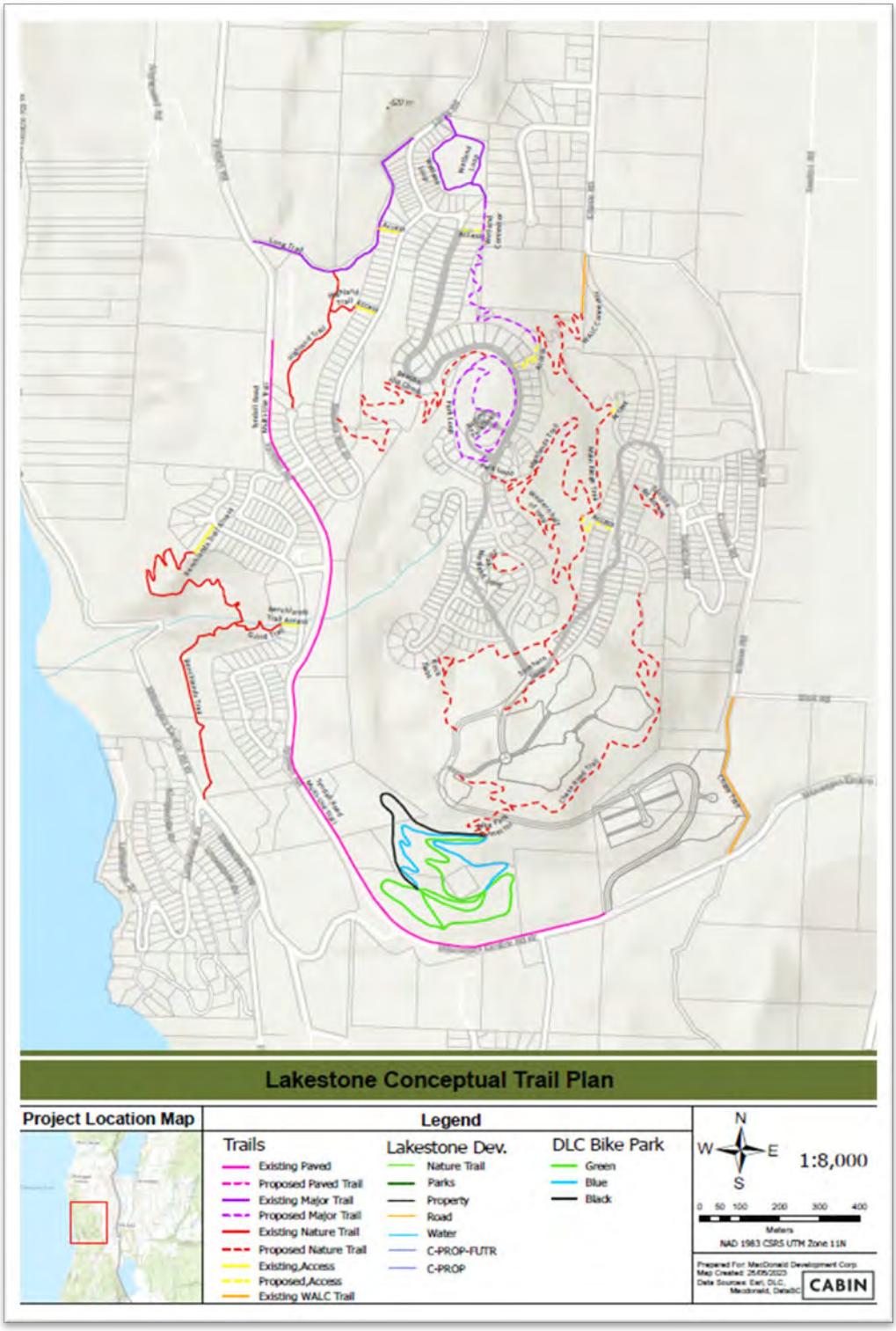
1. The Proposed Development is connected by a network of paths and trails. There will be 7.43 km of trails constructed over the Phases of the Proposed Development (including the Summit Phase).
2. The trails are rated by difficulty level and use. The breakdown of these remaining Trails can be found in the table below along with the Phase that the specified trail must be completed.
3. In locations where the topography permits along the trail system, open spaces will be created for outlooks with park benches or interpretative signage. Within these areas, the emphasis will be on retaining the natural vegetation and maintaining the character of the surrounding lands on which the trail system is built.
4. These park areas will consist of open green spaces where un-programmed activities can occur (e.g., dog walking, tossing a Frisbee, etc.).
5. Where it is possible to provide District access for servicing, waste receptacles will be provided. In locations where this is impractical, signage will be posted requesting that users not leave any waste in these areas.
6. Detailed design of these park spaces will be undertaken as the trail system is developed and built as it would be very difficult to understand the opportunities and challenges presented by each individual location until that time.
7. There are three principal ESA 1 areas where there may be some water at specific times of the year. In building these spaces, the approach will be minimal. The Developer will erect a simple barrier around the sensitive area and provide an interpretive marker or markers to highlight the features of the specific location. A narrow gravel path may also be included, with the primary goal being the retention of the natural features.
8. The park locations can be seen in the plan created by Bench Site Design in Appendix 09.05.01.
9. The agreed-on trial network can be seen in Appendix 09.08.01 – “Lakestone Conceptual Trail Plan 2021 MP” and Appendix 09.08.02 – “Lakestone Conceptual Trail Plan - Trail Difficulty – 2024”.

TRIGGER

When any new Subdivision occurs, the associated trails located within that Subdivision (as noted in the plan at Appendix 09.08.01) will be required to be built.

Trail Name	Status	Difficulty	DLC Type	Use	Phase .]	Length (m)
Benchlands Trail	Completed	Blue	3	Multi-Use	Benchlands	1365
Grind Trail	Completed	Black	3	Hiking	Benchlands	161
Tyndall Road Multi-Use Trail	Completed	Green	1	Multi-Use	Benchlands	1832
Tyndall Road Multi-Use Trail	Completed	Green	1	Multi-Use	Highlands	355
Highland Trail	Completed	Blue	3	Multi-Use	Highlands	414
Highland Trail	Completed	Blue	3	Multi-Use	Highlands	82
Long Trail	Completed	Blue	2	Multi-Use	Highlands	689
Chase Trail	Completed	Blue	3	Multi-Use	Highlands	440
Wetland Loop	Completed	Blue	2	Hiking	Highlands	564
Benchlands Trail Access	Completed	Blue	Access	Hiking	Benchlands	84
Grind Trail Access	Completed	Blue	Access	Hiking	Benchlands	40
Access	Completed	Blue	Access	Hiking	Highlands	53
Access	Completed	Blue	Access	Hiking	Highlands	52
Rock Slabs	Proposed	Black	3	Bike	Highlands West	102
Southern Loop	Proposed	Blue	3	Multi-Use	Highlands South	274
Main Ridge Trail	Proposed	Blue	3	Multi-Use	Highlands East (Partial)	1634
Access	Proposed	Blue	Access	Hiking	Highlands East (Partial)	30
Small Wetland Loop	Proposed	Green	3	Multi-Use	Highlands Central	145
Access	Proposed	Blue	Access	Multi-use	Summit	129
Santina Rd Access	Proposed	Blue	3	Multi-use	Highlands East (Partial)	199
Summit Park Trail	Proposed	Green	2	Multi-Use	Summit	756
Chase Road Loop	Proposed	Green	3	Multi-Use	Highlands East	345
Chase Road Trail	Proposed	Blue	3	Multi-Use	Highlands South	499
Park Loop	Proposed	Blue	3	Multi-Use	Summit	273
Lakestone Downhill	Proposed	Black	3	Multi-Use	Highlands East (Partial)	363
Tyndall Downhill	Proposed	Black	3	Bike	Highlands West	604
Chase Trail Connector	Proposed	Green	3	Multi-Use	Highlands South	119
Rock Slabs	Proposed	Black	3	Bike	Highlands West	102
Lakestone Climb Trail	Proposed	Blue	3	Multi-Use	Highlands East (Partial)	827
Beacon Hill Connector	Proposed	Green	2	Multi-Use	Summit	154
Summit Trail	Proposed	Blue	3	Multi-Use	Highlands Central	325
Summit Trail	Proposed	Black	3	Multi-Use	Highlands Central	559
					Total	**13,570m**

*The trail length does not include paved multi-purpose pathways Totalling 12,800m



Appendix 09.08.01 Lakestone Conceptual Trail Plan 2024

9.5 - COST OF PARKS AND DCCS

GENERAL POLICY

The Developer has and will continue to construct parks and recreation opportunities that are available to the public on the Lands.

PARKS CONTRIBUTIONS

For the purposes of this Schedule, the following terms shall have the following meanings:

"Neighbourhood Parkland Acquisition Contribution" means that portion of the Parks DCC to be devoted to neighbourhood parkland acquisitions, whether by way of cash contributions or land dedication, with such amount being $1,928 per single detached unit in a Subdivision of three lots or less. For Subdivisions creating 3 or more new lots, 5% parkland dedication / cash-in-lieu (as per Section 510 of the Local Government Act) applies for acquisition of neighbourhood parks and the neighbourhood parkland acquisition parks DCC contribution is credited back fully.

"Community Parkland Acquisition Contribution" means that portion of the Parks DCC to be devoted to community parkland acquisitions, whether by way of cash contributions or land dedication, with such amount being $5,784 per single detached unit in a Subdivision.

"Park Development Contribution" means that portion of the Parks DCC to be devoted to neighbourhood parkland and/or community parkland development, whether by way of cash contributions or completion of applicable Work, with such amount being $5,078 per single detached in a Subdivision.

"Parks DCC Contribution" means the Community Parkland Acquisition Contribution, the Neighbourhood Parkland Acquisition Contribution and the Park Development Contribution.

For clarity the dollar value attached to the three components of the park DCC contribution are based on the current DCC bylaw at the time of this Agreement being ratified and are subject to changes to the DCC bylaw during the term of this Agreement.

If the Developer dedicates parkland (whether neighbourhood parkland or community parkland) in accordance with the terms set out in this Agreement, it shall be entitled to the applicable credit for either a Neighbourhood Parkland Acquisition Contribution or a Community Parkland Acquisition Contribution.

If the Developer constructs parks as set out in this Agreement, they are entitled to a Park Development Contribution for those works based on the actual construction costs paid by the Developer.

Works and Services already required for parkland dedication and transfer to the District will not be credited back (ie. utility servicing, rough grading and drainage, danger tree removal, wildfire hazard mitigation, slope or rock fall hazard mitigation, restoration of disturbed lands, fencing to delineate property lines).

CURRENT PARKS DCC CHARGES

	Neighbourhood Parkland Acquisition	Community Parkland Acquisition	Park Development	Total	unit type
Single Detached	$1,928	$5,784	$5,078	$12,790	Lot
Multi family Residential	$1,928	$5,784	$5,078	$12,790	unit

Where excess Parks DCC Contributions, in respect of one or more of the three components of the Parks DCC Contributions, are provided in any given Subdivision, then the Developer shall receive credits (on a dollar-for-dollar basis) in respect of the applicable component and may apply such credits against its obligations for the Subdivision or Subdivisions yet to be built.

If the Developer has unused credits at the end of the Development, the District is not liable to refund the Developer for that over contribution.

The remainder of this page is left intentionally blank

EXAMPLE OF PARKS DCC CALCULATION

Eg. The Subdivision is 50 lots and the underlying value of neighbourhood parkland property being dedicated is $100,000. The Developer builds out a neighbourhood park for a cost of $250,000. No community parkland (aka $0) is dedicated as part of this Subdivision.

	Required Contributions for Subdivision	Contributions provided for Subdivision in the form of land and parkland development	Credits to Future Subdivisions
Neighbourhood Parkland Acquisition Contribution ("NPAC") OR 5% Parkland Dedication / Cash-in-lieu (for neighbourhood park acquisition purposes)	$75,000 value of parkland dedication (based on developable lands valued at $1,500,000)	$100,000 value of parkland dedication	$25,000
Community Parkland Acquisition Contribution ("CPAC")	$5,784 x 50 = $289,200	$289,200 - $0= $289,200	$0
Park Development Contribution ("PDC")	$5,078 x 50 = $253,900	$253,900 - $250,000 (hypothetical cost of park Work) = $3,900	$0
Total cash contribution required:	$543,100 (being $10,862 x 50 lots)	$0 (NPAC) + $289,200 (CPAC) + $3,900 (PDC) = $293,100 (Total Park DCC's owed for this Subdivision after crediting back works and dedication amounts after works completed unless works are completed prior to subdivision)	$25,000 (credit to 5% parkland / cash-in-lieu for future subdivisions)

The value of what is required and contributed is calculated using the Local Government Act method described in 510(6) and BC Regulation 20/86.

9.6 – PAST PARKS

9.6.1 - OKANAGAN CENTRE ROAD COMMUNITY PARKS

The Developer has dedicated to the District 8.9 HA of land over two parcels, PID 028-245-237 and 028-245-130 (one of which was intended for the playing field). The District has now developed part of PID 028-245-130 into a dog park, and PID 028-245-237 into the Lake Country Bike Park. Both parties agree that this change in use is acceptable and replaces the planned playing field.

9.6.2 - WATERSIDE PARK

The Developer has dedicated the waterfront property of the Waterside phase, PID 029-343-640, and has also built the improvements, including pathways to provide public access to Okanagan Lake, a pavilion, a washroom and park benches.

9.6.3 - BENCHLANDS PARK

The Developer has dedicated property in the Benchlands phase, PID 030-263-395, and has also built the improvements, including sports courts (multi-use, pickleball, and tennis), a washroom and a children's playground.

9.6.4 – BENCHLANDS PASSIVE PARK

The Developer has dedicated property along the ravine, PID 030-263-425, and has also built improvements including a grass field and park benches. This park is adjacent to a storm water retention dry pond and his been built in a way to accommodate sledding in the winter when the pond is empty.

9.6.5 - SUMMIT PARK

This park is presently under construction. The construction obligations are set out in PLR#S2020-027. The property will be dedicated to the District and will include a pavilion, a washroom and opportunities to enjoy the view of Okanagan, Kalamalka and Wood lakes.

Completion of this part is estimated to occur in summer 2027.

9.7 - PRIVATE AMENITIES

GENERAL POLICY

Three amenities for the private use of the residents of the Proposed Development were to be constructed and all three have been completed.

1. Lake Club Facility – Pool, beach access, fitness facility, washroom and shower facilities, kayak and water toy storage.



2. Centre Club – Pool, fitness facility, washroom and shower facilities, , meeting space.



3. Marina – Stop and go dock



SCHEDULE 10
SERVICING CAPACITY OWNERSHIP

GENERAL POLICY

1. The Developer has, and will continue to, oversize certain Works and Services constructed and installed in connection with the Proposed Development so that such Works and Services have capacity for the future development within the Proposed Development when it is fully built out. For example, the summit reservoir is being built with enough capacity to service, not just the summit phase (previously approved and under construction and not the subject of this Agreement) (the "Summit Phase"), but the future Highlands Phases of the Proposed Development with potable water. It has not been oversized to accommodate any development other than the Proposed Development.
2. The Developer and the District agree, and the District hereby covenants with the Developer, that even though ownership of certain Works and Services (for instance, the reservoir) constructed by the Developer either has been transferred (pursuant to the Lakestone Master Plan) or will be transferred (pursuant to this Agreement) to the District after completion, one hundred percent (100%) of the capacity of such Works and Services (the "Capacity") will be reserved exclusively for the Proposed Development.
3. An essential part of fulfilling the above is that the District will not issue Building Permits on subdivided parcels for densities above what has been allocated by the Developer. For example, the District may not approve a duplex, triplex, etc. on a single-family lot (which would use more services than a single-family home) if the Developer has allocated that parcel as being a single-family home. Similarly, a multifamily parcel may only have the number of units the Developer allocates to it.
4. If the Developer constructs other Works and Services with Capacity in excess of that required for the Proposed Development when it is fully built out, such the excess Capacity will be recorded in a similar manner.
5. For clarity, at this stage of the planning for the Proposed Development, there is no oversizing planned and so all Capacity of constructed Services will be reserved for the Proposed Development.

01.01 - EXISTING LEGAL OVERVIEW

CHASE ROAD
CROFTON ROAD
CRIMSON ROAD
CELESTE ROAD
SANTINA ROAD
GLENMORE ROAD
OKANAGAN CENTRE ROAD W
MCCOUBREY ROAD
TYNDALL ROAD
BEACON HILL DRIVE

LOT 123 SECTION 9 ODYD DISTRICT PLAN KAP521 TOWNSHIP 20

LOT 110 SECTION 9 ODYD DISTRICT PLAN KAP521 TOWNSHIP 20

LOT 2 SECTION 9 & 10 ODYD DISTRICT PLAN 33960 TOWNSHIP 20

LOT B SECTION 4 & 9 ODYD PLAN 38079 EXCEPT PLAN KAP46432 TOWNSHIP 20

LOT 1 SECTION 4 TOWNSHIP 20 ODYD PLAN KAP46432

LOT 3 SECTION 3 & 4 ODYD PLAN KAP25775 TOWNSHIP 20

LOT 15 SECTIONS 3 & 4 TOWNSHIP 20 ODYD DISTRICT PLAN 25775

LOT 136 SECTIONS 3, 4, 9 TOWNSHIP 20 ODYD DISTRICT PLAN 521 EXCEPT PLAN H10875

LOT 138 SECTIONS 3, 4, 9 TOWNSHIP 20 ODYD DISTRICT PLAN 521

LOT 137 SECTIONS 3, 4, 9 TOWNSHIP 20 ODYD DISTRICT PLAN 521

LOT 4 SECTION 3 & 4 ODYD PLAN 25775 EXCEPT PLAN KAP90965 TOWNSHIP 20

LOT 4 SECTION 4 ODYD PLAN 25775 TOWNSHIP 20

BLOCK B SECTION 3, 4, 9 ODYD DISTRICT PLAN KAP521 EXCEPT PLAN EPP86639

LOT 1 SECTION 4 ODYD PLAN KAP91504 TOWNSHIP 20

LOT B SECTION 4 ODYD PLAN EPP74336 TOWNSHIP 20

REMNANT LOT 85 PLAN KAP521

REMNANT LOT 87 PLAN KAP521

REMNANT LOT 86 PLAN KAP521

LOT 114 SECTION 9 TOWNSHIP 20 ODYD PLAN EPP86639

REMNANT LOT 89 PLAN KAP521

LOT A SECTION 4 & 9 ODYD PLAN EPP72821 TOWNSHIP 20

PHASE 4 & 5.1

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

LANDS ENCOMPASSED BY LAKESTONE PDA

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:3500	

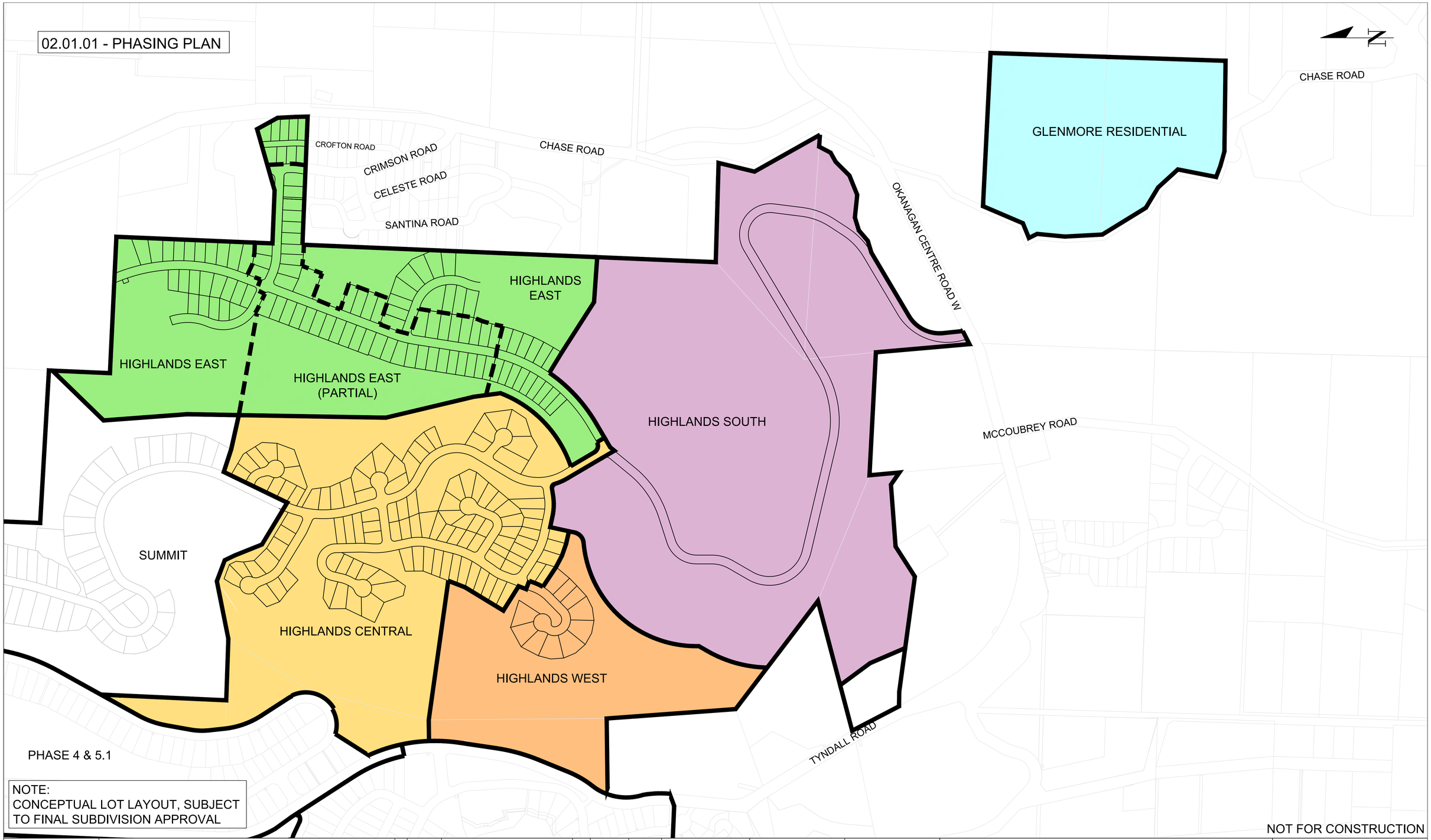
DISTRICT OF LAKE COUNTRY

EXISTING LEGAL OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 01.01	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 1 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\01.01 LEGAL OVERVIEW.dwg

02.01.01 - PHASING PLAN



NOTE:
CONCEPTUAL LOT LAYOUT, SUBJECT TO FINAL SUBDIVISION APPROVAL

NOT FOR CONSTRUCTION

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\02.01 PHASING PLAN.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PHASE BOUNDARY
- PARTIAL PHASE BOUNDARY

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

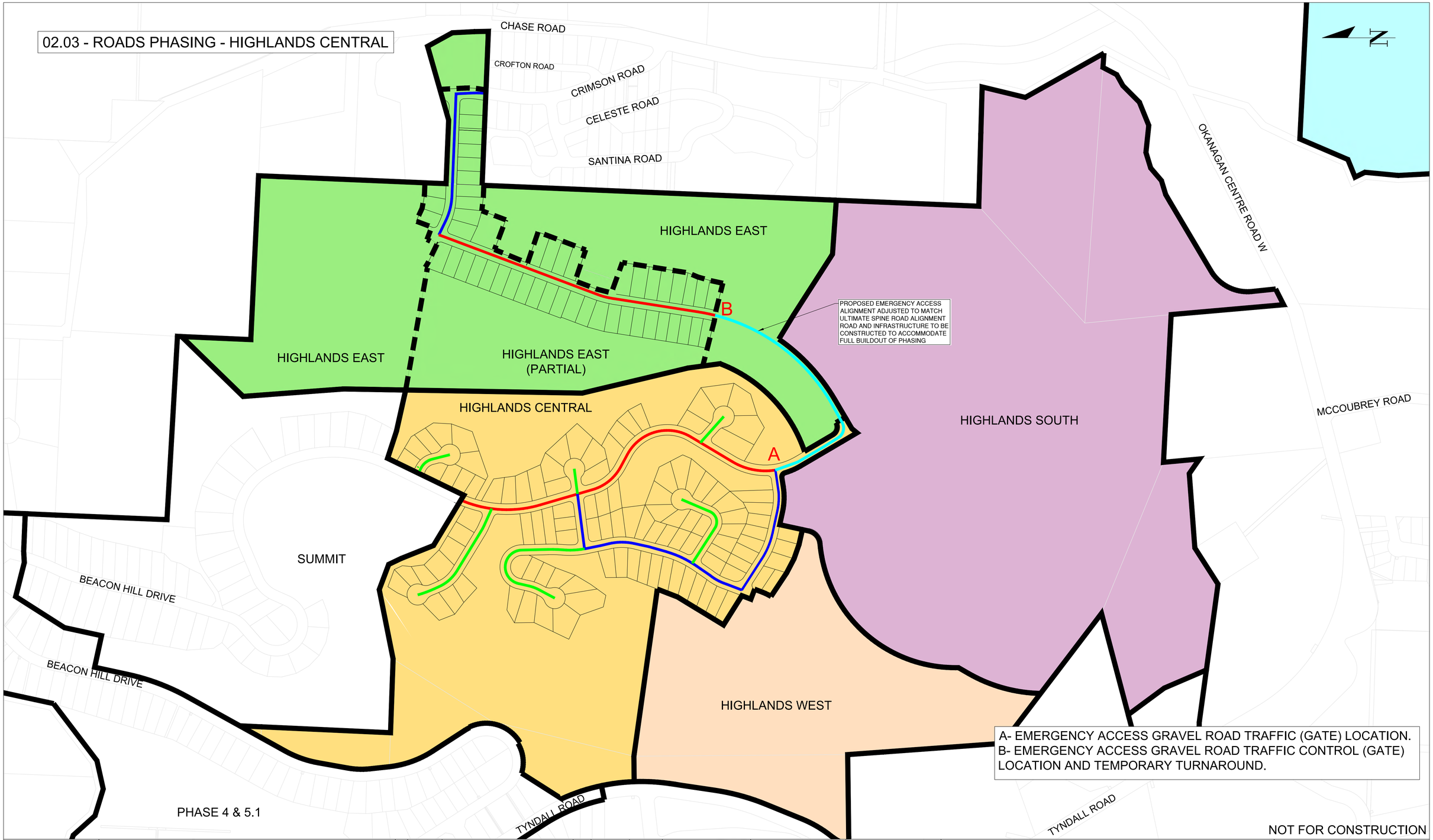
SURVEY: FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE: AR
DESIGN: AR	ENG. OF RECORD: JP
SCALE = 1:3500	

DISTRICT OF LAKE COUNTRY

PHASING PLAN
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.	INFRASTRUCTURE
DISTRICT FILE NO.	4019
PROJECT DRAWING NO.	02.01
REV NO.	1
DISTRICT RECORD NO.	N/A
SHEET NUMBER	2 OF 22

02.03 - ROADS PHASING - HIGHLANDS CENTRAL



A- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC (GATE) LOCATION.
B- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PROPOSED CONSTRUCTION ACCESS
- PROPOSED EMERGENCY ACCESS
- PROPOSED COLLECTOR ACCESS
- PROPOSED LOCAL ACCESS
- PROPOSED LOCAL CUL-DE-SAC ACCESS

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:2500	

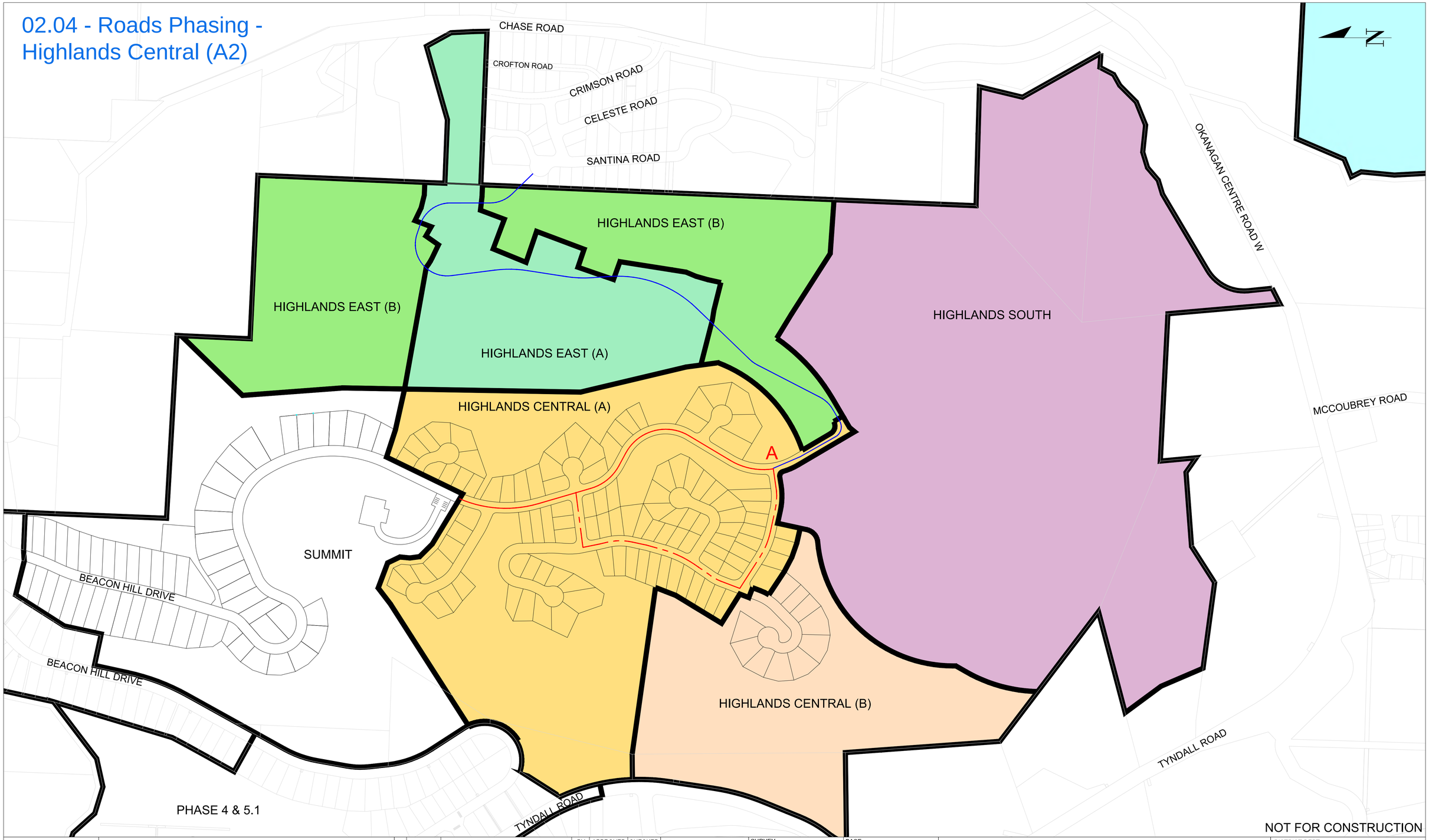
DISTRICT OF LAKE COUNTRY

ROADS PHASING - HIGHLANDS CENTRAL
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 02.03	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 3 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\02.03 PHASING HC Option 1.dwg

02.04 - Roads Phasing - Highlands Central (A2)



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- EXISTING EMERGENCY ACCESS
- PROPOSED COLLECTOR ACCESS
- PROPOSED LOCAL ACCESS

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
0	25/05/05	LAKESTONE MASTER PLAN PDA	AR	JP	JP

SEAL

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE 1:2500	

DISTRICT OF LAKE COUNTRY

ROADS PHASING - HIGHLANDS CENTRAL (A2)
PHASED DEVELOPMENT AGREEMENT
LAKESHORE MASTER PLANNED COMMUNITY

DISTRICT DEPT.	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. -	REV NO. 0
DISTRICT RECORD NO. N/A	SHEET NUMBER - OF -

PLOT DATE: May 5, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\4 - PDA\PROD-HE-PHASING.dwg

ECOSCAPE
Environmental Consultants Ltd.

Technical Memorandum

Date: May 2, 2025
To: Jonathon Campbell, MacDonald Development Corporation
From: Nikita Planz, Mary Ann Olson-Russello, Ecoscape Environmental Consultants ltd.
File: 20-3272.09 |Version 1
Subject: **Environmental Scope Guidelines for Lakestone Phased Development Agreement.**

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) has been retained by MacDonald Development Corporation to provide environmental scope guidelines for the Lakestone Development (study area) as part of a Phased Development Agreement (PDA) with the District of Lake Country (DLC). The purpose of this document is to provide a list of requirements for each development phase at Lakestone over next 15 - 20 years of construction.

In 2021, the Environmental Assessment and Mitigation Plan for the Lakestone Master Plan was developed. This report provided insight into the long-term planning for Lakestone, including proposed works across 14 phases, of which 6 are completed or under construction. Terrestrial Ecosystem Mapping (TEM), Environmentally Sensitive Areas (ESAs), waterbodies, and limited surveys for Species at Risk were undertaken (**Figure 1**). Mitigation measures and restoration recommendations were also provided.

A large-scale biophysical inventory and assessment was completed in the Master Plan, this information can be used going forward to simplify the environmental deliverables for each phase. However, an Environmental Impact Assessment (EA), although streamlined, must be carried out for each individual phase to identify areas of concern, changing conditions, and meet regulator requirements. The EA will be made up of an assessment and impact statement, as well as include mitigation measures and a restoration plan.

Additionally, if sustainable environment practises are integrated during the design phase, the reporting requirements can be further reduced. Sustainable practices include, as identified within the DLC's Official Community Plan:

- Protect identified upland and foreshore environmentally-sensitive areas and habitats through the preservation of ground water and habitat by avoiding clear cutting of trees,
- ensuring development does not disrupt corridors between natural areas,

- integrate natural features into development, and
- maintain sensitive ecosystems.

It is important to note that the 2023 wildfire took place after the Environmental Assessment for the Master Plan, and therefore site conditions in the study area may have changed.

2.0 SIMPLIFIED ENVIRONMENTAL ASSESSMENT

A full biophysical inventory is not required for each phase as ecosystem mapping and ESA determination has already been completed. Instead, the following field components must be completed within 12 months prior to DLC permit approval:

- Targeted, seasonally appropriate surveys of wildlife features within the proposed disturbance footprint, including but not limited to,
    - snake hibernacula;
    - snags, wildlife trees, or potential nesting areas;
    - amphibian surveys;
    - badger dens or digs, and;
    - bat roosts.
- Survey or data gathering, as needed, to ensure due diligence of the QEP, Macdonald Corporation, and the DLC is met.

The simplified EA must:

- Define the subject property or study area.
- Include a description and engineered designs of the proposed works, including all disturbance, utilities, connections to offsite infrastructure, and cut and fill slopes.
- Provide a summary of the potential species at risk or critical habitat within 1 km of the subject property, emphasizing changes or new occurrences from the Master Plan.
- Description of ecosystems (i.e. TEM from Master Plan) and important features within the phase (i.e. snake hibernaculum or water courses); and,
- Any wildlife or other notable features observed during the targeted surveys.
- A figure(s) that overlays the proposed works with the subject property and ESAs.

- Include an impact statement discussing the short and long term impacts of the development, considering wildlife connectivity and cumulative effects.
    - If critical habitat loss is to occur, it must be clearly stated, and a rational for why it cannot be avoided must be provided.
- Mitigation measures not already presented in the Master Plan, and;
- A Restoration Plan, that includes performance and securities.
- Outline Environmental Monitoring requirements.
- Include an Executive Summary, that clearly speaks to if the project meets the DLCs environmental objectives outlined within relevant bylaws and Official Community Plan.

Note: other reports, applications, and surveys may be required under other regulatory bodies, like the Ministry of Water, Lands, Resources and Stewardship or the Department of Fisheries and Oceans.

3.0 CLOSURE

We trust that this memo satisfies the present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully Submitted,

Ecoscape Environmental Consultants Ltd.

Written by:



Nikita Planz, M.Sc. B.I.T.
Junior Biologist
Direct Line: 778-749-1006

Reviewed by:



Mary Ann Olson-Russello, M.Sc., R.P.Bio
Senior Natural Resources Biologist
Direct Line: 778-940-3473

4.0 LIMITATIONS

This report has been prepared by Ecoscape and is intended for the sole and exclusive use of MacDonald Development Corporation, for the purposes set out in this report. Ecoscape has prepared this report with the understanding that all available information on the past, present, and proposed conditions of the subject property have been disclosed. Ecoscape has relied upon personal communications with MacDonald Development Corporation and other information sources to corroborate the documents and other records available for the subject property. MacDonald Development Corporation has also acknowledged that in order for Ecoscape to properly provide the professional service, Ecoscape is relying upon full disclosure and accuracy of this information.

Any use of this report by a third party, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Ecoscape accepts no responsibility for damages, if any, suffered by any third party as a result of actions or decisions made based on this report.

APPENDIX A: General Terms and Conditions

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
#2 – 2030 Matrix Crescent, Kelowna, BC., V1V 0G5

Tel: 250.491.7337
www.ecoscapeltd.com

General Conditions

This report applies and is subject to these "General Conditions".

Use of Report

This report concerns a specific site and a specific scope of work and is therefore not applicable to any other sites or any other developments not referred to in the report. Any deviation from the specific site or scope of work would require a supplementary investigation and assessment.

Conclusions and recommendations contained in this report are solely intended for the use of Ecoscape's client. Ecoscape bears no responsibility for the accuracy of information, the analysis of data or recommendations contained or referenced in this report when the report is utilized by or relied upon by any party other than Ecoscape's client unless otherwise authorized in writing by Ecoscape. Any unauthorized application of this report is at the discretion and sole risk of its user.

This report is subject to copyright, and therefore shall not be reproduced in part or in whole without prior written consent by Ecoscape. Additional copies of this report may be available upon request, if required, and will be supplied after receipt of payment for expenses associated with report production.

Limitations of Report

This report was derived solely from the conditions that were present on site during Ecoscape's investigation. The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are aware that conditions affecting the environmental condition of the site can vary both temporally and spatially, and that the conclusions and recommendations included in this report are temporally sensitive.

The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are also aware that conclusions and recommendations included within this report emanate from limited observations and information, and that both on-site and off-site conditions may vary, which in turn could affect the conclusions and recommendations that were made.

The client is aware that Ecoscape is not qualified to, nor is it making any recommendations in terms of purchase, sale, investment, or development of the subject property, as such decisions are the sole responsibility of the client.

Information Provided to Ecoscape by Others

During the extent of the preparation and work carried out in this report, Ecoscape may have relied upon information provided by parties other than the client. While Ecoscape strives to validate the accuracy of such information when instructed to do so by the client, Ecoscape accepts no responsibility for the validity of such information which may affect the report.

Limitation of Liability

The client acknowledges that property containing hazardous wastes and contaminants poses a high risk of claims brought by third parties stemming from the presence of those materials. Accounting for these risks, and in consideration of Ecoscape providing the requested services, the client agrees that Ecoscape's liability to the client, with respect to any issues relating to hazardous wastes or contaminants located on the subject property, shall be limited to the following:

With respect to any claims brought against Ecoscape by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to Ecoscape under this Agreement, whether the action is based on breach of contract or tort;

With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject property, the client agrees to indemnify, defend and hold harmless Ecoscape from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by Ecoscape, whether the claim be brought against Ecoscape for breach of contract or tort.

Disclosure of Information by Client

The client agrees to fully cooperate with Ecoscape with respect to the provision of all available information on the past, current, or proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for Ecoscape to properly provide the service, Ecoscape is relying on full disclosure and accuracy of any such information. Ecoscape does not accept any responsibility for conclusions drawn from erroneous, invalid, or inaccurate data provided to us by another party and used in the preparation of this report.

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
#2 – 2030 Matrix Crescent, Kelowna, BC., V1V 0G5

Tel: 250.491.7337
www.ecoscapeltd.com

Standard of Care

Services performed by Ecoscape for this report have been completed in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgement has been applied in developing the conclusions and/or recommendations made in this report. No warranty or guarantee, express or implied, is made concerning the results, comments, recommendations, or any other portion of this report.

Notification of Authorities

The client acknowledges that in certain instances the discovery of hazardous materials, contaminants or conditions and materials may require that regulatory agencies and other parties be informed and the client agrees that notification to such parties or persons as required may be done by Ecoscape in its reasonably exercised discretion. Further, Ecoscape reserves the right to notify Provincial agencies when rare or endangered flora or fauna are observed, whether the species classifications are identified as such at the local, Provincial, or Federal levels of government.

Ownership of Instruments of Professional Service

The client acknowledges that all reports, plans, and data generated by Ecoscape during the performance of the work and other documents prepared by Ecoscape are considered its professional work product and shall remain the copyright property of Ecoscape.

Alternate Report Format

Where Ecoscape submits both an electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Ecoscape's instruments of professional service), the client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by Ecoscape shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the client agrees and waives all future right to dispute that the original hard copy signed version archived by Ecoscape shall be deemed to be the overall original for the Project.

The client agrees that both electronic file and hard copy versions of Ecoscape's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party other than Ecoscape. The client warrants that Ecoscape's instruments of professional service will be used only and exactly as submitted by Ecoscape.

The client recognizes and agrees that electronic files submitted by Ecoscape have been prepared and submitted using specific software and hardware systems. Ecoscape makes no representation about the compatibility of these files with the client's current or future software and hardware systems.

APPENDIX B: Figure

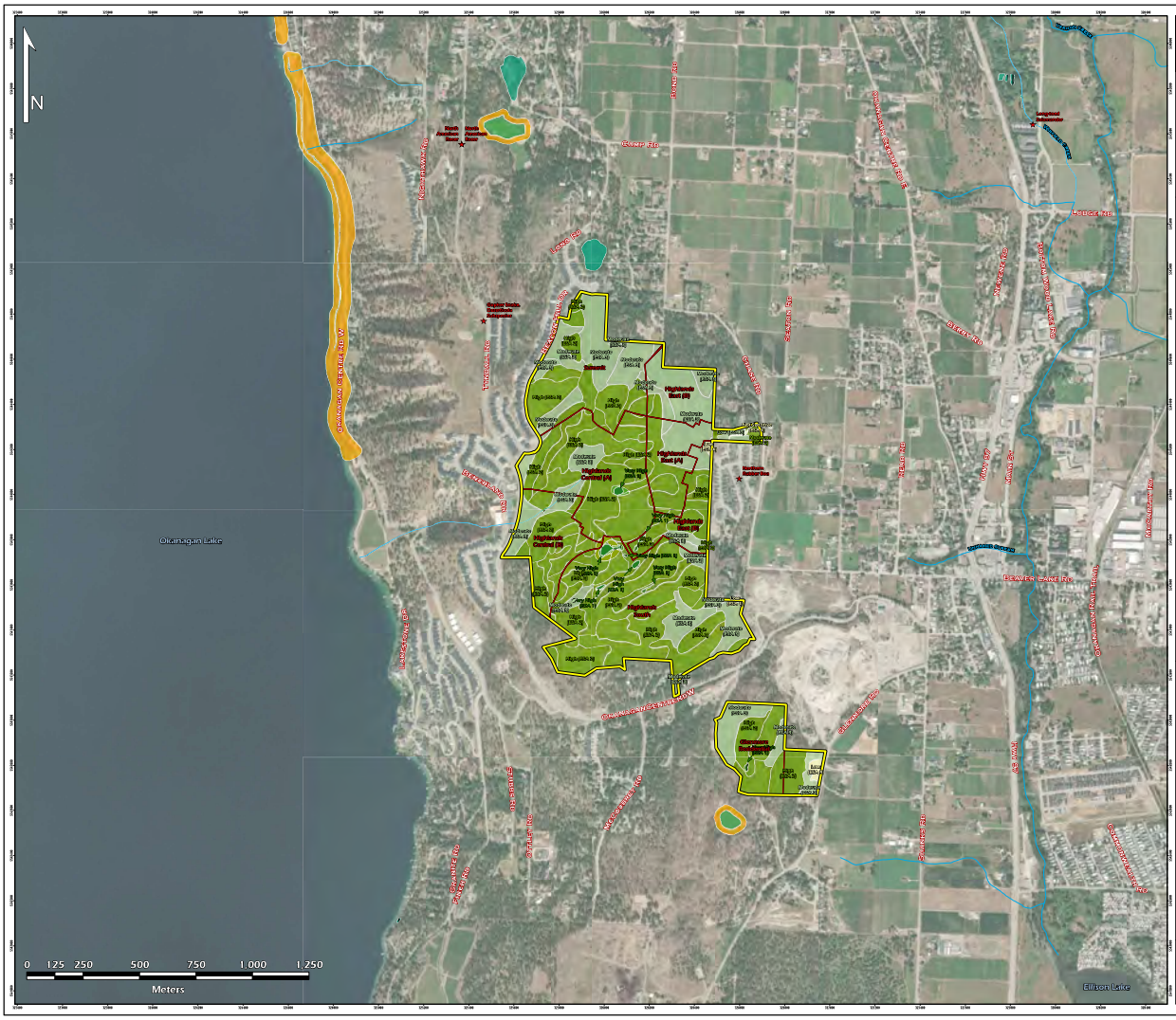


FIGURE 1
Site Location, Wetland Information, Species at Risk Occurrences & ESA

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272.09
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Vivien Nagy, GIS Technician
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery 2023
Field Visit:	N/A
Map Date:	May 2, 2025

LEGEND

- Wildlife Species Inventory (Survey)
- Wildlife Species Inventory (Incidental)
- Streams and Rivers
- Phasing Plan
- Wetland and Riparian Communities
- Okanagan Critical Habitat (Species at Risk)
- BC Conservation Data Center (CDC) Polygons*
- Study Area
- Cadastre

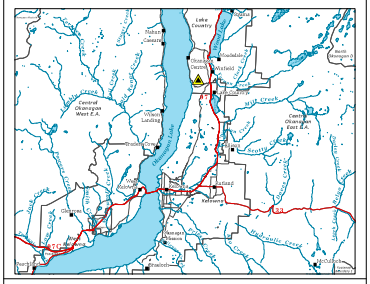
Environmental Sensitivity Rating

- Very High (ESA 1)
- High (ESA 2)
- Moderate (ESA 3)
- Low (ESA 4)

*A large Okanagan Critical Habitat polygon covers the entire map and subject property area representing the following wildlife species but is not shown on this figure:
- American Badger jeffersonii subspecies (Taxidea taxus jeffersonii)
- Western Rattlesnake (Crotalus oreganus)

Large Conservation Data Centre (CDC) polygons include:
- American Badger (Taxidea taxus)

Regional Location of Subject Property



DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE

ENVIRONMENTAL ASSESSMENT & MITIGATION PLAN
LAKESTONE MASTER PLAN

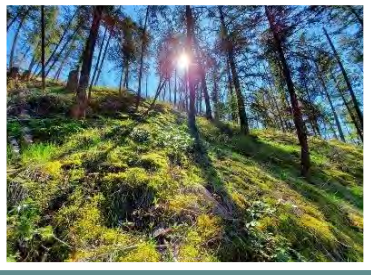














Prepared For:
Macdonald Lakeshore Properties LP

Prepared By:
Ecoscape Environmental Consultants Ltd.

January 2021

ENVIRONMENTAL ASSESSMENT & MITIGATION PLAN
LAKESTONE MASTER PLAN

Prepared For:

Macdonald Lakeshore Properties LP
11th Floor, 938 Howe Street
Vancouver, BC V6Z 1N9

ATTENTION TO: Don Erdely

Prepared By:

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
102 - 450 Neave Court
Kelowna, BC
V1V 2M2

January 7, 2021

Ecoscape File No. 20-3272

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Project Area 2
1.2 Proposed Works 2
2.0 Environmental Assessment 4
2.1 Ecosystems and Vegetation Communities 4
2.2 Wetland and Riparian Habitats 6
2.3 Wildlife 8
2.4 Species And Ecosystems At Risk 12
2.5 Environmentally Sensitive Areas (ESAs) 15
3.0 Impact Assessment 17
4.0 Mitigation Measures and Recommendations 18
4.1 Clearing and Grubbing 19
4.2 Tree Protection 20
4.3 Erosion and Sediment Control 21
4.4 Emergency Spill/Response Plan 24
4.5 Stormwater Management and Wetland Protection 24
4.6 Air Quality & Greenhouse Gas Reduction 25
4.7 Habitat Remediation and Enhancement 28
4.8 Rockfall Mitigation 31
4.9 Invasive Species Management 31
4.10 Site Clean Up 32
4.11 Environmental Monitoring 32
4.12 Restoration, Performance and Maintenance Bonding 33
5.0 CONCLUSION 33
6.0 CLOSURE 34
7.0 REFERENCES 35

TABLES

Table 1. Summary of Completed and Proposed Development 2012 – 2020. 3
Table 2. Summary of Disturbance Limits and Green Spaces for the 2020 Master Plan. 3
Table 3. Ecosystem communities occurring within the Project Area. 5
Table 4. Summary of herptile species and habitat associations within the Project Area. 8
Table 5. Summary of mammal species and habitat associations within the Project Area. 9
Table 6. Summary of bird species and habitat associations within the Project Area. 10
Table 7. Summary of vertebrate species at risk with the potential to occur in the Project Area based on the suitability of habitats for each species. 13
Table 8. Summary of invertebrate species at risk with the potential to occur within the subject Project Area. 15
Table 9. Percent composition of ESAs within the Project Area. 17
Table 10. Impact assessment of proposed development on identified ESAs 17
Table 11. Restoration Grass Seed mix 20
Table 12. DLC GHG Reduction and Conservation Factors Checklist 27

FIGURES

Figure 1 .....Site Location
Figure 2 .....Ecosystem Polygons
Figure 3 ..... Environmental Sensitivity Analysis
Figure 4 ..... Impact Assessment
Figure 5 .....Wildlife Crossings

APPENDICES

Appendix 1 ..... Lakestone 2020 Master Plan Phasing
Appendix 2 .....Lakestone Summit Phase
Appendix 3 ..... Proposed Parks and Open Space Areas
Appendix 4 ..... Common native plant species occurring within the Project Area
Appendix 5 ..... Bird and Bat Box Designs
Appendix 6 .....Native Plant Salvage Plan
Appendix 7 .....Guidelines for Amphibian and Reptile Conservation

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) was retained by Macdonald Lakeshore Properties LP (the Proponent) to conduct an Environmental Assessment (EA) and Environmentally Sensitive Areas (ESA) analysis for the proposed 2020 Lakestone Master Plan residential and multi-family development project (the Project) in Lake Country, BC (the Project Area).

Previous development completed for the Lakestone residential and multi-family development has included Phases 1 – 5.1, as shown in the Lakestone 2020 Master Plan (**Appendix 1**). Ecoscape completed an EA for the Summit Phase (**Appendix 2**) in November 2020, however the remaining phases in the Master Plan are in the conceptual stages, therefore the designs provided by the Proponent present a preliminary overview ahead of detailed designs for each phase.

The Project Area and scope of this assessment is composed of the following phases (**Figure 1**):

- Glenmore Industrial
- Chase Residential
- Ok Centre Plateau
- Highlands South
- Highlands West
- Highlands Central
- Highlands East
- East Ridge
- Summit Phase

The purpose of this report is to provide an environmental assessment for the proposed phases of the 2020 Lakestone Master Plan (**Appendices 1 - 2**).

This report identifies existing terrestrial, riparian, and wetland resource values, assesses the potential for rare and/or endangered species and habitats, and provides recommendations to maintain the natural integrity of existing ecological communities through sensitive design.

The on-site environmental impact of the Project has been reviewed by Ecoscape. With the Project Area largely undeveloped, impacts to environmental values are reduced for the Project through retention of greenspace. The retention of significant features of the environment is recommended, such as steep slopes and cliffs, wetlands, wildlife trees, existing trails, and wildlife crossings.

According to Lakestone's 2020 Master Plan Environmental Impact Statement (Macdonald Lakeshore Properties LP, 2020), environmental retention is a primary objective of Lakestone's approach to development. The Master Plan places a premium on environmental co-existence through introduction of the following:

- Clustering of development to allow for retention of substantial areas of existing forest, wetlands, rock outcroppings, and other natural features;
- Extensive open space provision (54%) which depends on retention of the natural setting with the residential, amenity, and foreshore facilities;

- Significant trail system, which also provides wildlife movement and habitat opportunities;
- Limited development at the environmentally sensitive foreshore, consisting of a drop-off/pickup wharf encouraging the use of kayaks, canoes, and other non-motorized watercraft;
- Building Design Guideline process which maximizes retention of existing site conditions through to the end of construction; and
- Specific road and servicing standards designed for hillside conditions that minimize scarring and maximize retention of the natural surround.

Following Ecoscape's field survey and ESA analysis, the Proponent modified their designs to accommodate the very high value ESAs (wetland, riparian, gullies, and moisture receiving areas) to keep those areas intact and maintain connectivity.

1.1 Project Area

The Project Area encompasses approximately 329.79 acres bounded by Glenmore Rd and Okanagan Centre Rd W to the south, Tyndall Rd to the west, Camp Rd to the north, and Chase Rd to the east (**Figure 1**).

The Project Area consists of one large parcel (Block B) and three lots (136, 137, 138) zoned as DC3 (Direct Control), legally described as:

- Block B, Plan KAP521, Section 3&4&9, Township 20, Osoyoos Div of Yale Land District, Except Plan EPP86639
- Lot 136, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District, Except Plan H10875
- Lot 137, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District
- Lot 138, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District

The Project Area occurs within District of Lake Country Natural Environment and Hillside Development Permit Areas (DPAs) and requires an environmental assessment to address the potential for adverse environmental effects resulting from the proposed development.

A mosaic of steep slopes and gullies, coniferous woodland, grassland, talus slope, cliff, wetlands, and riparian habitats encompass the Project Area. There are a number of wetlands and riparian communities that occupy the central region of the Project Area and the northern and southern extents of the Lakestone development. The Project Area contains a network of trails that are currently used recreationally. The surrounding areas have been previously disturbed, with extensive development to the north and west from Lakestone Phases 1 – 5.1, in addition to older residential and industrial developments to the north and east. Despite trail development and previous development disturbance and fragmentation, forest and wetland communities remain generally intact and in excellent condition.

1.2 Proposed Works

The proposed development includes the following:

- Clearing, grubbing, and earthworks for the development of single-family lots and multi-family townhomes, duplexes and apartments;
- Construction of roadways, including collector roads, local roads, strata roads, emergency access roads, and extensions of previously constructed roads from Phases 1 – 5.1;
- Retention of open green spaces;
- Retention/construction of urban recreational park areas;

Table 1 provides an overview of the number of lots, townhomes/duplexes, and apartments proposed for each phase of development, and **Table 2** provides the areas of disturbance, parks, and open spaces.

Table 1. Summary of Completed and Proposed Development 2012 – 2020.

Phase	Master Plan Reference	Lakestone Neighborhood	Single Family Lots	Townhome and Duplex	Apartment	Total	Density Transfer
Phase 1	2012	Waterside	20	0	0	20	N/A Completed
Phase 2	2012	Waterside	86	18	0	104	N/A Completed
Phase 3	2012	Benchlands	91	0	80	171	N/A Completed
Phase 4	2012	Highlands	52	28	0	80	N/A Completed
Phase 5.1	2012	Highlands	58	0	0	58	N/A Completed
Summit Phase	2020	Highlands	57	0	0	57	5.6
Highlands Central Phase	2020	Highlands	63	0	0	63	6.3
Highlands East Phase	2020	Highlands	34	33	0	67	6.7
East Ridge Phase	2020	Highlands	56	12	0	68	6.9
Highlands West Phase	2020	Highlands	73	0	0	70	7.3
Highlands South Phase	2020	Highlands	0	74	0	74	7.4
OK Center Plateau Phase	2020	Highlands	0	50	100	150	15
Glenmore Phase	2020	Glenmore	70	180	130	380	38
TOTALS			**660**	**395**	**310**	**1365**	

Table 2. Summary of Disturbance Limits and Green Spaces for the 2020 Master Plan.

Phase	Master Plan Reference	Neighborhood	Number of Lots	Limit of Disturbance (acres)	Park Area (acres)	Open Spaces (acres)
Summit Phase	2020	Highlands	57	22.0	7.85	26.65
Highlands Central Phase	2020	Highlands	63	21.6	1.74	12.21
Highlands East Phase	2020	Highlands	67	16.9		10.09
East Ridge Phase	2020	Highlands	68	16.5	0.96	15.49
Highlands West Phase	2020	Highlands	70	19.4	5.77	33.85
Highlands South Phase	2020	Highlands	74	21.0	3.23	59.53
OK Center Plateau Phase	2020	Highlands	150	20.2		7.88
Glenmore Phase	2020	Glenmore	380	22.1		15.7
TOTALS			**929**	**137.67**	**19.57**	**181.42**

The total area of the proposed development footprint is approximately 138 acres.

Access to the development will be from existing roads such as Glenmore Rd and Okanagan Centre Rd W, previously constructed roads from Phases 1 – 5.1 including Tyndall Rd, as well as newly constructed road extensions such as Beacon Hill Drive.

The Project will include public park areas and open green spaces (**Appendix 3**), roughly following the area's prominent wetlands, gullies and steep slopes. Wildlife crossings and funnel fencing should be incorporated into the road designs to allow wildlife access, particularly under the area's road system for continued connectivity between the wetlands in the central portion of the Project Area. A site plan showing the proposed lot and road layout is attached (**Appendix 1**).

2.0 ENVIRONMENTAL ASSESSMENT

Site visits were conducted between April 20 – 22, 2020 by Mary Ann Olson-Russello, M.Sc., R.P.Bio., Theresa Loewen, M.Sc., P.Ag, and Kyle Hawes, R.P. Bio., Natural Resource Biologists with Ecoscape. Subsequent visits were carried out in May 2020 to delineate ecologically sensitive talus slopes, cliffs, and wetland habitats. Other sources of information queried for the assessment include:

- District of Lake Country Official Community Plan (OCP);
- BC Conservation Data Centre (CDC) Species and Ecosystems Explorer;
- BC Habitat Wizard;
- Biogeoclimatic maps;
- Sensitive Ecosystem Inventory (SEI) and Terrestrial Ecosystem Mapping (TEM);
- Species at Risk Act Public Registry;
- Kelowna Wetland Inventory and Mapping; and,
- Provincial Best Management Practices (BMP).

2.1 Ecosystems and Vegetation Communities

The Project Area occurs within the Okanagan variant of the Ponderosa Pine biogeoclimatic zone, Very Dry Hot subzone (PPxh1) (Lloyd et al. 1990). Areas of the PP zone are the driest forested areas in B.C., with low snowfall and hot, dry, summers. The Project Area is a mosaic of steep slopes, talus, cliffs, gullies, open and closed conifer forest, grasslands, wetlands and riparian habitat. Ecosystems were refined for the Project Area adapting Terrestrial Ecosystem Mapping (TEM) and Sensitive Ecosystem Inventory (SEI) polygons (Iverson 2008). Polygon refinement involved finer scale community stratification into more specific areas at a 1:5000 scale. In total 81 community/habitat polygons were defined (**Table 3 and Figure 2**). Table 3 presents the ecosystem codes, their associated site series name, and provincial status.

Table 3. Ecosystem communities occurring within the Project Area.

Ecosystem Code	Site Series	Site Series Name	Provincial Status[1]
DM/FI07	08	Douglas-fir – Water birch – Douglas maple	Red
FB	00	Rough fescue – Bluebunch wheatgrass	Red
PF	02	Douglas-fir / Ponderosa pine – Pinegrass – Idaho fescue	Red
SA	00	Antelope brush – Selaginella	Red
DS	07	Douglas-fir / Ponderosa pine – Snowberry – Spirea	Blue
WB	00	Bluebunch wheatgrass - Balsamroot	Blue
PT	02	Ponderosa pine – Red three-awn	Blue
PW	01	Ponderosa pine – Bluebunch wheatgrass – Idaho fescue	Blue
SP	06	Douglas-fir / Ponderosa pine – Snowbrush - Pinegrass	Blue
CT/Wm05	00	Cattail marsh	Blue
BM/Wm06	00	Bulrush marsh	Blue
SW	N/A	Shallow water	Blue
Ws03	09	Willow – Sedge	N/A
SB	00	Selaginella – Bluebunch wheatgrass	N/A
SO	00	Saskatoon – Mock orange – Talus	N/A
CL	N/A	Cliff/bluff	N/A
ES	N/A	Exposed soil	N/A
RO	N/A	Rock outcrop	N/A
RW	N/A	Rural	N/A
RZ	N/A	Road surface	N/A
TA	N/A	Talus	N/A

1 Source: http://www.env.gov.bc.ca/cdc/
N/A: Non-listed **Blue:** Of special concern. **Red:** Endangered or threatened.

Five (5) different coniferous woodland ecosystems were identified in the Project Area, including DM/FI07 (Douglas fir – Water birch – Douglas maple), PF (Douglas-fir / Ponderosa pine – Pinegrass – Idaho fescue), DS (Douglas-fir / Ponderosa pine – Snowberry – Spirea), PT (Ponderosa pine – Red three-awn), PW (Ponderosa pine – Bluebunch wheatgrass – Idaho fescue), and SP (Douglas-fir / Ponderosa pine – Snowberry - Pinegrass). These are predominantly young forests, with sporadic mature trees and abundant snags and wildlife trees. Certain areas (specifically the SP at the north end of the Project Area) had a structural stage of pole sapling which can indicate recent logging activities (**Photos 1 - 2**). Younger stands such as this have lower environmental sensitivity.

Sparsely vegetated sites are associated with SO (Saskatoon – Mock orange talus), SA (Antelope brush – Selaginella), SB (Selaginella – Bluebunch wheatgrass), RO (Rock outcrop), and CL (Cliff/bluff) (**Photos 3 - 8**). Trees within these areas are classified with a structural stage 6/7 (mature or old forests).

A network of ponds, wetlands, and riparian communities exist within the Project Area (**Photos 9 - 11, Figure 1**). The ponds contain three (3) wetland associations including shallow water (SW) with submerged aquatic vegetation, bulrush marsh (BM/Wm06), and cattail marsh (CT/Wm05). Willow-sedge swamp (Ws03) and adjacent tall shrub riparian ecosystems including dominated by water birch, red-osier dogwood, and willow occur in moisture receiving depressions and around the fringe of the pond and marsh communities.

Anthropogenic sites include areas of previous disturbance, old gravel roads, and trails, were classified as ES (Exposed soil), RZ (road surface), and RW (rural) (**Photo 12**).

The DM, DS, SP, and SW communities are generally characterized by cooler aspects with higher moisture content, while PF, PT, PW, SO, SA, SB, and WB are generally characterized by warmer

aspects and lesser moisture content. The DM and PF communities are Red-listed in B.C., meaning that they are currently endangered or threatened. The DS, WB, PT, PW, SP, CT, and BM communities are Blue-listed in B.C., meaning they are of special concern due to loss and degradation throughout the region.

The coniferous woodlands that occur throughout the majority of the proposed development area are comprised of young to mature interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and ponderosa pine (*Pinus ponderosa*) stands. Interior Douglas-fir dominates on cooler-aspect slopes and within moisture receiving areas (**Photo 13**), while ponderosa pine dominates the warmer, drier, and ridge-top areas (**Photo 14**). Younger forests predominate the landscape, and while they have intrinsic ecological value and provide recruitment for older structural stages, the older structural stage forests are of higher conservation priority (Iverson, 2008).

A large number of veteran, wildlife trees, and snags (**Photos 15 - 23**) were noted throughout the Project Area, which are known to provide valuable habitat to multiple species, such as blue-listed Lewis's Woodpecker in the region. Snags and veteran wildlife trees should be retained where possible as they provide nesting opportunities for various bird species and potential roosts for bats. Coarse woody debris is scattered on the forest floor throughout the Project Area, providing habitat for various small mammals, herptiles, and other wildlife. Retention of some large coarse woody debris is recommended for the valuable wildlife habitat it provides.

A detailed vegetation survey was not conducted, however, vegetation was largely consistent with other adjacent upland areas with a greater prevalence of tall Oregon-grape (*Mahonia aquifolium*), common snowberry (*Symphoricarpos albus*), Saskatoon (*Amelanchier alnifolia*), arrow-leaved balsamroot (*Balsamorhiza sagittata*), and bunchgrasses (**Photos 24 – 25**). Additional native species common to the Project Area can be found in **Appendix 4**.

A detailed inventory of invasive vegetation and noxious weeds was not conducted, however observations during the site visits included great mullein (*Verbascum thapsus*) and diffuse knapweed (*Centaurea diffusa*), found primarily in areas of disturbance.

2.2 Wetland and Riparian Habitats

The wetlands, gullies, and moisture receiving areas in the Project Area are identified as Polygons 44, 67, 69, 70, 71, 74, and 75 (**Figure 3**)**.** These areas are biodiversity hotspots that are critical for supporting the biodiversity of the Lakestone area.

The isolated wetlands contain central shallow water habitats and have varying degrees of emergent marsh and riparian vegetation around the fringe, with extensive marsh communities consisting of both cattail and bulrush and submergent vegetation in the shallow water habitats. An example of the wetland in Polygon 67 is shown below.



Photo Plate: Showing pond/wetland communities - Polygon 44 (*left*) and Polygon 70 (*right*)

Below is a clip from **Figure 4** which shows the network of wetlands, gullies, and moisture receiving areas, and their proximity to development.



Figure Plate 1: Network of functionally connected wetlands, gullies, and moisture receiving areas

Maintaining connectivity between these areas and is essential to supporting the high ecological value of these ecosystems and the habitat they provide to a diversity of species, including many species at risk. See Section 4.7 for more on ecosystem connectivity and maintenance of movement corridors.

The common cattail marsh in the north outside of the Project Area, but within the existing Lakestone development (**Figure 1**), has an established trail that loops around the pond with an access point from Tyndall Road at the north end (**Photo 26**).

2.3 Wildlife

Detailed wildlife surveys were not conducted during the site assessment. The undeveloped nature of the area and connectivity to adjacent natural habitats suggest high potential for wildlife presence and use for a variety of species and life stages.

Wildlife observations during the field visits include evidence of mule deer, moose, coyote, cougar, black bear, chorus frogs, small mammals such as squirrels and chipmunks, and high potential for bats and snakes in the cliffs, talus, and sparsely vegetated areas. As such, there is a high risk of snake mortality on Tyndall Rd and future roads that do not have wildlife crossings or culverts.

The Project Area has high potential for reptiles, amphibians, and bats with overwintering habitat in the south and west facing slopes, wetlands, exposed rock features, extensive talus and adjacent riparian gullies and grasslands for feeding habitat (**Photos 3 – 11; 27 – 33**). These areas should be retained as much as possible for their high habitat value. **Table 4** presents a summary of herptile species with habitat associations within the Project Area.

Table 4. Summary of herptile species and habitat associations within the Project Area.

Species Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Amphibian	Long-toed salamander	*Ambystoma macrodactylum*	**Yellow**	**Not at Risk**	Wetland / Riparian
	Pacific chorus frog	*Pseudacris regilla*	**Yellow**	-	Wetland / Riparian
Reptile	Common garter snake	*Thamnophis sirtalis*	**Yellow**	-	Fractured bedrock / Riparian
	Great Basin gopher snake	*Pituophis catenifer deserticola*	**Blue**	**Threatened**	Rocky/Talus
	Northern alligator lizard	*Elgaria coerulea*	Yellow	Not at Risk	Shrub/Talus
	Rubber boa	*Charina bottae*	Yellow	**Special concern**	Fractured bedrock
	Western painted turtle	*Chrysemis picta*	**Blue**	**Special concern**	Wetland / riparian
	Western racer	*Coluber constructor*	**Blue**	**Threatened**	Fractured bedrock/ grassland
	Western rattlesnake	*Crotalus oreganus*	**Blue**	**Threatened**	Fractured bedrock/ grassland
	Western terrestrial garter snake	*Thamnophis elegans*	**Yellow**	-	Wetland / Riparian

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern: A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk: A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.

Endangered: A wildlife species facing imminent extirpation or extinction.
Data Deficient : A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

The open grassland and moisture-receiving areas provide suitable habitat for a variety of small mammals such as shrews, voles and mice. The cracks and crevices in the rocky outcrops and cliffs provide suitable roosting habitat and hibernacula for other small mammals such as bats. Snags and partially dead trees with cavities were noted throughout the Project Area, which also provide habitat for nesting or foraging small mammals. The grassland and forest habitats provide suitable habitat for mule deer, black bear and coyotes. **Table 5** lists common mammal species with habitat associations within the Project Area.

Table 5. Summary of mammal species and habitat associations within the Project Area.

Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
American black bear	*Ursus americanus*	Yellow	Not at Risk	Mixed Forest
Bushy-tailed woodrat	*Neotoma cinerea*	Yellow	-	Rocky Outcrop
Coyote	*Canis latrans*	Yellow	-	All
Meadow vole	*Microtus pennsylvanicus*	Yellow	-	Riparian
Mule deer	*Odocoileus hemionus*	Yellow	-	All
Northern pocket gopher	*Thomonys talpoides*	Yellow	-	Open grassland
Porcupine	*Erethizon dorsatum*	Yellow	-	Woodland
Red squirrel	*Tamiasciurus hudsonicus*	Yellow	-	Forest
White-footed deer mouse (North American deer mouse)	*Peromyscus maniculatus*	Yellow	-	All
White tailed deer	*Odocoileus virginianus*	Yellow	-	All
Yellow-pine chipmunk	*Neotamias amoenus*	Yellow	-	Shrubland

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern: A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk: A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Endangered: A wildlife species facing imminent extirpation or extinction.
Data Deficient : A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

Detailed surveys for bats were not conducted within the Project Area and it is uncertain which species may be present. However, the many rock outcrops, cliffs, and veteran trees and snags provide suitable roosting habitats and the open woodland and grassland provide suitable foraging habitat. Given the natural conditions and habitat availability within the subject property, it is likely that bat species occur, such as the Pallid bat, Spotted bat, Townsend's Big-eared Bat, Western small-footed myotis, California myotis, Long-eared myotis, Little brown myotis, Fringed myotis, Hoary bat and Silver-haired bat. Conservation of critical habitats would help prevent potential impacts to these sensitive species. In general, these habitats occur in High to Very High ESA value areas. Section 2.4, Table 7 lists the species of bats with habitat associations within the Project Area. Additional nocturnal surveys for bats are recommended.

Although a detailed avian survey was not conducted, a diversity of bird species was observed in the Project Area, as denoted by an Asterix (**Table 6**), including additional species with the potential to occur in the Project Area.

Table 6. Summary of bird species and habitat associations within the Project Area.

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Passerine (perching bird)	Alder flycatcher	*Empidonax alnorium*	Yellow	-	Riparian
	American crow*	*Corvus brachyrhynchos*	Yellow	-	All Types
	American goldfinch*	*Carduelis tristis*	Yellow	-	All Types
	American robin*	*Turdus migratorius*	Yellow	-	All Types
	Barn swallow*	*Hirundo rustica*	**Blue**	**Threatened**	Riparian/Buildings
	Black-billed magpie*	*Pica pica*	Yellow	-	All Types
	Black-capped chickadee*	*Poecile atricapillus*	Yellow	-	Mixed and coniferous forest
	Black-headed grosbeak	*Pheucticus melanocephalus*	Yellow	-	Broadleaf/Riparian
	Brewer's blackbird	*Euphagus cyanocephalus*	Yellow	-	Grassland/forest
	Brown-headed cowbird*	*Molothrus ater*	Yellow	-	All Types
	Bullock's oriole	*Icterus galbula*	Yellow	-	Riparian/broadleaf
	Cassin's vireo*	*Vireo cassinii*	Yellow	-	Woodlands/Forest edge
	Chipping sparrow*	*Spizella passerina*	Yellow	-	Coniferous Forest
	Clark's nutcracker*	*Nucifraga columbiana*	Yellow	-	Coniferous Forest
	Common raven*	*Corvus corax*	Yellow	-	Coniferous Forest
	Dark-eyed junco*	*Junco hyemalis*	Yellow	-	Forest/Shrubland
	Dusky flycatcher*	*Empidonax oberholseri*	Yellow	-	Forest/Shrubland
	Eastern kingbird	*Tyrannus tyrannus*	Yellow	-	Forest edge / fields
	European starling*	*Sturnus vulgaris*	Exotic	-	Rural
	Golden-crowned kinglet*	*Regulus satrapa*	Yellow	-	Coniferous Forest
	Hammond's flycatcher*	*Empidonax hammondii*	Yellow	-	Mixed and Coniferous Forest
	House finch*	*Carpodacus mexicanus*	Yellow	-	Rural
	House wren	*Troglodytes aedon*	Yellow	-	Forest/Shrubland
	Lazuli bunting*	*Passerina amoena*	Yellow	-	Riparian/broadleaf
	Least flycatcher	*Empidonax minimus*	Yellow	-	Shrubland /open forest
	Marsh wren*	*Cistothorus palustris*	Yellow	-	Wetland
	Mountain bluebird	*Sialia currucoides*	Yellow	-	Forest/Shrubland
	Mountain chickadee	*Poecile gambeli*	Yellow	-	Mixed Forest
	Nashville warbler*	*Vermivora ruficapilla*	Yellow	-	Broadleaf/Riparian
	Northern shrike*	*Lanius borealis*	Yellow	-	Open forest/shrubland
	Orange-crowned warbler*	*Vermivora celata*	Yellow	-	Woodlands/riparian shrubs
	Purple finch*	*Haemorhous purpureus*	Yellow	-	Mixed and Coniferous Forest
	Pine siskin	*Carduelis pinus*	Yellow	-	Coniferous Forest
	Pygmy nuthatch*	*Sitta pygmaea*	Yellow	-	Coniferous Forest
	Red-breasted nuthatch*	*Sitta canadensis*	Yellow	-	Mixed Forest
	Red-eyed vireo	*Vireo olivaceus*	Yellow	-	Deciduous Forest
	Red-winged blackbird*	*Agelaius phoeniceus*	Yellow	-	Wetland
	Ruby-crowned kinglet*	*Regulus calendula*	Yellow	-	Mixed and Coniferous Forest
	Savannah sparrow	*Passerculus sandwichensis*	Yellow	-	Open Grassland
	Say's phoebe	*Sayornis saya*	Yellow	-	Forest/Shrubland
	Song sparrow*	*Melospiza melodia*	Yellow	-	Broadleaf/Riparian
	Spotted towhee* (formally Rufous sided towhee)	Pipilo maculatus	Yellow	-	Broadleaf and shrub thickets

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
	Swainson's thrush	*Catharus ustulatus*	Yellow	-	Coniferous Forest
	Townsend's solitaire*	*Myadestes townsendi*	Yellow	-	Coniferous Forest
	Townsend's warbler*	*Dendroica townsendi*	Yellow	-	Mixed Forest
	Tree swallow	*Iridoprocne bicolor*	Yellow	-	All habitats
	Vesper sparrow*	*Pooecetes gramineus*	Yellow	-	Shrubland/ Grassland
	Violet-green swallow*	*Tachycineta thalassina*	Yellow	-	All habitats
	Warbling vireo	*Vireo gilvus*	Yellow	-	Broadleaf/shrub thickets
	Western bluebird	*Sialia mexicana*	Yellow	-	Open grassland/forest edge
	Western meadowlark	*Sturnella neglecta*	Yellow	-	Open grassland
	Western kingbird	*Tyrannus verticalis*	Yellow	-	Forest edge/fields
	Western tanager*	*Piranga ludoviciana*	Yellow	-	Mixed and open coniferous forest
	Western wood-pewee*	*Contopus sordidulus*	Yellow	-	Mixed and Coniferous Forest
	White crowned sparrow*	*Zonotrichia leucophrys*	Yellow	-	Open grassland
	Wilson's warbler*	*Wilsonia pusilla*	Yellow	-	Broadleaf/Riparian
	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	Yellow	-	Wetland and riparian
	Yellow-rumped warbler*	*Dendroica coronata*	Yellow	-	Mixed Forest
Falconiformes (hawks, eagles, falcons)	American kestrel	*Falco sparverius*	Yellow	-	Mixed forest/open grassland
	Cooper's hawk	*Accipiter cooperii*	Yellow	Not at Risk	Mixed Forest
	Northern harrier	*Circus cyaneus*	Yellow	Not at Risk	Open Riparian / grassland
	Osprey*	*Pandion Haliaetus*	Yellow	-	Open/mature forest
	Red-tailed hawk*	*Buteo jamaicensis*	Yellow	Not at Risk	Mixed Forest
	Sharp-shinned hawk*	*Accipiter striatus*	Yellow	-	Open/mature forest
Anseriformes (ducks, swans, geese)	Mallard*	*Anas platyrhynchos*	Yellow	-	Wetland/ riparian
Ciconiiformes (Herons, new world vultures)	Great blue heron	*Ardea herodias*	**Blue**	-	Wetland
	Turkey vulture*	*Cathartes aura*	Yellow	-	All habitats
Apodiformes (Hummingbird)	Anna's hummingbird*	*Stellula calliope*	Yellow	-	Forests
	Rufous hummingbird	*Selasphorus rufus*	Yellow	-	Woodlands
Strigiformes (Owls)	Great grey owl	*Strix nebulosa*	Yellow	NAR	Coniferous Forest
	Great-horned owl*	*Bubo virginianus*	Yellow	-	Open Forest / grassland
Galliformes (Quail, Fowl, Pheasents)	California quail*	*Callipepla californica*	Yellow	-	Open shrub
	Dusky grouse	*Dendragapus obscurus*	Yellow	-	Mature open forest
	Ring-necked pheasant	*Phasianus colchicus*	Exotic	-	All habitats
	Ruffed grouse	*Bonasa umbellus*	Yellow	-	Mixed and Coniferous Forests
Piciformes (Woodpeckers)	Lewis's woodpecker*	*Melanerpes lewis*	**Blue**	**Threatened**	Woodlands
	Hairy woodpecker	*Picoides villosus*	Yellow	-	Woodlands
	Northern flicker*	*Colaptes auratus*	Yellow	-	All habitats
	Pileated woodpecker	*Dryocopus pileatus*	Yellow	-	Dense, mature forest
	Red-naped sapsucker	*Sphyrapicus nuchalis*	Yellow	-	Mixed and Coniferous Forests
Columbiformes (Pigeons, doves)	Mourning dove*	*Zenaida macroura*	Yellow	-	Open grassland

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Charadriiformes (Shorebirds)	Common snipe	*Gallinago gallinago*	Yellow	-	Wetland
	Killdeer	*Charadrius vociferus*	Yellow	-	Riparian/Open grassland
	Spotted sandpiper	*Actitis Macularia*	Yellow	-	Wetlands
Caprimulgiformes (Poorwills, nighthawks)	Common poorwill	*Phalaenoptilus nuttallii*	Yellow	Data Deficient	Forest/Shrubland
	Common nighthawk	*Chordeiles minor*	Yellow	**Threatened**	All habitats

Observed in the Project Area

2.4 Species And Ecosystems At Risk

Species at risk are identified in the context of provincial and national ranking systems. The provincial ranking system applies to species that have been assessed by the BC Conservation Data Centre (CDC). The national ranking system applies to species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The CDC mapping service was reviewed for occurrences of species at risk within one kilometer of the subject property. Query results included Species and Ecosystems at Risk polygons, Species at Risk Critical Habitat Areas, and Wildlife Species Inventory (WSI), and are as follows:

- Object ID 245323, Critical Habitat ID 110302, is associated with critical habitat for the provincially Red-listed Desert Nightsnake (*Hypsiglena chlorophaea*) and encompasses the subject property.
- Object ID 245208, Critical Habitat ID 110187, is associated with the critical habitat for the provincially Blue-listed Western Rattlesnake (*Crotalus oreganus*) and encompasses the subject property.
- Object ID 245438, Critical Habitat ID 110417, is associated with critical habitat for the provincially Blue-listed Great Basin Gophersnake (*Pituophis catenifer deserticola*) and encompasses the subject property.
- Object ID 9599987, Occurrence ID 10214, is associated with occurrence data for the provincially red-listed American Badger (*Taxidea taxus*) and encompasses the subject property.
- Object ID 9592538, Occurrence ID 12963, is associated with occurrence data for the provincially blue-listed ecological community, Common Cattail Marsh (*Typha latifolia Marsh*), found in the southern wetland on the subject property.
- Object ID 41665, Masked Occurrence (Secured CDC data in this area).

The BC Ministry of Environment's Species and Ecosystem Explorer was queried to identify plant and wildlife species potentially present in the region; search terms used to query this database are provided in the footnotes of **Tables 7 and 8,** below.

Table 7. Summary of vertebrate species at risk with the potential to occur in the Project Area based on the suitability of habitats for each species.

Species Group	Scientific Name	Common Name	Provincial Status[1]	COSEWIC Listing[2]	Suitability of Habitats in Project Area and likelihood of occurrence
Amphibians	*Anaxyrus boreas*	Western toad	Blue	SC (2012)	High
	Lithobates pipiens	Northern Leopard Frog	Red	E (2009)	Low
	Spea intermontana	Great Basin Spadefoot	Blue	T (2007)	Moderate
Birds	*Aechmophorus clarkii*	Clark's Grebe	Red	-	Nil
	Aechmophorus occidentalis	Western Grebe	Red	SC (2014)	Nil
	Aeronautes saxatalis	White-throated Swift	Blue	-	High
	Ammodramus savannarum	Grasshopper Sparrow	Red	-	Nil
	Ardea herodias herodias	Great Blue Heron, *herodias* subspecies	Blue	-	High
	Asio flammeus	Short-eared Owl	Blue	SC (Mar 2008)	Nil
	Athene cunicularia	Burrowing Owl	Red	E (Apr 2017)	Nil
	Bartramia longicauda	Upland Sandpiper	Red	-	Low
	Botaurus lentiginosus	American Bittern	Blue	-	Low
	Buteo lagopus	Rough-legged Hawk	Blue	-	Moderate
	Buteo platypterus	Broad-winged Hawk	Blue	-	Low
	Buteo swainsoni	Swainson's Hawk	Red	-	High
	Butorides virescens	Green Heron	Blue	-	Low
	Calcarius pictus	Smith's Longspur	Blue	-	Low
	Catherpes mexicanus	Canyon Wren	Blue	-	Nil
	Chondestes grammacus	Lark Sparrow	Blue	-	Low
	Chordeiles minor	Common Nighthawk	Yellow	SC (May 2018)	High
	Coccothraustes vespertinus	Evening Grosbeak	Yellow	SC (Nov 2016)	Moderate
	Coccyzus americanus	Yellow-billed Cuckoo	Red	-	Low
	Contopus cooperi	Olive-sided Flycatcher	Blue	SC (May 2018)	Moderate
	Cypseloides niger	Black Swift	Blue	E (2015)	Low
	Dolichonyx oryzivorus	Bobolink	Blue	T (2010)	Nil
	Dryobates albolarvatus	White-headed Woodpecker	Red	E (2010)	Low
	Empidonax wrightii	Gray Flycatcher	Blue	NAR (1992)	Low
	Eremophila alpestris merrilli	Horned Lark, *merrilli* subspecies	Blue	-	Low
	Euphagus carolinus	Rusty Blackbird	Blue	SC (Apr 2017)	Moderate
	Falco mexicanus	Prairie Falcon	Red	NAR (1996)	Low
	Falco peregrinus anatum	Peregrine Falcon, anatum subspecies	Red	NAR (2017)	Moderate
	Hirundo rustica	Barn Swallow	Blue	T (May 2011)	High
	Hydroprogne caspia	Caspian Tern	Blue	NAR (1999)	Low
	Icteria virens	Yellow-breasted Chat	Red	E (Nov 2011)	Low
	Larus californicus	California Gull	Blue	-	Nil
	Limnodromus griseus	Short-billed Dowitcher	Blue	--	Low
	Limosa haemastica	Hudsonian Godwit	Red	T (2019)	Low
	Megascops kennicottii macfarlanei	Western Screech-Owl, *macfarlanei* subspecies	Blue	T (May 2012)	Low
	Melanerpes lewis	Lewis's Woodpecker	Blue	T (Apr 2010)	Moderate
	Melanitta perspicillata	Surf Scoter	Blue	-	Nil
	Numenius americanus	Long-billed Curlew	Blue	SC (2011)	Nil
	Nycticorax nycticorax	Black-crowned Night-heron	Red	-	Low
	Pelecanus erythrorhynchos	American White Pelican	Red	NAR (1987)	Nil
	Phalacrocorax auritus	Double-crested Cormorant	Blue	NAR (1978)	Nil
	Phalaropus lobatus	Red-necked Phalarope	Blue	SC (2014)	Low
	Pluvialis dominica	American Golden-Plover	Blue	-	Nil

Species Group	Scientific Name	Common Name	Provincial Status[1]	COSEWIC Listing[2]	Suitability of Habitats in Project Area and likelihood of occurrence
	Podiceps nigricollis	Eared Grebe	Blue	-	Low
	Psiloscops flammeolus	Flammulated Owl	Blue	SC (Apr 2010)	Moderate
	Recurvirostra americana	American Avocet	Blue	-	Nil
	Sphyrapicus thyroideus thyroideus	Williamson's Sapsucker, thyroideus subspecies	-	E (2017)	Moderate
	Sterna forsteri	Forster's Tern	Red	DD (1996)	Nil
	Tympanuchus phasianellus columbianus	Sharp-tailed Grouse, columbianus subspecies	Blue	-	Nil
	Tyto alba	Barn Owl	Red	T (2010)	Low
Mammals	*Antrozous pallidus*	Pallid Bat	Red	T (2010)	Moderate
	Aplodontia rufa	Mountain Beaver	Yellow	SC (2012)	Low
	Corynorhinus townsendii	Townsend's Big-eared Bat	Blue	-	Low
	Euderma maculatum	Spotted Bat	Blue	SC (Nov 2014)	High
	Gulo gulo luscus	Wolverine, luscus subspecies	Blue	SC (2014)	Low
	Lasionycteris noctivagans	Silver-haired Bat	Yellow	-	Moderate
	Lasiurus cinereus	Hoary Bat	Yellow	-	Moderate
	Lepus townsendii	White-tailed Jackrabbit	Red		Nil
	Myotis californicus	Californian Myotis	Yellow		Moderate
	Myotis ciliolabrum	Western Small-footed Myotis	Blue	-	Moderate
	Myotis evotis	Long-eared Myotis	Yellow	-	Moderate
	Myotis lucifugus	Little Brown Myotis	Yellow	E (Nov 2013)	High
	Myotis thysanodes	Fringed Myotis	Blue	DD (May 2004)	High
	Oreamnos americanus	Mountain Goat	Blue	-	Nil
	Ovis canadensis	Bighorn Sheep	Blue	-	Nil
	Pekania pennanti	Fisher	Blue	-	Low
	Perognathus parvus	Columbia Plateau Pocket Mouse	Blue	-	Low
	Reithrodontomys megalotis	Western Harvest Mouse	Blue	SC (Apr 2007)	Moderate
	Sorex merriami	Merriam's Shrew	Red	-	Low
	Sorex preblei	Preble's Shrew	Red	-	Moderate
	Sylvilagus nuttallii	Nuttall's Cottontail	Blue	SC (Nov 2016)	Nil
	Taxidea taxus	American Badger	Red	E (Nov 2012)	Moderate
Reptiles	*Charina bottae*	Northern Rubber Boa	Yellow	SC (Apr 2016)	High
	Chrysemys picta pop. 2	Painted Turtle - Intermountain - Rocky Mountain Population	Blue	SC (2016)	High
	Coluber constrictor	North American Racer	Blue	T (Nov 2015)	High
	Crotalus oreganus	Western Rattlesnake	Blue	T (May 2015)	High
	Hypsiglena chlorophaea	Desert Nightsnake	Red	E (2011)	Low
	Pituophis catenifer deserticola	Gopher Snake, deserticola subspecies	Blue	T (Apr 2013)	High
	Plestiodon skiltonianus	Western Skink	Blue	SC (Nov 2014)	Moderate

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Search type: Animals AND Species Subgroups: Amphibians (Frogs, Toads, Newts & Salamanders) OR Reptiles & Turtles (Lizards, Skinks, Snakes, & Turtles) OR Birds, All Species OR Birds, Species Breeding in BC OR Mammals AND BC Conservation Status: Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern) AND 'Municipalities': Lake Country (Restricted to Red, Blue, and Legally designated species) AND Habitat Subtypes: Cliff, Conifer Forest – Dry,

Grassland, Marsh, Riparian Shrub, Riparian Forest, Rock/Sparsely Vegetated Rock, Talus, Roadside/Ditch, Urban/Suburban (Restricted to Red, Blue, and Legally designated species) AND BGC Zone: PP.

Table 8. Summary of invertebrate species at risk with the potential to occur within the subject Project Area.

Common Name	Scientific Name	Provincial Status[1]	COSEWIC Listing[2]	Likelihood of being found on the property
Attenuate Fossaria	*Galba truncatula*	Blue	-	Low
California Hairstreak	*Satyrium californica*	Blue	-	Low
Checkered Skipper	*Pyrgus communis*	Blue	-	Nil
Common Sootywing	*Pholisora catullus*	Blue	-	Low
Badlands Tiger Beetle	*Cicindela decemnotata*	Red	-	Nil
Half-moon Hairstreak	*Satyrium semiluna*	Red	E (2006)	Low
Immaculate Green Hairstreak	*Callophrys affinis*	Blue	-	Moderate
Lance-tipped Darner	*Aeshna constricta*	Blue	-	Nil
Lilac-bordered Copper	*Lycaena nivalis*	Blue	-	Moderate
Monarch	*Danaus plexippus*	Blue	E (2016)	Low
Mormon Fritillary, erinna subspecies	*Speyeria mormonia erinna*	Red	-	Moderate
Mormon Metalmark	*Apodemia mormo*	Red	E (2014)	Moderate
Nevada Skipper	*Hesperia nevada*	Blue	-	Nil
Pale Jumping-slug	*Hemphillia camelus*	Blue	-	High
Sagebrush Tiger Beetle	*Cicindela pugetana*	Blue	-	Nil
Sandhill Skipper	*Polites sabuleti*	Red	-	Moderate
Satyrium Californica	*California Hairstreak*	Blue	-	Low
Sonora Skipper	*Polites sonora*	Blue	NAR (2016)	Low
Silver-spotted Skipper, clarus subspecies	*Epargyreus clarus clarus*	Blue	-	Low
Twelve-spotted Skimmer	*Libellula pulchella*	Blue	-	Low
Viceroy	*Limenitis archippus*	Red	-	Low
Western Pondhawk	*Erythemis collocata*	Blue	-	Low

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Search type: Animals AND Species Subgroups: Invertebrates AND BC Conservation Status: Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern) AND Regional Districts: Central Okanagan (CORD) (Restricted to Red, Blue, and Legally designated species) AND Habitat Subtypes: Cliff, Conifer Forest – Dry, Grassland, Marsh, Riparian Shrub, Riparian Forest, Rock/Sparsely Vegetated Rock, Talus, Roadside/Ditch, Urban/Suburban (Restricted to Red, Blue, and Legally designated species) AND BGC Zone: PP.

2.5 Environmentally Sensitive Areas (ESAs)

An evaluation rubric was derived from the Regional District of Central Okanagan Terms of Reference (RDCO, 2006) used to perform an Environmental Sensitivity (ES) analysis to categorize the defined ecosystem/habitat polygons in the Project Area based on the degree of environmental sensitivity. Evaluation criteria included: provincial CDC status (i.e., Red or Blue listed), rare and endangered species occurrence potential, landscape condition (i.e., connectivity, fragmentation), successional stage, regional rarity, relative biodiversity, and level of disturbance.

The four categories of environmental sensitivity are described below along with relative retention expectations. The degree of retention is based on the continuous (0-100) score that each polygon received in the ES analysis:

- **Very High (ESA 1):** These areas represent extremely high ecological value and typically contain rare or critical habitat areas for sensitive or at-risk species, undisturbed or pristine ecosystems and habitats, and biodiversity hotspots (e.g., wetlands, old growth forest). They substantially contribute to the regional habitat function and connectivity and are highest priority for conservation.
    - **80 – 100% retention:** Core conservation areas. Allocation for development depends on identification of non–sensitive sites e.g. for minimal impact road crossings. If development should occur within these areas (Only after it proves impossible or impractical to maintain the same level of ecological function) compensation will promote no net loss to the habitat (typically with a 3:1 replacement of equivalent functioning habitat).
- **High (ESA 2):** These areas contribute to the regional biodiversity and connectivity of the surrounding landscape but lack critical habitats for at risk species (e.g., riparian areas, mature forest). Development should generally avoid these areas to conserve the important features or to allow potential progression to the Very High category (e.g., mature forest becoming old growth). Encroachment into these areas should be compensated for by restoration in other areas to work towards achieving a no net loss of High value habitats.
    - **40 – 80% retention:** Low intensity public use, cluster development to maintain the function of site. If development is pursued in these areas portions of the habitat should be retained and integrated to maintain the contiguous nature of the landscape. Some loss to these ESAs can be offset by habitat improvements to the remaining natural areas found on property.
- **Moderate (ESA 3):** Ecosystems of moderate significance represent disturbed habitats or fragmented features with the potential to return to High value through natural succession (e.g., young or fragmented forest, degraded habitats). Moderate areas contribute to the diversity of the landscape; however, their condition and adjacency may limit significant function. These areas will benefit from restoration and enhancement activities which will facilitate succession to higher value habitats.
    - **20 – 40% retention:** Important features or remnant stands/sites with intrinsic ecological value. Maintain important features within (e.g., tree patches, rock outcroppings, drainages and corridors). If development is pursued in these areas the impacts should be offset by habitat improvements in other more sensitive natural areas found on property.
- **Low (ESA 4):** These areas contribute little to no value with regard to habitat diversity and have limited potential for supporting significant wildlife (e.g., heavily impacted or disturbed sites). Development is typically focused on these areas based on their limited contribution to regional biodiversity and limited capacity to return to high value through natural succession. These areas may be restored through intensive remediation and management practices.
    - **0 – 20% retention**: Development is encouraged to be focused in these areas. Retained areas may offer some opportunity for some ecological function and/or enhancement/restoration.

The ESA composition of the Project Area is summarized in **Table 9** and depicted on **Figure 3**.

Table 9. Percent composition of ESAs within the Project Area.

ESA Value	ESA Area (m^2)	Percentage of Project Area (%)
Very High (ESA 1)	8,515	0.6
High (ESA 2)	916,656	69
Moderate (ESA 3)	402,469	30
Low (ESA 4)	6,914	0.4
Total	**1,334,554**	**100**

Environmental sensitivity analysis indicates that 0.4% of the Project Area is represented by Low (ESA 4) communities, based upon the presence of exposed soils and encroachment of invasive plant species (**Figure 3**). 30% of the Project Area is represented by Moderate (ESA 3) communities made up of recently harvested pole saplings, based upon non-critical open and closed woodland and grassland. 69% of the Project Area is represented by High (ESA 2) communities, based upon critical open woodland and sparsely vegetated features such as cliffs and rocky outcrops. 0.6% of the Project Area is represented by Very High (ESA 1) communities, based upon critical habitat features of riparian and open water ponds and wetlands. These Very High communities are mostly concentrated in the central region of the Project Area.

3.0 IMPACT ASSESSMENT

The proposed development will impact approximately 42% (138 acres) of the Project Area (**Table 10**). About 89 acres (27%) of the development occurs within High-value ESAs and 48 acres (14%) of the development occurs in Moderate ESAs. Very High and Low ESAs had nominal losses less than 1%. The Project plan aims to retain as much of ESA 2 as possible, with development focused as much as possible in areas of ESA 3 (**Figure 4**).

The proposed development will result in the loss of provincially Red-listed "endangered or threatened" (DM/Fl07, FB, PF, SA) and Blue-listed "special concern" (DS, WB, PT, PW, SP, CT/Wm05, BM/Wm06) ecological communities within the Project Area. Retention should be targeted toward High ESAs and associated ecosystems. Development in the Project Area should focus on areas with trees of structural stage 4 (pole/sapling), and seek to retain and protect areas of intact grasslands, mature/veteran/wildlife trees, and habitat features such as rock outcrops/talus, large woody debris (LWD) and snags wherever possible.

Table 10. Impact assessment of proposed development on identified ESAs

Environmental Sensitivity Category	Total (m^2)	Undisturbed Area (outside development) (m^2)	Disturbed Area (within development) (m^2)	ESA relative loss (%)
Very High (ESA 1)	8,515	5,677	2,838	<1%
High (ESA 2)	916,656	558,219	358,438	27%
Moderate (ESA 3)	402,469	208,999	193,470	14%
Low (ESA 4)	6,914	4,553	2,361	<1%
Total	**1,334,554**	**777,448**	**557,106**	**42%**

The following section summarizes the potential environmental impacts associated with the Project. Potential environmental impacts include:

- Loss of and perforation and fragmentation of coniferous woodland and associated habitats.
- Potential to directly or indirectly impact wildlife and wildlife habitat during earthworks, roadworks and tree clearing, including disruption of migration, breeding, or other behavior as a result of noise, impacts to air quality, and alterations to existing wildlife habitat and cover.
- Potential for water quality impairments to the pond and wetland habitats from improper stormwater management.
- Potential for the release of deleterious substances (e.g., fuel, oil, hydraulic fluid) to the environment during clearing, grubbing, and site servicing works or as a result of improper storage, equipment re-fueling, and/or poorly maintained equipment.
- Disturbance beyond the proposed development footprint if the areas are not clearly and accurately delineated in the field prior to initiating construction activities.
- Potential to introduce or facilitate the spread of non-native and invasive plant species resulting from ground disturbance.
- While we have estimated 42% for the extent of disturbance, actual disturbance may be slightly greater. All attempts should be made to ensure that works do not greatly exceed the extent of disturbance.

4.0 MITIGATION MEASURES AND RECOMMENDATIONS

In general, connectivity between the adjacent wetland communities must be maintained, therefore disturbance should be limited. The development footprint occurs primarily within High (ESA 2) and Moderate (ESA 3) ESAs, and to a lesser extent ESA 1 (Very High) and ESA 4 (Low). *See Section 4.7 for more detailed mitigation measures regarding connectivity between wetland habitats and wildlife crossings.*

Recommendations to avoid or minimize the potential impacts that may arise during the proposed construction works are summarized below and based on Best Management Practices (BMP).

- Disturbance beyond the proposed development footprint should be avoided. Clearly delineate with flagging and snow fence (where appropriate) the development extents to mitigate the risk of clearing/disturbance beyond what has been indicated in the development plan.
- Any applicable permitting / approvals must be obtained from the District of Lake Country and the Province of BC prior to construction activities within the Project Area. Copies of permits/approvals and this report must be kept onsite at all times.
- Any applicable permitting / approvals must be obtained from the District of Lake Country prior to construction activities within the Project Area. Copies of permits/approvals and this report must be kept onsite at all times.

- Construction activities must be contained within the development footprint within the Project Area.
- It is important that the civil contractor and environmental monitor have a startup meeting to discuss earthworks, as this stage of construction poses the greatest risk.
- All works should generally conform to the following Best Management Practices for British Columbia:
  - Develop with Care Environmental Guidelines for Urban and Rural Land Development (BC MoE 2014)
  - Best Management Practices for Recreational Activities on Grasslands in the Thompson and Okanagan Basins (BC MoEWLAP 2004)
  - Best Management Practices for Amphibian and Reptile Salvages in British Columbia (BC MoE 2016)
  - Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (BC MoE 2014)
  - Guidelines for Raptor Conservation during Urban and Rural Land Development in British Columbia (BC MoE 2013)
  - Best Management Practices Guidelines for Bats in British Columbia (BC MoE 2016)
  - Standards and Best Management Practices for Instream Works (BC MoEWLAP 2004)

4.1 Clearing and Grubbing

Clearing, stripping, and grubbing limits must be clearly marked in the field prior to construction and minimized wherever possible. Unnecessary impacts to native vegetation and soils must always be avoided. Important wildlife habitat, including veteran trees, snags, and other important features, will be identified by the environmental monitor (EM) prior to construction works. Native vegetation, including trees, shrubs, and groundcover, should be retained to mitigate the establishment of invasive plants and to maintain the existing ecological value sustained within the Project Area.

- A meeting between the EM and civil contractors must occur prior to any earthworks. The development extents, general practices, and full extent of cuts and fills should be discussed, to try and ensure that the works are generally consistent with this impact statement.
- Flagging or snow fencing must be used to clearly delineate the construction disturbance limits prior to the commencement will also be used to clearly identify setbacks and buffers associated with other identified environmentally sensitive areas (e.g., wildlife trees, nests).
- **Section 34 of the *Wildlife Act* protects all birds and their eggs, and Section 34(c) protects their nests while they are occupied by a bird or egg**.
  - If tree or shrub clearing activities are required during the identified avian nesting period (i.e., March 15 to August 15), pre-clearing surveys must be conducted by the EM to identify active nests and other critical habitat features, such as burrows, dens,

etc. Surveys will focus on songbird, raptor and heron nests, stick nests, and snags and cavities that may be used over multiple years or year-round (i.e., winter resident and hibernating species).

- If active nests are found within the clearing limits, a buffer will be established around the nest until such time that the EM can determine that nest has become inactive. The size of the buffer will depend on the species and nature of the surrounding habitat. Buffer sizes will generally follow provincial BMP guidelines or other accepted protocol (e.g., Environment Canada). In general, a minimum 20 m buffer will be established around songbird nests or other non-sensitive (i.e., not at risk) species.
- Clearing and other construction activities must be conducted within 72 hours following the completion of the pre-clearing nest surveys. If works are not conducted in that time, the nest surveys are considered to have expired and a follow-up survey will be completed to ensure that no new nests have been constructed.

- Prevention of the spread of non-native and invasive species can be achieved by limiting disturbance to soils and native vegetation where possible. Areas that have previously been disturbed should be restored with native plantings or grass seeding. Infestation areas must be controlled with regular manual removal of weeds (e.g., mowing, pulling).
- In the event that land and/or natural vegetation is disturbed or damaged beyond the development footprint area, these areas will be restored and/or replanted with plant material indigenous to the area under the direction of the EM.
- Exposed soils must be seeded immediately following any activities that result in disturbance to native vegetation and soils. Grass seed mixes must be comprised of native species, appropriate for the environmental conditions and certified as Canada #1 Grade by Agriculture Canada to minimize the weed seed count. A recommended seed mix can be found in **Table 11**.

Table 11. Restoration Grass Seed mix

Seed Weight	Botanical Name	Common Name
40%	*Pseudoroegneria spicata*	Bluebunch wheatgrass
25%	*Festuca campestris*	Rough fescue
15%	*Festuca idahoensis*	Idaho fescue
10%	*Lolium perenne*	Perennial ryegrass
5%	*Poa secunda*	Sandberg bluegrass
4%	*Koeleria macrantha*	Junegrass
1%	*Poa compressa*	Canada bluegrass

4.2 Tree Protection

A large number of veteran trees, wildlife trees, and snags were noted throughout the Project Area, which are known to provide valuable habitat to multiple species, such as blue-listed Lewis's Woodpecker in the region. Snags and veteran wildlife trees should be retained where possible as they provide nesting opportunities for various bird species and potential roosts for bats. Coarse woody debris is scattered on the forest floor throughout the Project Area,

providing habitat for various small mammals, herptiles, and other wildlife. Retention of some large woody debris (LWD) is recommended for the valuable wildlife habitat it provides.

Specific measures should be made for protecting tree species within the property, particularly those of high value such as mature/veteran trees, wildlife trees, and large snags. Since the majority of the trees are outside of the limit of disturbance, it is anticipated that there should be minimal disturbance to these trees, and that efforts will be made to retain the trees that do occur within development. The following recommendations are proposed for any future development proposed within the property:

- Trees with high wildlife value, such as veteran trees (mature trees greater than 60cm DBH) and snags (standing dead trees with cavities, coarse woody debris), must be conserved for their habitat value for a range of species including birds, bats, and other small mammals.

- Equipment/machinery used must not be operated or stored within the drip line of the trees and equipment must not come into contact with the tree, which could result in physical damage to the bark or limbs.
- If roots are damaged or exposed with excavation activities, the roots must be cut clean with a saw to minimize the potential for disease and mortality.
- Soil and other construction materials must not be stockpiled adjacent the tree boles or beneath the tree dripline.

4.3 Erosion and Sediment Control

The mitigation described below should be followed as required to provide erosion and sediment control during future construction works.

- Works involving ground disturbance should not be conducted during heavy rains wherever feasible to reduce the potential for sediment and erosion issues. Exposed soils and stockpiles must be stabilized and covered where appropriate using geotextile fabric, poly sheeting, tarps, or other suitable materials to reduce the potential for erosion and/or mobilization of sediment resulting from rainfall, seepage, or other sources of surface water flows. Exposed embankments shall be covered and stabilized as soon as possible.

- At the beginning of construction, limits of disturbance should be reviewed with the QEP and contractor to determine necessary locations of silt fence to mitigate the risk of siltation to natural areas and specifically Okanagan Lake. Silt fence must be staked into the ground and trenched (minimum of 10 cm) to prevent flow underneath the fence. Alternatives to silt fencing include earthen berms, or other associated techniques and can be utilized under the direction of the EM, where appropriate to do so.

- Erosion and sediment control measures should be installed at all low points, where water may concentrate during a storm event. These areas are likely ever changing on an active construction site and should be field reviewed by the Environmental Monitor at a minimum of every two weeks. Field inspections should focus on implementation of key erosion and sediment control techniques best suites to mitigating erosion or

sediment release from or within the construction footprint. Recommendations of the EM must be implemented within 24 hours of being made, or prior to any foreseen storm events, whichever occurs first.

- It is the contractor's responsibility to inspect all mitigation measures daily and additional measures will be installed, maintained, and repaired or replaced as required using a field-fit, adaptive management approach.

- The contractor should have the following erosion and sediment control measures readily available onsite:

    - Several rolls of non-woven geotextile fabric of various grades

    - Several rolls of silt fencing with sufficient wooden stakes to allow for installation

    - Pumps of appropriate size and hoses

    - Tarps, poly sheeting and sandbags

- Other suitable erosion control measures may include; slope drains and interceptor ditches, earthed berms, check dams, grass seeding, and mulch. Hay bales and straw are a wildlife attractant and are not desirable mitigation measures based on the potential to disperse non-native and invasive plant material.

- Stockpiled soils and fill material must be stored away (i.e., >30 m) from watercourses, ditches, and other aquatic habitats to prevent sediment laden runoff. Stockpiles must not be allowed to slough beyond the disturbance limits at any time.

- Road surfaces adjacent to the project area must be kept clean and free of fine materials. Sediment accumulation upon the road surfaces must be removed (i.e., swept or scraped) on a regular basis and disposed of appropriately.

- The release of silt, sediment, sediment-laden water, or any other deleterious substance into any ditch, watercourse, ravine, or other drainage feature must be prevented at all times. Similarly, there is to be no sediment release into areas of vegetation growth or sensitive areas in levels that would adversely alter growing or hydraulic conditions.

- During construction, the EM should review all erosion and sediment control measures at least every 2 weeks, although high risk work such as work below the PNB of watercourses will likely require more frequent if not full-time monitoring. A site inspection should also occur prior to foreseen weather events that may cause problems, such as prior to winter freeze up or prior to spring thaw as examples.

- The contractor must implement all erosion and sediment control recommendations within a 24-hour period to ensure that the site is stable.

- If any concrete works are required; sediments, debris, concrete, concrete fines, or wash water associated with pouring of the concrete must not come into contact with any ditching, watercourse or municipal storm drain system.

- Excess concrete from pouring must be taken offsite and disposed of or recycled appropriately and must not be discarded or deposited within the subject property or adjacent lands.

- Ensure that onsite machinery is in good operating condition, clean and free of leaks, excess oil or grease. Any equipment that will be used for works below the PNB must only use environmentally friendly hydraulic fluid.

- No equipment fueling or servicing is to be undertaken within 30 m of any watercourses/wetlands whenever possible.

- Silt fencing will be installed as directed by the EM in a field-fit manner, as required. Silt fence must be staked into the ground and trenched a minimum of 15 cm to prevent flow underneath the fence and must remain taut to prevent material from moving over the fence. Silt fencing should contain sufficient storage capacity to collect runoff and sediment deposition during storm events. Silt fencing will be monitored on a regular basis and any damages or areas where the integrity and function of the fencing has been compromised should be repaired or replaced promptly. Silt fence must remain in place where required until the completion of the project.

- Erosion and sediment control should incorporate the measures described below to mitigate risks during construction works. The plan is generally based upon provincial BMPs and other specifications and includes the following principles:

    - Construction works should, when possible, be conducted during periods of warm, dry weather with minimal forecasted precipitation;

    - Construction works should be scheduled to reduce the overall amount of time soils are exposed;

    - Exposed soils should be hydroseeded as soon as possible following excavation to prevent invasive species establishment;

    - Natural drainage patterns should be maintained where possible;

    - Existing native vegetation should be retained where possible;

    - Stormwater and sediment-laden runoff should be directed away from exposed soils within the construction area;

    - Sediment-laden water should not be directed to any surface water feature, gully, or other drainage system;

    - Slopes should be stabilized as soon as possible following disturbance;

    - Exposed soils along slopes must be stabilized and covered where appropriate using geotextile fabric, poly sheeting, tarps, or other suitable materials to reduce the potential for erosion resulting from rainfall, seepage, or other unexpected causes;

- Other erosion and sediment control measures should be implemented, inspected, maintained, and/or replaced as required to provide appropriate mitigation.

4.4 Emergency Spill/Response Plan

Spills of deleterious substances can be prevented through awareness of the potential for negative impacts and with responsible housekeeping practices onsite. Maintenance of a clean site and the proper use, storage and disposal of deleterious liquids and their containers are important to mitigate the potentially harmful effects of spills and/or leaks. The following BMP are adapted from Chilibeck *et al*. (1992) to provide guidance in the control of deleterious substances.

- Ensure that onsite machinery is in good operating condition, clean, and free of leaks, excess oil or grease.
- Equipment and tools used for concrete works must be washed offsite away from any watercourses. Concrete waste water must not be washed into any watercourse or the storm water system (i.e. must not be poured in a location that drains into municipal catch basins and subsequently into watercourses).
- Spills occurring on dry land will be contained, scraped and disposed of appropriately. Contaminated material will be stored on tarps and covered to prevent mobilization and will be disposed of in accordance with the *Environmental Management Act*.
- Copies of contact phone numbers for notification of all of the required authorities in the event of a spill/emergency response will be kept posted and clearly visible onsite.
- Spill containment kits should be kept readily available on-site during construction in case of the accidental release of a deleterious substance to the environment. Any spills of a reportable amount of a toxic substance must be immediately reported to Ecoscape at 250-491-7337 and the **Emergency Management BC's 24-hour hotline at 1-800-663-3456.**

4.5 Stormwater Management and Wetland Protection

- No untreated stormwater should be discharged to any natural ponds, wetlands, or riparian habitats. Any discharges to a waterbody will require a Section 11 under the Water Sustainability Act.
- Wetland habitats within the subject property provide critical habitat for small mammals, snakes, amphibians, and a broad diversity of invertebrate fauna, which play an important role in ecological processes. Inputs of untreated stormwater to any of the wetlands may have negative effects on these communities. Stormwater runoff should not be directly discharged into any of the existing wetlands / shallow open water areas due to the potential for degrading the aquatic communities.
- The stormwater management plan for the development must aim at maintaining existing drainage patterns, rates and flows without directly introducing runoff into aquatic environments. Run-off flows must not be directed away from natural receiving basins, which may result in a loss of wetland and moisture receiving ecosystems. This can be accomplished by the creation of a stormwater management plan, incorporating

guidelines from Chilibeck (1992) and the BC Stormwater Planning Guidebook. In particular, BMP practices typically emphasize the use of in-ground stormwater disposal methods to direct stormwater runoff into underlying soils.

- Turbid water management may be required as sediment from excavations has the potential to enter the wetland system during works. If dirty water is encountered, the following recommendations are to be implemented:

- At the point of discharge, appropriate erosion and sediment control measures must be established to prevent erosion.

- Water quality sampling will be conducted in situ with a portable HACH 2100P Turbidimeter to measure ambient Nephelometric Turbidity Units (NTU) and/or a Hanna HI98129 portable pH meter. If sampling of total suspended solids (TSS) is deemed necessary, samples will be collected in 1 litre bottles and analyzed ex situ at a reputable laboratory (e.g., CARO). Other alternative, calibrated meters or laboratories may also be used. Turbidity levels will be monitored as required and must conform to provincial guidelines;

- During clear flow periods, induced turbidity should not exceed 8 NTU above background levels at any given time and no more than an average of 2 NTU above background levels over a 30-day period;

- During turbid flow periods, induced turbidity should not exceed background levels by more than 5 NTU at any time when background turbidity is between 8 and 50 NTU. When background exceeds 50 NTU, turbidity should not be increased by more than 10% of the measured background level at any one time.

- pH levels will also be monitored as required. Levels must conform to ministry of environment and climate change strategy (ENV) guidelines (2018).

- Emergency measures must be implemented if downstream pH has changed more than 1.0 pH unit, measured to an accuracy of +/- 0.2 pH units from the background level, or is recorded to be below 6.5 or above 9.0 pH units.

4.6 Air Quality & Greenhouse Gas Reduction

Dust control can be achieved by reducing the spatial extents and amount of time that soils are exposed to construction activities. Reducing traffic speed and volume can also reduce dust concerns. Surface and air movement of smoke and dust during project activities can be mitigated through preventive measures and design criteria.

- Where suitable, exposed soils should be watered as required to suppress dust. Sediment-laden runoff water must not be conveyed to the storm drain system, off the project site, or over steep slopes. Oil and other petroleum products must not be used for dust suppression.

- Idle time of construction equipment and contractor vehicles should be kept to a minimum to reduce the release of greenhouse gases. The contractor should inform

and educate employees and sub-contractors on the importance of minimizing idling time and develop guidelines to direct the practice of reducing unnecessary idling.

- If possible, alternate energy sources should be considered during development of the site, such as solar panels and ground source heating and cooling. Other options for greenhouse gas reducing features include rainwater recycling systems, landscaping with native species, and utilizing water efficient products.
- All road surfaces along Okanagan Centre Road East, Tyndall Road, and other access roads must be kept clean and free of fine materials (i.e., swept or scraped) regularly to prevent the increase of airborne particulate matter.

Table 12 outlines the Greenhouse Gas Reduction measures recommended by the District of Lake Country's OCP. The checklist is required to be completed for Development Permit applications.

Table 12. DLC GHG Reduction and Conservation Factors Checklist			
GHG Factor and Description	**Yes**	**No**	**N/A**
Has site density been maximized for subdivisions?	X		
Has the building footprint been minimized in order to allow for maximum green space?	X		
Have lots been oriented to maximize solar orientation of building envelopes? Have buildings been oriented to maximize solar gain? (Partial)	X	X	
Is the subdivision laid out to minimize the length and amount of infrastructure (such as sewer & water lines and roads)?	X		
Does the layout allow for alternative transportation options and transit?	X		
Is the subdivision laid out to maximize site connectivity to nearby amenities and services?	X		
Do the materials and colors used in building construction minimizer heat absorption? Is the roof not a dark color?	X		
Are large windows sheltered by overhands which maximize solar input during winter months?	X		
Do proposed buildings incorporate green roofs, living walls or other measures to reduce heat gains cause by hard surfaces?		X	
Are alternative energy sources being proposed in large scale structures?			X
Do buildings have a south oriented roof to allow for future use of solar panels? (Partial)	X	X	
Are there opportunities for natural ventilation and airflow incorporated into the building?	X		
Do building materials encourage thermal massing and seasonal thermal energy storage?		X	
Are building envelopes well sealed and energy efficient?	X		
Is vegetation low maintenance and require minimal irrigation?	X		
Is the enhanced landscaping located along the south and west facing parcel boundaries to create shade?		X	
Is rainwater recycling included in landscape designs?		X	
Have porous material been maximized throughout the landscaping?	X		
Do water features use recirculation systems as opposed to once through systems?			X
Are opportunities for local food production and public food gardens incorporated into larger developments and subdivisions?			X

4.7 Habitat Remediation and Enhancement

The loss of rare, sensitive, at risk and core habitats from construction activities must be carefully considered prior to development. Habitat loss has a cumulative effect on wildlife species and ecological communities which may lead to negative effects to identified species at risk.

The noise, vibrations, and pollution associated with construction activities have the potential to disrupt important wildlife activities including migrating, foraging, and breeding. Timing and proximity to environmentally sensitive areas that are more likely to support sensitive species are important considerations to reduce impacts to wildlife during both the construction and occupation stages of the development.

Construction activities have the potential to cause direct harm to wildlife. In particular, small wildlife species that are less motile or that tend to seek refuge in snags, coarse woody debris, or within rock outcrops, talus, or other natural debris, are vulnerable as they are less likely to vacate the subject property prior to construction activities taking place. All wildlife, including bird and small mammal nests that occur along the ground, in live and dead trees, or within rock crevices, are protected by the provincial Wildlife Act and federal Migratory Birds Convention Act. Raptor and heron nests that are used over numerous breeding seasons are protected whether they are active or not.

Snags and Wildlife boxes

- Bird houses should be installed on trees throughout the Project Area, particularly in areas where wildlife trees or snags have been removed. These bird houses are to compensate for lost cavity nesting opportunities due to tree removal. Bird box design and installation are specific to the bird species. The number and location of bird boxes will be determined by the QEP at the time of construction startup.
- A list of species-specific designs and considerations can be found at:

  The Cornell Lab of Ornithology: Nestwatch

  The Canadian Wildlife Federation
- Bat boxes should be installed adjacent to ponds. The exact number and locations will be established by the QEP at the time of construction startup. It is recommended that bat boxes be installed on poles in open areas to maximize the opportunity for bats to find the boxes. Bat box design and installation should conform specifications outlined in Building Homes for Bats: A Guide for Bat Houses in British Columbia (2015), which can be found at:

  Community Bat Programs in BC

  An example of bird and bat box designs has been included as **Appendix 5**.

Revegetation

- Invasive Species Management and Restoration are addressed in Sections 4.9 and 4.12, respectively.
- Weed management and erosion control must occur in all areas disturbed during development. At a minimum, hydro-seed or loose grass seed must be applied to re-vegetate areas that have been disturbed.

- Hydroseed and/or grass seed with mulch must be applied to exposed soils following construction. Grass seed mixes should be native to the Okanagan and certified as Canada #1 Grade by Agriculture Canada to minimize the weed seed count. Fodder species such as clover and alfalfa must not be included in the mixture. The seed mixture must contain native species appropriate for the ecological conditions and will be reviewed by the EM prior to application. Grass seed should not be applied during periods of extremely hot and/or dry weather (i.e., July and August).
- If additional disturbance occurs outside the development footprint, these areas will need to be addressed by the EM and restored with native plantings and/or hydroseeding.
- Retention of some coarse woody debris within the Project Area is recommended for the wildlife habitat value and slope stabilization it provides.
- Plant salvages of existing native species within the limit of disturbance should be considered for future restoration of the Project Area (**Appendix 6**).

Wildlife Surveys

At the start of each phase of the Project, wildlife inventories and salvages (where applicable) are required prior to development commencing in order to survey each phase for species occurrences and habitat features. Ideally, surveys will be conducted in the spring and the fall when feasible.

Avoidance of Hibernaculum

Habitat for sensitive and at-risk herptiles including the Great Basin Gopher Snake, North American Racer, Western Rattlesnake and Rubber Boa were identified onsite during the field inventory. The rock outcrops and talus slopes in the Project Area, particularly any south and west facing slopes, provide ideal habitat for snakes and must be given careful consideration to avoid conflicts and habitat destruction. Additional spring snake surveys are recommended to document locations of critical habitat for these species that should be retained within the Project Area. Movement corridors and retention areas should focus on retention of critical snake habitat and linkages to adjacent natural areas. Should snakes be discovered during construction, Ecoscape must be contacted immediately to conduct a snake salvage. The Province has issued a draft BMP document of Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia (**Appendix 7**), which will provide additional guidance and recommendations for the Project.

Western Rattlesnake habitat is believed to be strongly associated with rock outcrops, talus slopes, shrub-steppe / grassland, riparian and ponderosa pine habitats (SIRART 2008). Winter hibernacula (dens) are typically located within south facing rock outcrop associated with talus slopes which also provide important basking habitat in the spring and fall (SIRART, 2008). As such, these habitats should be avoided by the development and connectivity maintained with adjacent habitats.

The ESA mapping (**Figure 3**) provided by Ecoscape is meant to reflect the important association of talus and rock outcrop habitats and to maintain suitable habitats associated with the at risk herptile occurrences.

Other sensitive snakes known to occur or that have the potential to occur within the subject property, including gopher snakes, racers, western skink, rubber boa, and great-basin spadefoot have similar habitat associations as the western rattlesnake (e.g., talus, rock outcrop, hibernacula) (SIRART 2008). As such, the avoidance of suitable habitats and mitigation of

development activities for the western rattlesnake will benefit these species as well. Avoidance of the most suitable habitats and maintenance of connectivity with adjacent lands will also prevent the isolation of critical habitats and fragmentation of the subject property.

In general, the development planning should attempt to avoid rock outcrops, talus, cliffs, and other rocky and sparsely vegetated sites that are suitable for important life history stages for the sensitive reptile species identified within the subject property (MELP 1999; MWLAP 2004a; MWLAP 2004b). Coarse woody debris and large rocks should be conserved where possible. Wetland, riparian, and other aquatic habitats should be avoided to conserve the critical habitat they provide to identified reptile and amphibian species.

Contractors, construction workers, property owners and the general public should be educated about the presence of the sensitive herptile species that occur within the subject property and shown how to limit disturbance and re-locate individuals if necessary. Signage should be installed informing the public / property owners about the presence of these species and the importance of protecting them and their habitat.

Road planning and construction should avoid maximum retention areas and movement corridors. Construction activities near critical habitats should be avoided between April and October when snakes are most active (SIRART 2008). Roads are known to lead to snake mortalities from basking or crossing (MWLAP 2004b).

Known locations of sensitive herptile species should be monitored during development and construction and salvage of individuals conducted as required by QEP's to limit disturbance and mortality.

Ecosystem Connectivity and Maintenance of Movement Corridors

Connectivity between occurrence locations and suitable habitats must be maintained within the Project Area. This will prevent the arbitrary buffering of potentially less important habitat and instead focus on critical habitats required to sustain the species within or adjacent to the subject property, such as talus slopes and rocky outcrops that provide hibernacula and denning areas and other areas suitable for migratory and dispersal corridors.

Constructed roadways within the subject property have the potential to impact wildlife movement. Habitat fragmentation as a result of development affects numerous ecological processes across multiple spatial and temporal scales, including shifts in habitat use, altered population dynamics of species, and changes in species compositions. Fragmentation of habitats can ultimately result in displacement or the local extirpation (i.e., extinction at a local scale) of species. Connectivity between natural areas should be maintained to preserve habitat for resident species.

In order to maintain connectivity at the site, the development designs should incorporate, where feasible, exclusion fencing (e.g., drift fence and funnel fencing) and customized crossings (e.g., ecopassage tunnels, minimum 600 box culverts, and arch culverts) at key corridors and habitat linkages where road crossings may lead to wildlife mortalities or reduced migration potential. Proposed areas for these crossing can be found in **Figure 5**. Ecoscape must review the crossing designs to ensure an adequate size is provided and ensure natural ambient light is provided throughout the length of the crossing. The wildlife crossings must be wildlife specific and not a dual purpose wildlife crossing / stormwater management culvert. The proposed crossings providing a movement corridor between development phases must be an adequate size to allow larger mammals to travel through the crossing.

Example designs for an ecopassage can be found at http://www.acowildlife.us/at500.html. Example of designs for wildlife fencing can be found at http://www.acowildlife.us/fence.html.

Culverts must be designed to allow for natural ambient light throughout the culvert and should be specific for wildlife and not a dual purpose wildlife / stormwater culvert. The exact design and size of the crossings must be reviewed and approved by Ecoscape prior to implementation. Upon completion of the spring snake surveys a review of the proposed culvert locations will be undertaken with adjustment in the number of culverts and locations completed by Ecoscape.

In addition to wildlife crossings, signage is recommended along the roadsides in the Project Area and the greater Lakestone development to raise public awareness and facilitate education, and discourage human disturbance during and post-construction of habitat features, ecosystems, and wildlife.

4.8 Rockfall Mitigation

- The prominent cliff areas should be designated as No Disturb Areas to protect important habitat for bats including the federally endangered little brown myotis. Therefore, requirements for rockfall mitigation in these cliff habitats has been mitigated by avoiding development beneath.
- Rockfall mitigation will be required in areas of proposed development near cliff and talus features. Rock scaling (by hand) should be conservative – taking care to preserve cracks and fissures that do not present imminent risk and enhancing downslope secondary stop measures to intercept any potential rockfall. A more detailed rockfall mitigation strategy will be discussed at the time of construction startup.
- Rock scaling and any additional measures should be reviewed onsite with the environmental monitor/biologist prior to initiation.

4.9 Invasive Species Management

A noxious weed management plan for each phase of the Project must be prepared by a Qualified Environmental Professional prior to development. Ahead of detailed designs for each phase, general practices include:

- Ongoing invasive species control will be required within any areas with exposed/disturbed soils in the first few years until vegetation becomes established. Species that are aggressive have the potential to outcompete native species.
- Invasive plant species should be hand pulled or brushed/mowed using mechanical means. Mowing or brushing of invasive plant species should only occur before they have flowered or gone to seed. The use of chemical treatments is not recommended, particularly since herbicides can kill native species and due to plantings associated with stormwater runoff which enters watercourses untreated.
- The contractor will ensure that all equipment and vehicles are washed and free of weed seeds prior to mobilization and de-mobilization. Vehicles and equipment should not be stored, parked, or staged within weed infested areas if possible. Contractor clothing

should also be inspected daily for signs of weed seeds. If found, weed seeds should be disposed of in a contained refuse bin for offsite disposal.

- Care must be taken to ensure that invasive species removal does not impact existing or planted native tree and shrub species.
- Invasive plant species must be disposed of in a landfill; however, invasive species material must not be composted in the yard waste section of the landfill. Invasive plant species must not be transported to or deposited in other natural areas.

4.10 Site Clean Up

- Effective site cleanup and restoration refers to returning a site to a state resembling the original habitat characteristics. Protection of existing ecosystems is generally much more efficient than ecosystem enhancement and restoration following construction. As per the District of Lake Country OCP, ESA 3 areas will benefit from restoration and enhancement activities which will facilitate succession to higher value habitats.
- Silt fencing and other temporary mitigation features must be removed upon substantial completion of construction works. All equipment, supplies, waste, and other non-biodegradable construction materials must be removed from the site following completion of construction activities.

4.11 Environmental Monitoring

An environmental monitor (EM) should be retained during construction activities at the discretion of the District of Lake Country. The EM will be an appropriately qualified environmental professional (QEP) to guide and document compliance with BMPs, mitigation measures, and other recommendations and provide guidance for implementation of best practices (e.g., erosion and sediment control, restoration) throughout each phase of construction. In the event that greater disturbance occurs due to unforeseen circumstances, the EM will recommend measures to protect/restore the natural integrity of the site. If the District of Lake Country requires monitoring, the following schedule is recommended;

- For each phase of development, a pre-construction meeting should be held between the EM and the contractor(s) undertaking the work onsite to ensure a common understanding of the mitigation measures and best practices required for the project. Copies of relevant permits and this report must be kept readily available at the site for reference while the work is being conducted. Site delineation must be in place prior to project startup. At the start of each phase, the EM will conduct any relevant inventories, identify veteran and wildlife trees, wildlife crossings, and provide general monitoring throughout each phase of construction.
- The EM will be authorized to halt construction activities should an incident arise that is causing undue harm (unforeseen or from lack of due care) to terrestrial resource values.
- Construction activities should be monitored on a monthly basis and more regularly during high risk activities (e.g. clearing and grubbing, concrete pours, large material excavations) until the completion of the project.

- Regular monitoring reports will be submitted to the primary contractor, client, and the District of Lake Country. Once construction and restoration are complete, a substantial completion site visit and report will be undertaken by the EM.

4.12 Restoration, Performance and Maintenance Bonding

At this stage, a formalized landscape plan or restoration plan has not been prepared given the preliminary design stage of the Project. Once formal designs have been finalized for the Project, a detailed Restoration Plan including security bonding must be prepared by a Qualified Environmental Professional. Ecoscape must review and approve any plans prior to implementation. Restoration Plans will be prepared for each phase of the Project to include a site-specific assessment of ecosystems, aspect, slope, and soils to provide a species planting list, intended ecosystem target species, and a planting plan that will be adapted at the time of construction based on site conditions observed and implemented in a field-fit manner.

Restoration bonding will be prepared individually for each phase and will include:

- Species planting list
- Installed plant costs
- Grass seed mix, amount, and cost
- Habitat feature installation (coarse woody debris, etc.)
- Maintenance (irrigation, labour)
- Invasive species management
- Environmental monitoring

5.0 CONCLUSION

This Environmental Assessment report has been prepared to address the Natural Environment Development Permit guidelines as described in the District of Lake Country Official Community Plan (DLC OCP), related to the proposed Lakestone project in Lake Country, BC. Based on the site assessment and proposed site plans, the primary environmental concern is for the conservation and maintenance of habitat features within the Project Area and the functionality and connectivity of the Project Area's high value ecosystems such as wetlands, gullies, and cliff/talus communities. As the Project progresses, detailed assessments, inventories and surveys will be needed for each phase as the designs and specifications are developed.

The impact of the Project on environmentally sensitive areas (ESAs) will results in a loss of 27% of ESA 2 (High) and 14% of ESA 3 (Moderate) in the Project Area. Recommended mitigation measures must be incorporated into the design and construction, and the development footprint must be limited to the areas proposed as least disturbance to high ESA values in order to meet the intent of the Development Permit guidelines as described in the DLC OCP.

Provincial regulations and best management practices will provide suitable guidance in the development of avoidance, mitigation and/or compensation strategies for the sensitive habitats described in this report. Appropriate mitigation planning should provide reasonable protection to maintain the ecological integrity of the Project Area. Other potential negative impacts associated with construction can be appropriately mitigated by adhering to the recommended mitigation measures, best management practices, construction standards, and applicable District of Lake Country Development Permit guidelines and government regulations, as described in this report.

6.0 CLOSURE

This letter has been prepared for the exclusive use of Macdonald Lakeshore Properties LP. for the proposed Lakestone development in Lake Country, BC.

This report has been prepared with the understanding that all available information on the past, present, and proposed conditions of the site have been disclosed. Macdonald Lakeshore Properties LP. has acknowledged that in order for Ecoscape to properly provide the professional service, Ecoscape is relying upon full disclosure and accuracy of this information.

If you have any questions or comments, please contact the undersigned at your convenience.

Respectfully submitted,
ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.

Prepared By:



Theresa Loewen, M.Sc., P.Ag.
Environmental Scientist / Agrologist
Direct Line: (250) 491-7337 ext. 214
Email: tloewen@ecoscapeltd.com

Reviewed By:



Jason Schleppe, M.Sc., R.P.Bio.
Senior Natural Resource Biologist
Direct Line: (250) 491-7337 ext. 202
Email: maolson-russello@ecoscapeltd.com



Kyle Hawes, B.Sc., R.P.Bio.
Senior Natural Resource Biologist
Direct Line: (250) 491-7337 ext. 203
Email: khawes@ecoscapeltd.com

7.0 REFERENCES

Aresco, M. 2003. Highway Mortality of Turtles and Other Herpetofauna at Lake Jackson, Florida, USA, and the Efficacy of a Temporary Fence/Culvert System to Reduce Road Kills. Recent Work, Road Ecology Centre, John Muir Institute of the Environment, UC Davis. Retrieved February 12, 2019 at: https://longpointcauseway.com/library/Lake%20Jackson%20Florida%20-%20Aresco.pdf

B.C. Conservation Data Centre, 2018. BC Species and Ecosystems Explorer. B.C. Ministry of Environment Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (Accessed: May 23, 2018).

Chilibeck, B., G. Chlslett, G. Norris. 1992. Land Development Guidelines for the Protection of Aquatic Habitat. Prepared for the Department of Fisheries and Oceans Canada. Retrieved February 12, 2019 at: http://www.dfo-mpo.gc.ca/Library/165353.pdf

Grods, J. 2012. Environmental Assessment of Lakestone 2012 Master Plan. Makonis Consulting Ltd.

Iverson, K. 2008. Sensitive Ecosystems Inventory: Kelowna, 2007. Volume 2: Terrestrial Ecosystem, Terrain, Terrain Stability, and Surface Erosion Mapping and Expanded Legend. Prepared for City of Kelowna, British Columbia.

Lloyd, D., K. Angove, G. Hope, and C. Thompson, 1990. A guide to site identification and interpretation for the Kamloops Forest Region. Land Management Handbook No. 23. February 1990. BC Ministry of Forests.

Macdonald Lakeshore Properties LP. 2020. Lakestone 2020 Master Plan Environmental Impact Statement. Macdonald Communities Limited, pp. 67.

Polster, D., J. Cullington, T. Douglas, and T. Hooper, 2014. Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia. Prepared for the BC Ministry of Environment. Victoria (BC).

PHOTOGRAPHS



Photo 1. View of the north end of the Project Area with various structural stages including pole sapling. All photos taken April 20 – 22, 2020.



Photo 2. View of the north end of the Project Area with various structural stages including pole sapling.



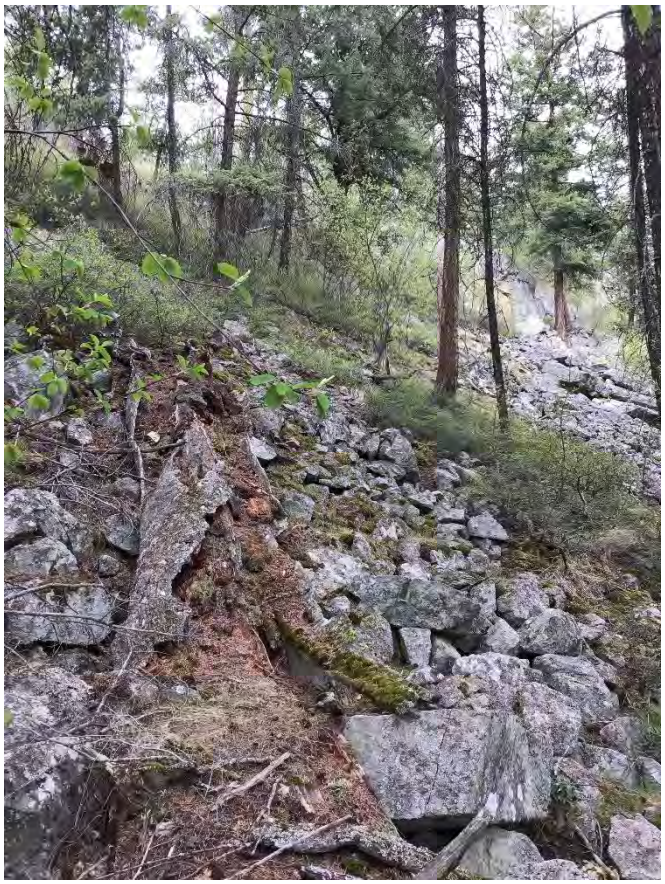
Photo 3. View of rock outcrop/sparsely vegetated ecosystem.



Photo 4. View of talus slope on the western extent of the Project Area.



Photo 5. View of rock outcrop on the eastern extent of the Project Area (photo facing east).





Photos 6 and 7. View of talus slope and cliff feature on the east side of the Project Area.



Photo 8. View of cliff/bluff feature at the western extent of the project area alongside Tyndall Rd.



Photo 9. View of open pond and wetland ecosystem (common cattail marsh) in the southern area of the Project Area



Photo 10. View of open pond and wetland ecosystem in the southern area of the Project Area.



Photo 11. View of open pond and wetland ecosystem in central area of the Project Area.



Photo 12. View of previous disturbance (walking trail) in the Project Area.



Photo 13. View facing east downslope of the Project Area with interior Douglas-fir and Saskatoon.



Photo 14. View facing east on the ridge top of the Project Area with ponderosa pine, arrow-leaf balsamroot, and Saskatoon.




Photos 15 and 16. View of veteran / wildlife trees throughout the Project Area.



Photo 17. View of veteran / wildlife trees throughout the Project Area.




Photos 18 and 19. View of veteran / wildlife trees throughout the Project Area.



Photo 20. View of veteran / wildlife trees throughout the Project Area.





Photos 21 and 22. View of veteran / wildlife trees throughout the Project Area.



Photo 23. View of veteran / wildlife trees throughout the Project Area.



Photo 24. View of native vegetation including arrow-leaf balsamroot, bunchgrasses, ponderosa pine, and interior Douglas fir.



Photo 25. View of native vegetation including tall-Oregon grape and Saskatoon.



Photo 26. View of open pond and wetland ecosystem (common cattail marsh) in the north, outside of the Project Area but within the Lakestone development.



Photo 27. View of frog species found within the Project Area.



Photo 28. View of moisture receiving areas within the Project Area.



Photo 29. View of moisture receiving areas within the Project Area.



Photo 30. View of facing east of gulley within the Project Area.



Photo 31. View of gulley within the Project Area.



Photo 32. View of gulley within the Project Area.



Photo 33. View of wetland within the Project Area.

FIGURES

FIGURE 1
Site Location, Wetland Information and Species at Risk Occurrences

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

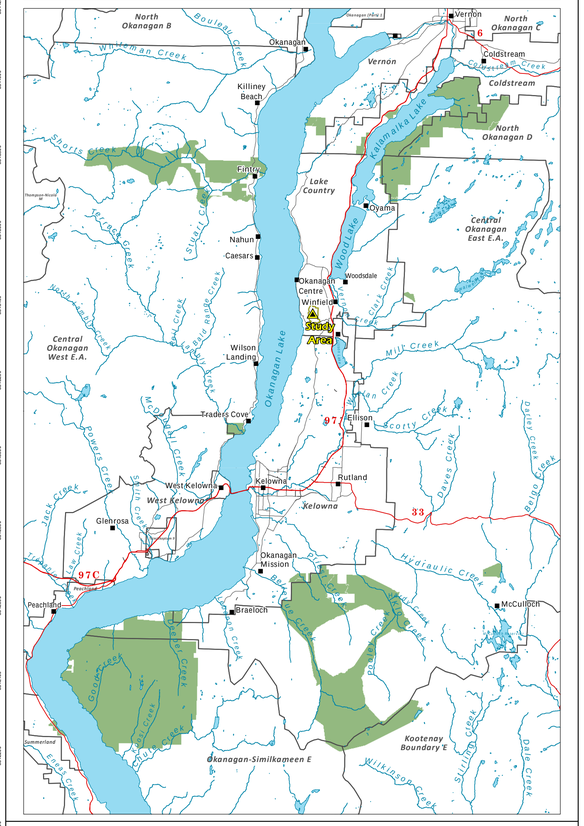
LEGEND

- Study Area
- Phasing Plan
- Cadastre
- Wetland and Riparian Communities
- Okanagan Critical Habitat (Species at Risk)
- BC Conservation Data Center (CDC) Polygons*
- Streams
- Wildlife Species Inventory (Survey)
- Wildlife Species Inventory (Incidental)

*A large Okanagan Critical Habitat polygon covers the entire map and subject property area representing the following wildlife species but is not shown on this figure:
- Western Rattlesnake (*Crotalus oreganus*)
- Desert Nightsnake (*Hypsiglena chlorophaea*)
- Great Basin Gophersnake (*Pituophis catenifer deserticola*)

Large Conservation Data Centre (CDC) polygons include:
- American Badger (*Taxidea taxus*)

Regional Location of Subject Property



DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd.

FIGURE 2
Ecosystem Polygons

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	January 4, 2021

LEGEND

- Study Area
- Cadastre
- Ecosystem Polygons
- Contour (10 Metre)
- Streams

Ecosystem Polygon Key

2402 ← Polygon Number
Decile (60%) → 6PFks6C ← Stand Modifier (C)
Ecosystem Unit (PF) → PFks3 ← Structural Stage (3)
Site Modifiers (wc) → PFwc6Ckc ← Seral Stage (kc)

Ecosystem Units

CL	Cliff
DM	Douglas fir - Water birch - Douglas maple
DS	Dougas fir - Ponderosa pine - Snowberry - Spirea
ES	Exposed Soil
FB	Rough fescue - Bluebunch wheatgrass
FI07	Fd - Water birch - Douglas maple
PF	Dougas fir - Ponderosa pine - Pinegrass - Idaho fescue
PT	Ponderosa pine - Red three-awn
PW	Ponderosa pine - Bluebunch wheatgrass - Idaho fescue
RO	Rock Outcrop
RW	Rural
RZ	Road surface
SA	Antelope brush - Selaginella
SB	Sellaginella - Bluebunch wheatgrass
SO	Saskatoon - Mock Orange - Talus
SP	Dougas fir - Ponderosa pine - Snowbrush - Pinegrass
SW	Shallow Water
TA	Talus
WB	Bluebunch wheatgrass - Balsamroot
Wm05	Cattail Marsh
Wm06	Bulrush Marsh
Ws03	Willow - Sedge

Site Modifiers

c	Coarse-textured soils
g	Site occurs in a gully
j	Gentle to moderate slope (slope < 25%)
k	Cool aspect (25% - 100% slope, 135° - 285°)
r	Ridged or ridge crest
s	Shallow soils (20-100 cm to bedrock)
v	Very shallow soils (<20 cm to bedrock)
w	Warm aspect (25% - 100% slope, 135° - 285°)

Structural Stage

2	Herb
3	Shrub/Herb
3b	Shrub/Herb - Tall Shrub
4	Pole Sapling
5	Young Forest
6	Mature Forest
7	Old Forest

Stand Modifiers

B	Broadleaf
C	Coniferous
M	Mixed

Disturbance Modifiers

Le	Forest harvesting (group selection, single tree, strip)
Ll	Land clearing (includes abandoned agriculture)

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

0 50 100 200 300 400 500
Meters

FIGURE 3

Environmental Sensitivity Analysis

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

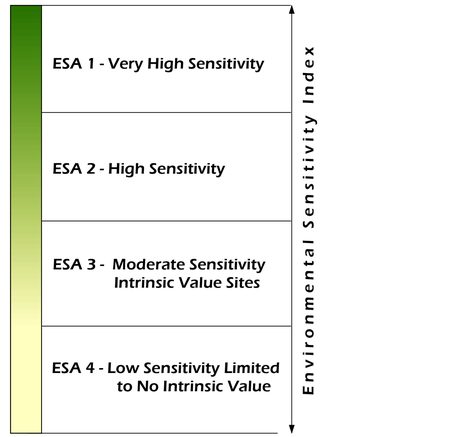
LEGEND

- Subject Property
- Cadastre
- Streams and Rivers
- Contour (10 Metre)

Environmental Sensitivity Rating

- Very High (ESA 1)
- High (ESA 2)
- Moderate (ESA 3)
- Low (ESA 4)

Environmental Sensitivity Gradient



DISCLAIMER

The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

FIGURE 4
Impact Assessment

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

LEGEND

- Subject Property
- Cadastre
- Phasing Plan
- Limit of Disturbance
- Proposed Development Roads/Lots
- Proposed Development Easement
- Streams and Rivers

Proposed Limit of Disturbance [557271 m²]

Proposed Development Roads/Lots

Summit Phase

East Ridge

Highlands Central

Highlands West

Highlands East

Highlands South

OK Centre Plateau

Chase Residential

Glenmore Industrial

Okanagan Lake

LONG RD
BEACON HILL DR
CHASE RD
KEL-VERN CRES
OKANAGAN CENTRE RD E
SEATON RD
READ RD
SANTINA RD
DICK RD
CENTRESTONE DR
BENCHLAND DR
TYNDALL RD
SLATEVIEW CRES
LIMESTONE DR
LAKESTONE DR
GRANITE RD
FINCH RD
STUBBS RD
HERITAGE DR
MCCOUBREY RD
OKANAGAN CENTRE RD W
GLENMORE RD
SHANKS RD

0 50 100 200 300 400 500
Meters

Source: Esri, Maxar, Geolay, EarthStar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

FIGURE 5
Crossings and Signage

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

LEGEND

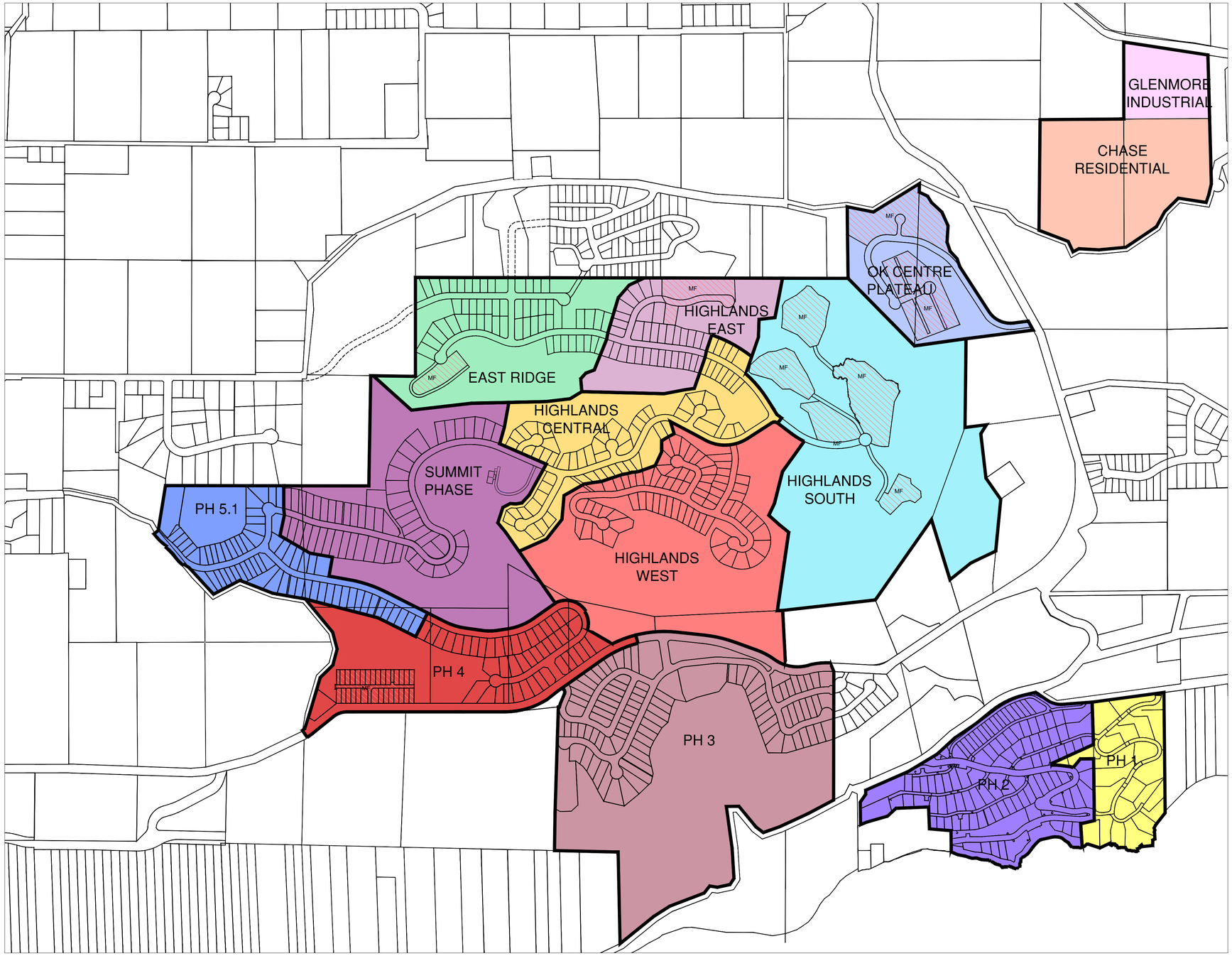
- Subject Property
- Cadastre
- Phasing Plan
- Limit of Disturbance
- Proposed Development Roads/Lots
- Proposed Development Easement
- Streams and Rivers
- Arch Culvert
- Box Culvert
- Ecopassage Tunnel
- Wildlife Crossing Signage

DISCLAIMER

The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

APPENDIX 1:
Lakestone 2020 Master Plan Phasing



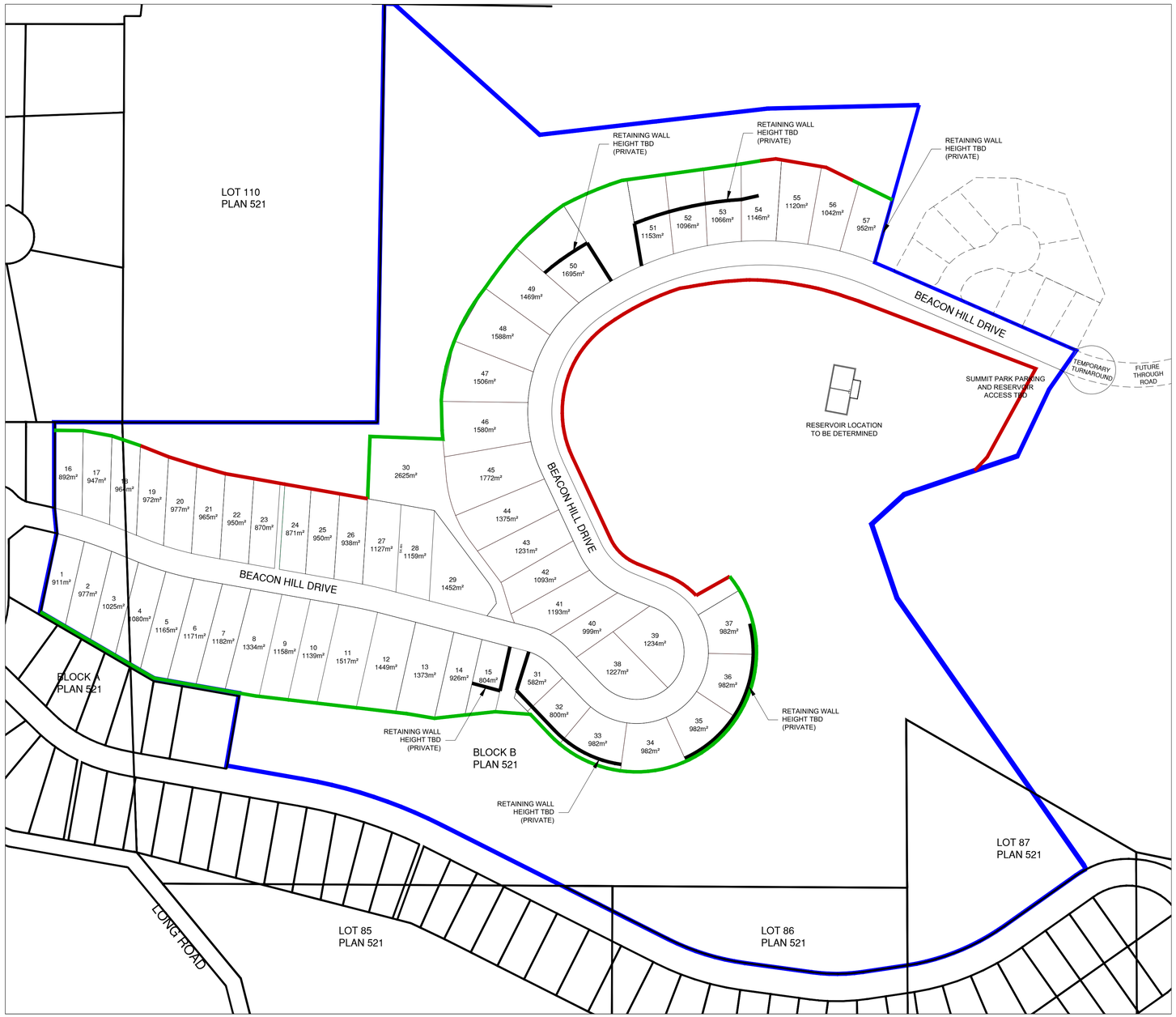
PHASING PLAN

ALPINE CONSULTANTS LTD

FIG.1

FILE LOCATION: F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - MP Figures\PROD-MPFIG 1-3.dwg PRINTED ON: 11/18/2020 9:25 AM

APPENDIX 2:
Lakestone Summit Phase



LEGEND:

- LIMIT OF DISTURBANCE - FILL EXTENT
- LIMIT OF DISTURBANCE - CUT EXTENT
- RETAINING WALL

NOTE:
LIMIT OF DISTURBANCE EXTENTS DO NOT INCLUDE DEVELOPMENT EXTENTS FOR PARKS, TRAILS, AND ASSOCIATED WORKS

FILE LOCATION: F:\1 Projects\4029 Summit\4029-4 Drawings\4029-41 Current Drawings\CIVIL\3 - PRODUCTION\PROD-PLR.dwg PRINTED ON: 11/18/2020 8:59 AM

NO.	YY/MM/DD	BY	REVISION	CH'KD

ALPINE CIVIL ENGINEERING

BASE	JP
DESIGN	JP
APPROVED	JBK
DATE	2020/10/30
SCALE	1:1500

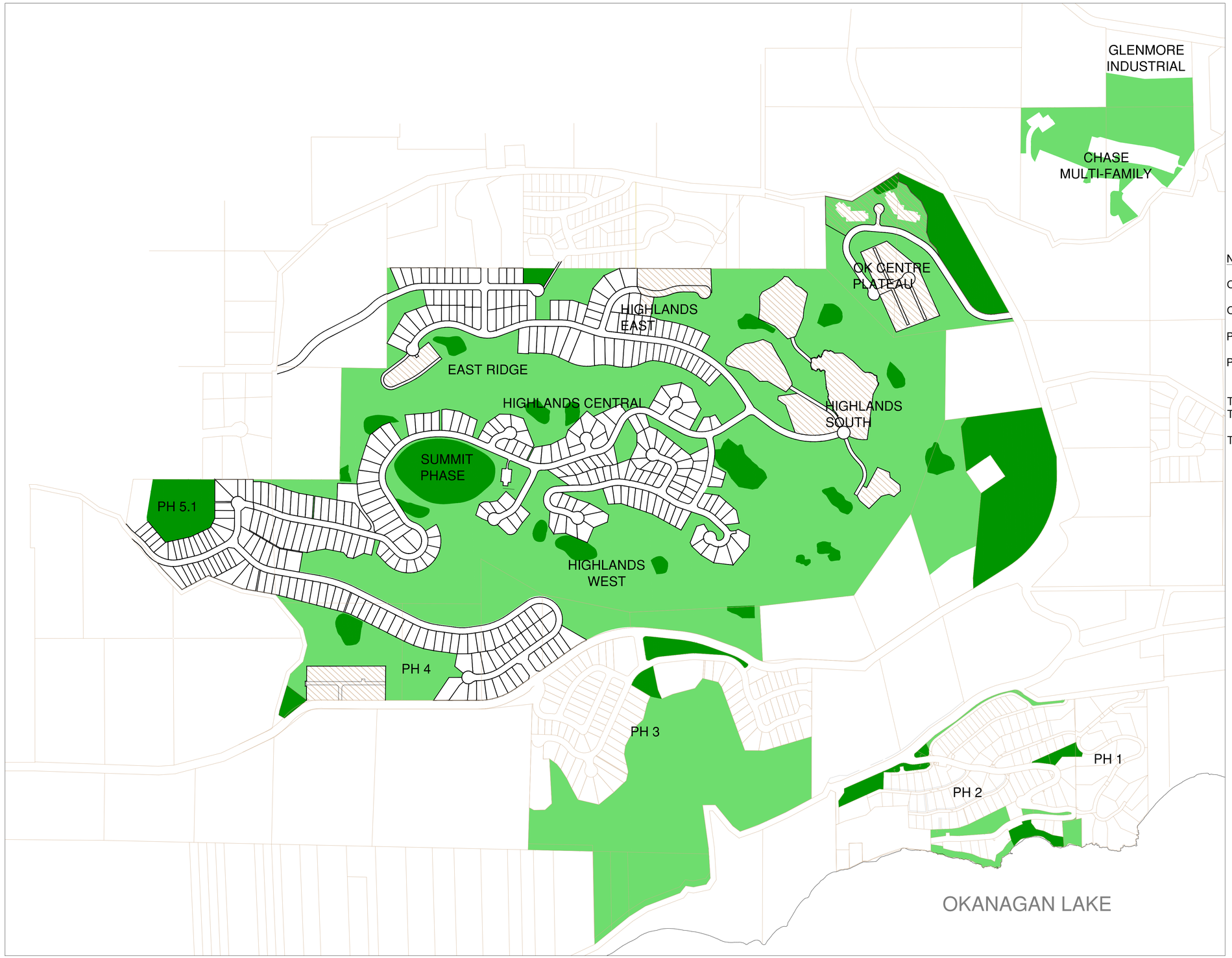
DISTRICT OF LAKE COUNTRY
DESIGN AND CONSTRUCTION

LAKESTONE SUMMIT PHASE
LAKESTONE MASTER PLANNED COMMUNITY
LIMIT OF DISTURBANCE

The location of existing underground utilities are shown in an approximate way only & have not been independently verified by the owner or its representative. The contractor shall determine the exact location of all existing utilities before commencing work, and agrees to be fully responsible for any and all damages which might be occasioned by the contractor's failure to exactly locate and preserve any and all underground utilities.

DRAWING NO. 1
REV. NO. 0
SHEET NO. 1 OF 1

APPENDIX 3:
Proposed Parks and Open Space Areas



NOTES:

OPEN SPACE-

OPEN SPACE AREA- 99.84ha

PARKS-

PARKS AREA- 11.54ha

TOTAL DEVELOPMENT AREA- 202.12ha
TOTAL PARKS & OPEN SPACE AREA- 111.38ha (55%)

TOTAL DEDICATED PARKS AREA- 8.9ha

PARKS &
OPEN SPACE

ALPINE
CONSULTANTS LTD

FIG.11

FILE LOCATION: F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODUCTION\1 - MP Figures\PROD-MPFIG.11.dwg PRINTED ON: 7/29/2020 9:13 AM

APPENDIX 4:
Common native plant species occurring within the Project Area

Appendix Table 1 below lists native vegetation observed during the site visits, as well as common species which are known to occur within the Project Area. Please note this is not an exhaustive list, as a detailed inventory was not conducted.

Appendix Table 1. Common native plant species occurring within the Project Area.

Family	Scientific Name	Common Name	Provincial Status [1]	COSEWIC Listing [2]
Trees				
Betulaceae	*Betula occidentalis*	Water birch	Yellow	N/A
Salicaceae	*Populus tremuloides*	Trembling aspen	Yellow	N/A
	Populus trichocarpa	Black cottonwood	Yellow	N/A
Pinaceae	*Pinus ponderosa var. ponderosa*	Ponderosa pine	Yellow	N/A
	Pseudotsuga menziesii var. glauca	Interior Douglas-fir	Yellow	N/A
Shrubs				
Asteraceae	*Chrysothamnus viscidiflorus ssp. lanceolatus*	Rabbitbrush	Yellow	N/A
Berberidaceae	*Berberis aquifolium*	Tall Oregon grape	Yellow	N/A
Caprifoliaceae	*Symphoricarpos albus*	Common snowberry	Yellow	N/A
Cornaceae	*Cornus sericea*	Red-osier dogwood	Yellow	N/A
Cupressaceae	*Juniperus communis var. depressa*	Dwarf juniper	Yellow	N/A
	Juniperus scopulorum	Rocky Mountain juniper	Yellow	N/A
Ericaceae	*Arctostaphylos uva-ursi*	Kinnikinnick	Yellow	N/A
Hydrangeaceae	*Philadelphus lewisii*	Mock orange	Yellow	N/A
Rosaceae	*Amelanchier alnifolia*	Saskatoon	Yellow	N/A
	Rosa nutkana	Nootka rose	Yellow	N/A
	Spirea lucida	Birch-leaved spirea	Yellow	N/A
Sapindaceae	*Acer glabrum*	Douglas maple	Yellow	N/A
Herbs				
Anacardiaceae	*Toxicodendron rydbergii*	Poison ivy	Yellow	N/A
Asteraceae	*Arnica cordifolia*	Heart-leaved arnica	Yellow	N/A
	Eurybia conspicua	Showy aster	Yellow	N/A
	Balsamorhiza sagittata	Arrowleaf balsamroot	Yellow	N/A
Lamiaceae	*Prunella vulgaris*	Self-heal	Yellow	N/A
Liliaceae	*Fritillaria affinis*	Chocolate lily	Yellow	N/A
Onagraceae	*Epilobuim brachycarpum*	Tall annual willowherb	Yellow	N/A
Rosaceae	*Fragaria virginiana*	Wild strawberry	Yellow	N/A
	Potentilla anserina ssp. anserina	Silverweed	Yellow	N/A
Grasses				
Poaceae	*Calamagrostis rubescens*	Pinegrass	Yellow	N/A
	Pseudoroegneria spicata	Bluebunch wheatgrass	Yellow	N/A

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

APPENDIX 5:
Bird and Bat Box Designs







Building Homes for Bats

A Guide for Bat Houses in British Columbia

INSIDE THIS HANDBOOK

- Key Features of Effective Bat Houses
- Bat House Designs
- Optimal Bat House Location
- Tips for Installing a Bat House
- Frequently Asked Questions about Bat Houses

Revised January 2017

community bat programs of BC

Contents

Background 1
Key Features of Effective Bat Houses 2
Bat House Designs 8
Optimal Bat House Location 12
Enhancing Bat Habitat on a Community Scale 16
Frequently Asked Questions About Bat Houses 17
Resources 20
APPENDIX 1: Register Your Bat House 21
APPENDIX 2: Annual Bat Count Information 22
APPENDIX 3: Bat House Plans 23

Acknowledgments

This document was prepared by Juliet Craig and updated by Mandy Kellner for the BC Community Bat Program. The information is adapted from "The Bat House Builder's Handbook" by Bat Conservation International but has been adapted to BC based on expert opinion. Very special gratitude to Mike Sarell, Cori Lausen, and Greg Falxa for sharing their knowledge and expertise on bat house design and placement. Special thanks to Doug Burles, Katie Calon, Christian Englesoft, Purnima Govindarajulu, Margaret Holm, Leigh Anne Isaac, Tanya Luszcz, Paula de la Vega, Cory Olsen, and Peter Ommundsen for their comments and thoughtful reviews. We are grateful to Julianne Leekie, Fairwinds Design, for developing the graphics and Dr. Greg Utzig for preparing the climate maps. We are indebted to our partners, the BC Conservation Foundation and BC Ministry of Environment.

This project was undertaken with the financial support of the Government of Canada. Ce projet a été réalisé avec l'appui financier du gouvernement du Canada. The BC Community Bat Project network recognizes the Habitat Conservation Trust Foundation and anglers, hunters, trappers and guides who contribute to the Trust for making a significant financial contribution to support the BC Community Bat Project. Without such support, this project would not have been possible. We also gratefully acknowledge the financial support of Columbia Basin Trust which supports efforts to deliver social, economic and environmental benefits to residents of the Columbia Basin, and of the Regional District of Central Kootenay's Kootenay Lake Local Conservation Fund.



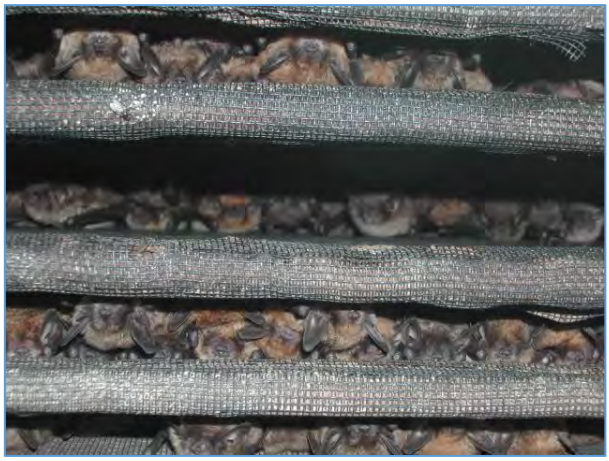
This version was updated in January 2017. Please see our website for updated versions: www.bcbats.ca.

Background

Bats are an essential component of healthy ecosystems and provide important control of agricultural and forest insect pests as well as flying insect populations. Two species of bats are federally endangered, and over half of the 16 bat species in British Columbia are considered to be “at risk” due to habitat loss and degradation, intentional extermination, wind turbines, pollution, climate change, and White-Nose Syndrome (WNS), a devastating disease that has decimated bat populations in the eastern parts of North America and has now been confirmed on the west coast.

Bats need our help, through protection of individuals and enhancement of habitat. You can support bat populations in your area by preserving snags (dead trees) and planting trees that will mature and provide roosting habitat. Installing a bat house is also a great way to enhance habitat for bats in your backyard. A bat house is a structure designed to provide bats with a warm, dry and safe summer roost site. Similar to birdhouses, they are often wooden “boxes” that can be installed on a high structure like a tall post or a building. Many people want bats because they want to promote backyard biodiversity or help control insects (particularly mosquitoes). Some people install bat houses in coordination with evicting bats from a building so that the bats will have an alternate roost site and the eviction will be more successful. Although **bat houses do not provide the same opportunities as natural roost structures for bats**[1], they are still an excellent option for increasing summer roosting habitat where natural features are limited or where bats are already in a human-made roost. In general, preservation of diverse natural features should be a priority; however, having safe, appropriate roosting habitat may help bats recover from the impacts of WNS and other threats, and in human-altered landscapes, bat houses may help fill this need.

Bat houses are often for sale in BC at garden centres, hardware stores, craft markets and other locations, or they are home-built. Whether you buy or build a bat house, ensure that it meets the criteria for good bat house design (see section *Key Features of Effective Bat houses*). Standardized information for bat houses in BC has only recently become available, and commercially-available bat houses may not meet these new criteria for size or design. Design is important, but it is also essential to install the bat house in an optimum location for success (see section *Optimal Bat House Location*).

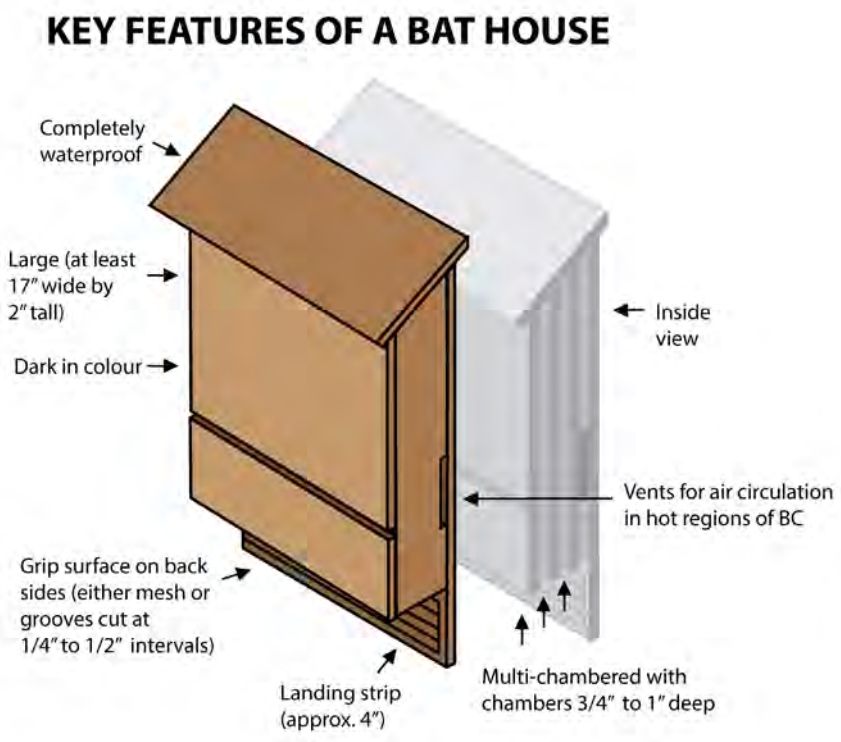


[1] Lausen, C.L. and Barclay, R.M.R. 2006. The benefits of living in a building: Comparing maternity colonies of big brown bats (*Eptesicus fuscus*) in rock crevice and building roosts. *Journal of Mammalogy* 87: 362-370.

The purpose of this document is to provide information about effective bat house design and placement for private landowners in BC. There is still much for us to learn about how bats determine which roost is most suitable, so try experimenting by putting bat houses in different locations, varying the dimensions, or staining one and not the other. Monitor occupancy by bats in summer by looking for guano under the bat house or observing the bat house at dusk to see if bats fly out. Register your bat house and report your results to the BC Community Bat Program (Appendix 1 or http://bcbats.ca/index.php/bat-houses/register-your-bat-house) so we can continue to improve the information in this document.

Key Features of Effective Bat Houses

There are several factors to consider when building or purchasing a bat house. Factors that influence success in attracting bats include the design, size, number of chambers, chamber spacing, surface roughness, and presence of vents and landing strip. Other factors to consider when selecting a style are cost, size of the bat colony (if you are excluding bats from a building), and location options. The most common designs on the market are bat boxes, rocket boxes and condos (see *Bat House Designs* section).



Size

Many bat houses sold in BC are too small for our temperate climate. For bat houses, **bigger IS better**! A larger house will provide a wider range of temperatures inside, allowing bats to choose a site that suits their needs (see side bar *Some Like It Hot!*). Bat boxes should be at least 24"[2] tall and 17" wide and have a landing strip of at least 4". Rocket boxes should be at least 3' tall and have at least 1' of linear roost space (meaning that each of the four sides would be at least 3" wide).

Chambers

Chambers are the cavities that bats actually roost within. Chambers should be carefully spaced to ¾" (for most bat species) or 1" (for Big Brown Bats). Bat houses with wider chambers don't hold heat as well and can attract wasps, and smaller chambers do not provide adequate roosting space. **Multiple chambered bat houses not only provide added roosting space, but also give bats the opportunity to select an appropriate temperature by moving between chambers.** This range in temperature is particularly important during heat spells when bat pups can otherwise die from overheating.

Movement Between Chambers

Holes or gaps in the dividers between chambers allow bats to move between chambers inside the bat house. These gaps can be developed by leaving a 1" gap about ½ way up the divider (so the divider is made out of two pieces of wood rather than one), or drilling holes about ½ way up (usually two 1 ½" diameter holes per divider)[3].

Some Like It Hot!

Bats require certain temperature ranges, depending on their sex, and whether they are raising a pup or not. Bats have the interesting ability to go into torpor (taking on the temperature of their surroundings, similar to cold-blooded animals like snakes). In doing so, they don't have to use their precious fat stores to generate heat for their bodies. When raising pups, adult females prefer warm roosts; males, which tend to roost alone during the day, are more likely to select cool roost locations. A female's need for warmth changes throughout the season, from pregnancy through to weaning her pup, and can also fluctuate on a daily basis depending on whether she is trying to nurse a pup, or save energy. The more chambers a bat house has, the greater its variety of microclimates and the more likely bats can find conditions suitable to their differing needs. Multi-chambered roosts can also attract more bats, which will raise roost temperatures and allow bats to reduce heat loss through huddling.

[2] Although Canada uses metric measurements, the building industry still uses imperial so that is what is used to describe building sizes and materials.
[3] Greg Falxa, personal communication.

Materials

For wood bat houses, a combination of cedar and exterior-grade plywood is best. Plywood for the exterior of the bat house should be at least ¾" thick with at least four plies. Pressure-treated wood should not be used due to the chemicals it may contain. Also, it can warp over time preventing use of the chambers. Be sure to use exterior-grade screws (not nails), staples, and hardware. Caulk any cracks and seams to ensure that water does not enter the house and to provide a good thermal habitat for the bats.

Landing Strip

A place for bats to land is a key feature of a bat house. Bat houses that do not have a landing strip or that have a slippery surface are usually ineffective. Landing strips should be at least 4" high and the width of the bat house, and have a rough surface.

Rough Surface

All areas where bats will be hanging (including the landing strip and one side of each chamber) should have a rough enough surface that bats can easily grip. Plywood on its own is too slippery. There are several methods that can be used to create a rough surface:

- **Score the wood** by cutting grooves (1/16" to 1/32" deep) at ½" intervals. This method creates excellent grip and has proven to be very effective although it is time consuming to build.
- **Affix fiberglass mesh** (door screen) onto the wood. This method has commonly been used in BC and is effective but there are concerns that the staples will corrode over time and guano (droppings) or bats can get trapped beneath. It is best to hide the staples between chamber spacers or on the edges of the divider plates. Avoid using metal screen since it corrodes and develops sharp points.
- Utilize a **naturally rough substrate** to build the chambers (such as rough cedar) which may be effective if it is heavily textured with deep grooves.
- **Mix a gritty substance with non-toxic stain** to create a roughly textured surface[4]. For example, paint boards with latex paint, sprinkle ground up cork or walnut shells (available as walking surface non-slip treatment) and then paint another layer of latex paint. This method is relatively simple yet effective. A blender can be used to grind the cork, and ground walnut shells are available through jewelry polishers or at home building supply centers for applying to decks while being painted.[4]
- **Use a low grit sandpaper** on a power sander[5].
- Make a "scouring pad" by putting many screws or nails through a board (like the bristles of a hair brush) and **"rake" this nail or screw pad** over the wood to create grooves[4.]

[4] Greg Falxa, personal communication.

[5] Justin Stevenson, RD Wildlife Management, personal communication.

Mounting Brackets or Lips

Since large bat houses are quite heavy once they are built, installation can be challenging. Building a bat house with installation in mind (such as creating lips on the edges or top of the bat house to drill screws through) can make it easier. A mounting bracket can also be built onto the bat house or onto the structure to which it will be attached.

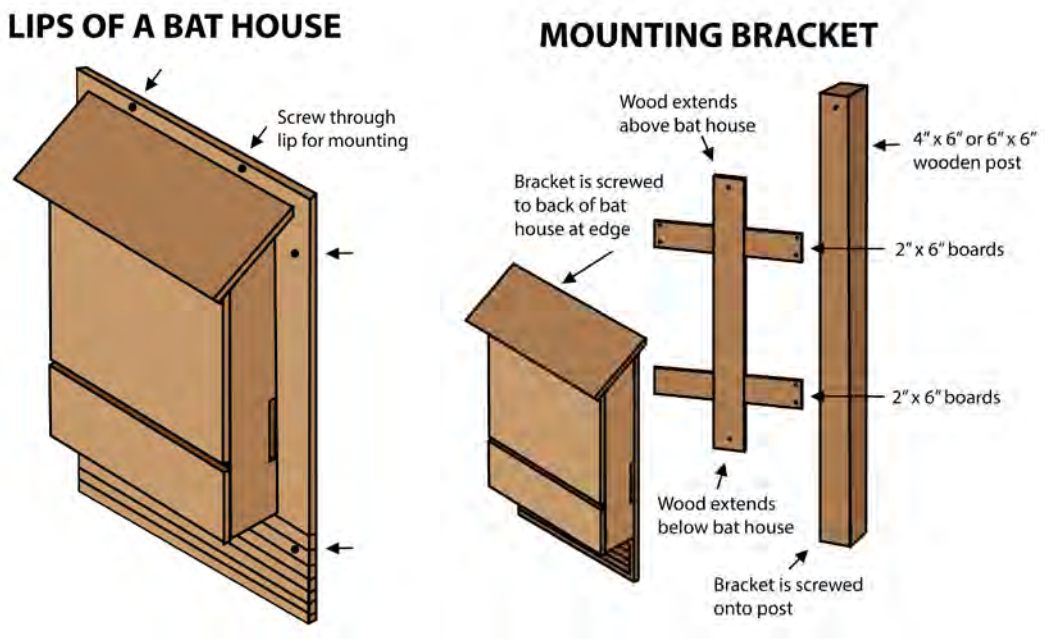


DIAGRAM SHOWING LIPS (LEFT) AND MOUNTING BRACKET (RIGHT) FOR MOUNTING BAT HOUSE.

Vents (in hotter regions of BC)

Although not necessary in all regions of BC, vents allow air movement and increase the range of temperatures inside a roost. During intense heat, vents may be important for preventing extreme temperatures inside the bat house. Vents are approximately ½" wide, and can be placed approximately 1/3 of the length of the bat house up from the bottom. The front vent should be as wide as the house. In hot areas of BC, including the Kootenays, Okanagan and Thompson/Fraser, vents are recommended whereas in the rest of the province, they are optional.

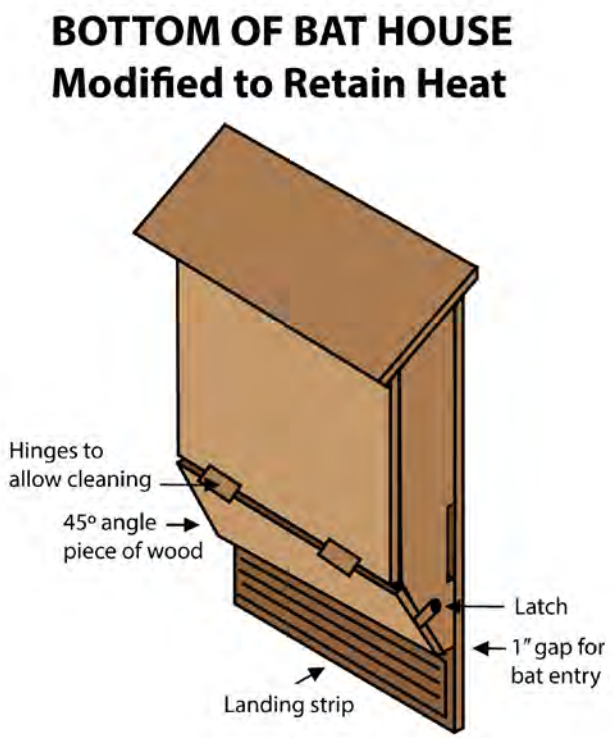
Overheating

In hotter parts of the province, bat houses may overheat. Regular observation of your bat house can reveal if it is too hot at times, and needs to be relocated to a cooler site - an overly-hot house will cause bats to cluster at the lowest exit point during the day, or even lead to death of bats, although mortalities may be due to many causes. Never touch dead bats with your bare hands, and report any mortality to your community bat program at 1-855-922-2287. Several community bat projects are conducting research into temperatures in bat houses, to improve our understanding of bat preferences. If you are

interested in having your bat house monitored or installing temperature monitoring equipment, contact your local community bat program to discuss.

Retaining Heat (in cooler/ northern regions of BC)

In northern BC, bat houses should be designed to retain heat. Vents should not be used. A partial bottom can be added that is at an angle of 45° or greater to reduce guano build-up and that leaves a 1" entry gap at the back (see diagram). Since guano may accumulate inside this flap, consider adding a hinge to allow for annual cleaning.



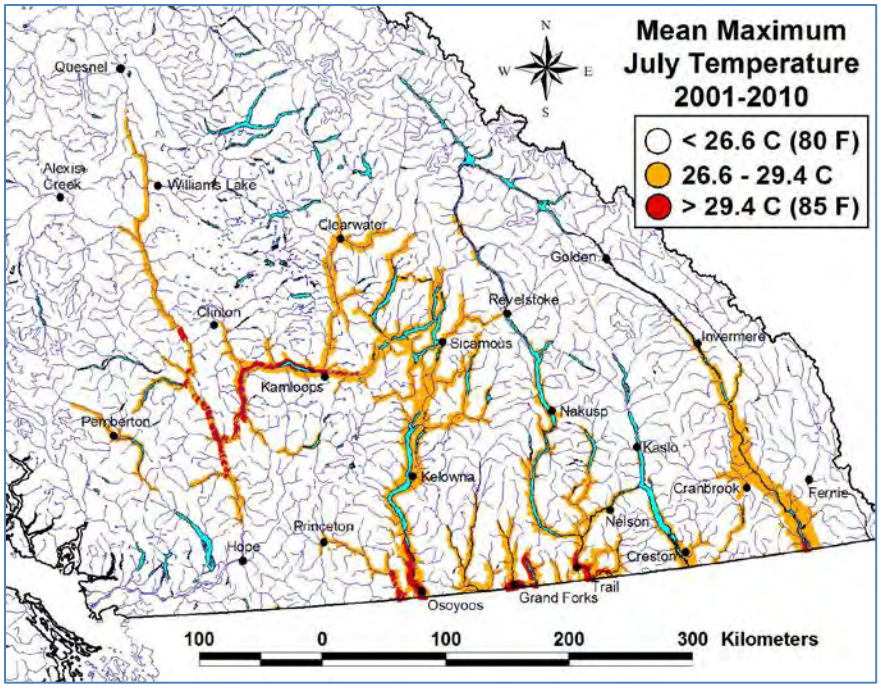
Stain Colour

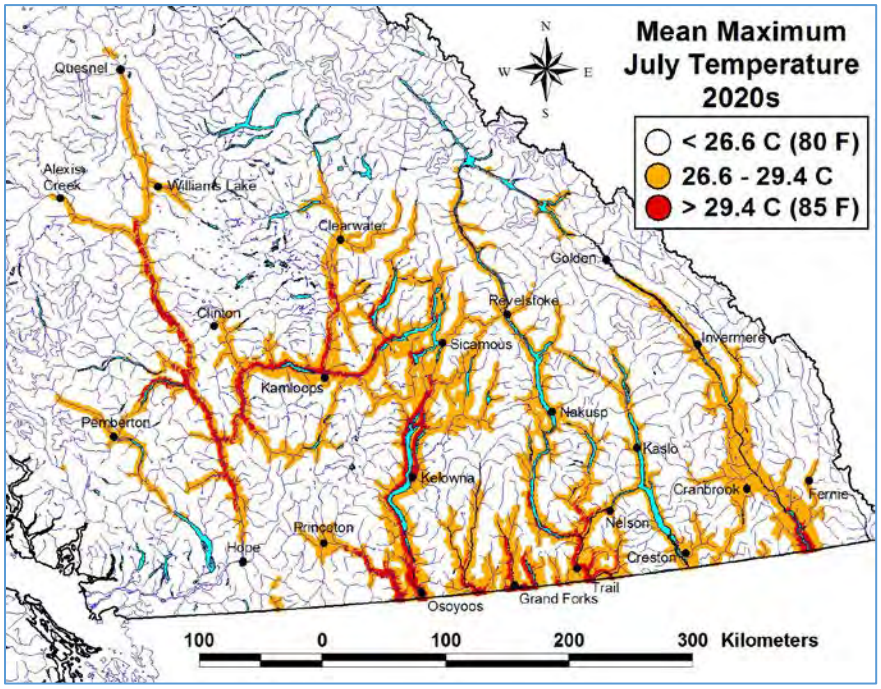
Avoid oil paints or other stains with strong odours or Volatile Organic Compounds (VOCs), which are off-gassing chemicals, since they can be harmful and/or repel bats. Use a water-based stain. Consider using all-natural products such as the "Tall Earth" stain[6]. Some people choose not to stain their bat house and leave it as natural wood and these bat houses have also been successful. Although mentioned in some construction plans, **staining the interior is neither required nor recommended** (unless you are using the stain as part of roughening the surface – see *Rough Surface* section above, or are installing the house immediately outside of a window, as staining may reduce smells associated with the bat house).

Warmth is a key feature of effective bat houses. In areas where the mean maximum July temperature is less than 29°C (85°F), bat houses should be stained black or dark colours, and areas from 29°C to 35°C (85°F to 95°F), the colour should be a lighter colour[7]. Based on climate data from 2000 to 2010, the only regions of the province where bat houses should not be stained black or dark are lower elevations in the Kootenays, Okanagan and Caribou (see temperature maps, below). In these regions, bat houses should be a lighter colour such as beige, light or medium brown, or even natural wood colour (e.g. transparent wood protector).

[6] http://tallearth.com/

[7] Tuttle, M. D., M. Kiser, and S. Kiser. 2004. *The Bat house Builder's Handbook: Second Edition*. Bat Conservation International, Austin, Texas. Available online: http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf





TEMPERATURE MAPS OF PREDICTED MEAN MAXIMUM JULY TEMPERATURE FOR SOUTHERN BRITISH COLUMBIA FROM 2000 TO 2010 (TOP) AND PREDICTED FOR 2020'S (BOTTOM). STAIN BAT HOUSES A MEDIUM BROWN COLOUR IN AREAS THAT ARE SHADED. IN ALL OTHER AREAS, STAIN THEM BLACK. MAP PREPARED BY GREG UTZIG[8].

[8] Mapping by: G. Utzig, P.Ag. Kutenai Nature Investigations Ltd. 2015. Climate data extracted from ClimateBC v5.21 based on a 1 km provincial grid.

Bat House Designs

There are several designs of bat houses that are known to be effective in BC. Most bat houses have one to four roosting chambers. Plans can be found in Appendix 2 or at www.bcbats.ca.

Bat Boxes



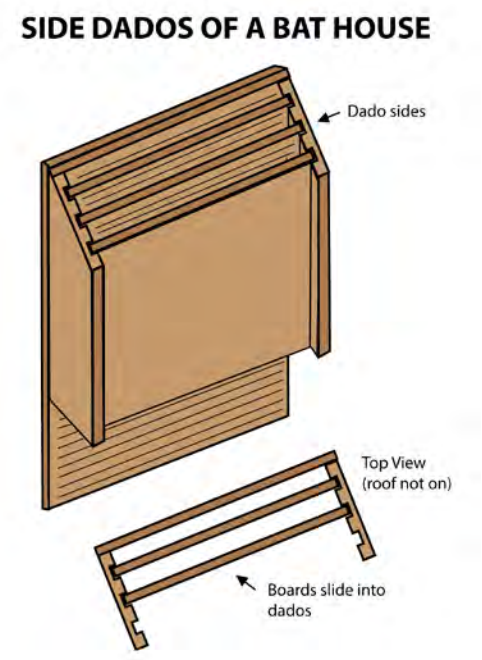
Four-chambered Nursery Box

Four-chambered nursery boxes offer ample roosting space and provide bats with the opportunity to move between chambers with changes in temperature. Multiple-chambered bat boxes can hold hundreds of bats and are more successful than single-chambered bat houses. Bat boxes can be installed on buildings or posts. An ideal set-up is to put two multi-chambered bat boxes back to back on a post – leaving a gap between them creates further roosting space.

Useful adaptations to this design:

Lips: An adaptation to the design that may be useful is to lower each chamber and the roof on the back board so there is an upper lip or make chambers slightly narrower so that there is a lip on either edge of the bat house for easier installation (see *Mounting Brackets or Lips* section).

Dados: Some woodworkers prefer to cut grooves (dados) in side boards rather than use separate spacers to create the chambers (see diagram to right). Mass production cutting plans[9] using dados for woodworking programs or bat house builders are available by contacting info@bcbats.ca.



Larger size: All bat houses can potentially be built larger. For example, large multi-chambered or single-chambered bat houses can be built approximately 50" high (double the height of the small ones) by 24" wide. They can be built as a single chamber or multiple-chambered style with the potential to hold thousands of bats. Large multi-chambered bat boxes are an excellent design for extremely large bat colonies in BC, such as colonies of over 2,000 bats. To build one, adapt the designs above to make the bat house taller or wider.

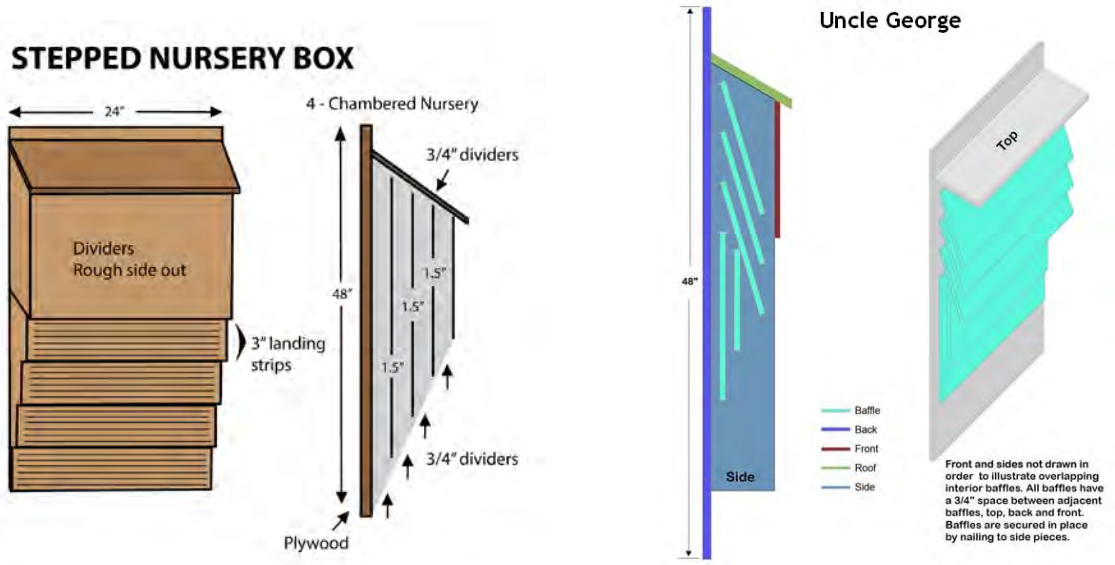
Runways: Ideally, back to back multi-chambered nursery boxes should have a little 'hallway' or other connection between the boxes at the back. If they are mounted back to back with no space in between, this could simply be a hole cut through the backs of

[9] Prepared by Donald Liszt, Woodworking Instructor, Stanley Humphries Secondary School

the bat houses approximately half way up (see *Mounting Structure* section). If the bat houses are separated by a pole or post, this could be a PVC pipe or other tube that creates an access.

Stepped Nursery Box

The Stepped Nursery Box is an adaptation that has each chamber slightly shorter from the back to the front so the bat house forms "steps" of chambers and each chamber has its own landing strip[10]. An "Uncle George" design has been described for the Pacific Northwest where chambers are angled approximately 20° from vertical[11] but research on the use of this design indicates that they are not used as well-used as maternity roost sites except by California Myotis[10]. Although regular or stepped maternity boxes appear to be more successful[10] , there is still the potential for experimentation with all these designs in BC, particularly where they are installed on buildings.



Single-Chamber Bat Box

Single-chamber (small) bat boxes **are ideally at least 2' wide and 2' high**. Although they are easier to make than other designs, we do not recommend these houses. Observations in the Kootenays have indicated that single-chambered bat boxes are more often used by males or non-reproductive females[12]. These bat houses occasionally provide a roost space for up to 50 bats. *They must be installed on the side of a heated building to be effective*. Since they don't offer the temperature gradient that multi-chambered bat houses do, they can also become "bat traps" in hot spells, with pups getting too hot and dying. Although single chambered bat boxes may be simpler to construct, cost less and are less heavy to mount in high places, **multi-chambered bat houses are safer for bats and more effective as roost sites.**

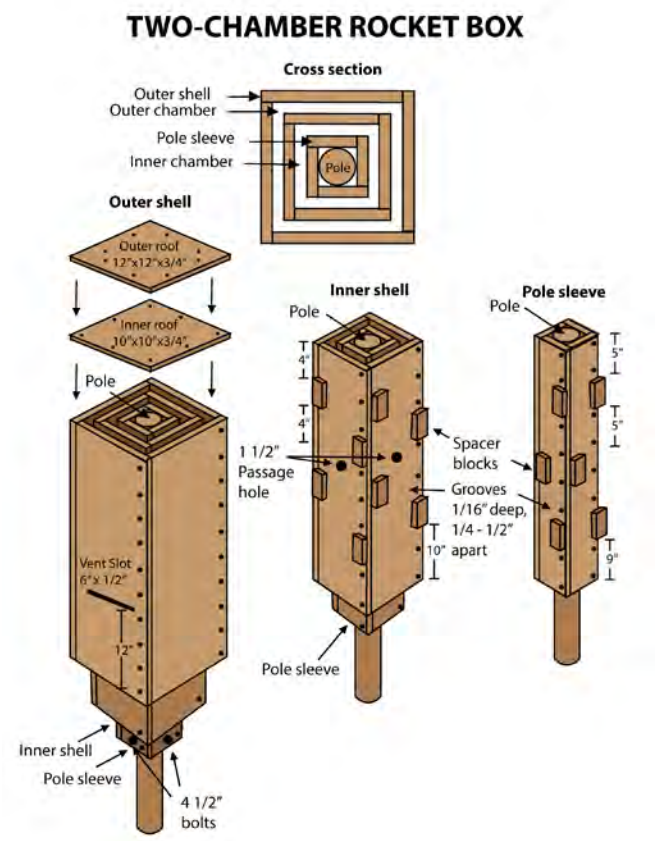
[10] Greg Falxa, personal communication.
[11] http://cascadiaresearch.org/bats/BatBoxPreference_screen-view.pdf
[12] Juliet Craig, personal observation.

Rocket Boxes

Another form of bat house is the rocket box. Two-chambered rocket boxes have been extremely successful on the coast of BC, especially for Yuma Myotis, a common bat species. There are two styles of rocket boxes.

Two-chambered Rocket Box

Two-chambered rocket boxes are usually 3 ft. (1 m) tall and contain concentric roosting chambers around a post or pole. By increasing the number of square roosting chambers, the rocket box becomes wider and can house more bats as well as provide more micro-climate options. Installation of this bat house style simply requires fixing the post in the ground and putting the bat house on as a "cap". These bat houses are extremely effective in attracting roosting bats which is likely because the chambers face all cardinal directions and thus provide a multitude of microclimates within the bat house. For example, bats could follow the warmth of the sun's radiation throughout the day by shifting inside the box. On very hot days, they can also avoid the heat by moving to the north side of the box.





Simple Rocket Box

Simple rocket boxes are made from a 4" by 4" post that has wedges cut into it and is then covered by an outer plywood box. The materials are cheap and they are easy to construct. *However, their success rate has not yet been determined in BC.* As there are less microclimate options, it is possible this style would be less popular than a double or multi-chambered rocket box.

Bat Condos



Bat condos are very large structures that can potentially house thousands of bats. They are costly and time consuming to build but can house large colonies of bats (more than 6,000). Because they provide a variety of microclimates, bat condos are designed for use by multiple species of bats, and both males and females. Condos typically provide roosting chambers towards the outside of the structure (e.g. under planking), in addition to roosting chambers inside the structure. Bat condos are generally built on poles that elevate the structure well above the ground. The increased height has multiple benefits such as providing bats with a sufficient height off the ground for take-off and landing, avoiding predation, and decreasing the likelihood of potential vandalism and disturbance.

There are many different designs, including 'mini condos', and 'bat motels'. In BC, where climate is colder, the designs should be modified to partially close chambers to trap air and thus increase roosting temperatures. Decreasing gap size between roosting boards will also help trap warm moist air when bats are roosting as a group. Additionally, creating purposeful gaps between exterior boards or planks during construction can increase the variety of microclimates created for bats in the structure. Bat condos can be considered when there are large bat colonies being evicted from a building, for wildlife and restoration projects, and for increased insect control. If you are considering building a bat condo, contact your local community bat program to discuss options.

Slabs



Slabs are a wooden board or metal flashing secured on a wall of a building under the eaves that provides a dry crevice for roosting on the exterior of the building. Short strips of wood can be used as spacers to create the roosting chamber (approx. ¾"). The overhanging roof of the building should protect the roost from precipitation but it is important that the top of the chamber be sealed to trap heat. One slab/sheet of wood will create a single chambered roost or they can be layered to create multiple chambers. The length of the roost can be as long as one wishes to make it and the entire roost can be made of scrap lumber. These types of bat houses mimic the conditions that wall or shingle roosting bats often use. Guano and urine can mark the wall of the building so installing slabs on outbuildings and not on homes may be preferable. One may have to compromise on choosing the best aspect (e.g. south) versus which side of the building is acceptable to become marked (e.g. east or west).

Gable Vents

Gable vent covers may provide roosting habitat for bats. These slotted structures cover the openings that allow airflow from attic spaces, and are installed over existing vents and tough screening to ensure that bats do not enter the attic. Airflow from the attic helps warm the bat house. Adjusting the size of the slats will accommodate different species (3/4" for Little Brown or Yuma Myotis, 1" for Big Brown). Some houses may come with slotted gable vents – in this case, ensure that the screening is solid, to ensure that bats do not enter the attic. Other houses may require a retro-fit to add a bat-friendly vent cover. As with slabs, these bat houses may result in guano or urine staining of the wall below the structure.

Optimal Bat House Location

The location of a bat house is critical to its success. There are many factors to consider when selecting a site including solar exposure, habitat, mounting, obstacles, protection from predators, and wasps. In summary, bat houses should be placed:

- at least 10' (3 m) high but 12' to 20' is better,
- south, east or west facing to ensure correct sun exposure,
- in an uncluttered location that does not have branches, buildings, or poles in front of it, and
- away from lights or high wind.





NURSERY BAT BOX ON SHED (LEFT) AND TWO-CHAMBERED ROCKET BOX ON POST (RIGHT). PHOTOS COURTESY OF JULIET CRAIG AND ALYSIA DOBIE.

Height

The base of a bat house should be at least 3 m (10') above the ground although 12' to 20' is better. The height is measured from what a bat would perceive as the "ground' which may be the roof of a shed or other building if the bat house is mounted above a structure (such as a lower roof) rather than the ground.

Sun exposure

An important criterion for bat house location is sun exposure. If you have several possible sites to choose from, observe the site during the summer to determine sun exposure (this could change depending on the time of the year). Bat houses placed on a post should face due south to allow for the best temperature gradient. Bat houses placed on buildings may face east, west or south, depending on the ideal hours of direct sun (see below).

For the hottest regions of BC including lower elevations of the Okanagan, Kootenay, and Thompson areas (shaded red in temperature maps) select sites with approximately 6 hours of direct sun each day (e.g. away from direct afternoon sun). Ideally a bat house in these hot regions will face east or south-east, to be exposed to morning sun and not the hot afternoon sun. A spot with afternoon shade is ideal. For warmer regions of BC (shaded orange in temperature maps), place bat houses in areas with 6 to 10 hours of direct sun. In all other areas of BC, place bat houses to receive as much sun as possible (at least 10 hours). In most regions of BC, bat houses should be placed in direct sun, facing south or southeast, to receive at least 10 hours of direct exposure each day.

Obstacles

Bats like a clear path to fly out of their house so that they can detect predators and easily avoid obstacles. Bat houses should be placed in open areas where there is no or little clutter such as on a post in the middle of a field or on the side of a building with no obstructions for at least 5 m. If a bat house is mounted on a tree (not recommended), the branches should be de-limbed below and around the bat house to create an open, uncluttered area.

Habitat

Ideally, bat houses should be situated near good foraging and drinking habitat such as streams, rivers, lakes or ponds. Bat houses within 400 m of a larger pond or lake have been known to have great success than those farther away[13]. However, it is still worth installing a bat house in areas away from water since bats can travel many kilometres each night to drink and forage. Forest openings are good settings for placing a bat house as they have good solar exposure and are uncluttered. If a bat house is being installed in combination with bat exclusion from a building, you may wish to try several bat houses in different locations including at least one near the current roost site. However, placing a bat house where bats are exiting and entering the building is not always the best location, depending on solar exposure, clutter, and other factors. It is more important for the bat house to be in a high, uncluttered and warm location than it is to be near the current roost site. Avoid mounting bat houses close to bright lights and select sites that are free from heavy winds.

[13] Tuttle, M. D., M. Kiser, and S. Kiser. 2004. *The Bat house Builder's Handbook: Second Edition*. Bat Conservation International, Austin, Texas. Available online: http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf

Protection from Predators

House cats are one of the largest predators of bats in BC, although raptors, weasels, and other animals may prey on bats. Predation can be avoided by mounting a bat house up high, since cats may be able to kill bats if the access point to the bat house is too low. A slippery sheet-metal guard can be wrapped on the bottom of a wooden post or tree to deter cats or other ground-based predators. To reduce predation by raptors, try to mount the bat house at least 20' (6 m) from the nearest tree branches, wires or other potential perches for aerial predators. Bat houses on stand-alone poles should have multiple nails in the top to deter predatory birds from perching on top.





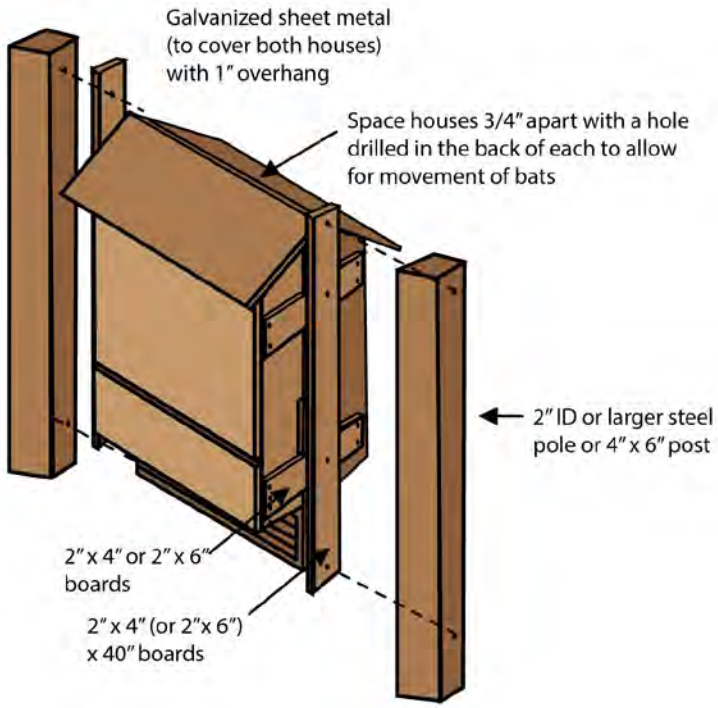
OWL ON BAT HOUSE (LEFT) AND GUARD FOR NON-FLYING PREDATORS (RIGHT). BAT HOUSES MOUNTED ON POLES SHOULD HAVE SPIKES ON TOP TO PREVENT AERIAL PREDATORS FROM PERCHING. PHOTOS COURTESY OF MICHELLE EVELYN (LEFT) AND RICK O'NEILL (RIGHT).

Interaction with People and Pets

Bat houses should be placed high enough to avoid direct contact between people (e.g. curious children) and pets. To minimize the chance of young children coming into contact with a bat that may fall from the roost, bat houses and condos in public spaces, such as parks and school grounds, should be placed in sites that do not experience a high level of human activity. This site selection will also reduce potential vandalism and disturbance issues.

Mounting Structure

Bat houses can be successfully placed on poles or posts or on the sides of buildings or outbuildings. **Bat houses mounted on wood, brick, or stone buildings with good solar exposure are good choices** since the building helps radiate heat into the bat house during the evenings. Mounting on a building is critical for single-chambered bat houses.

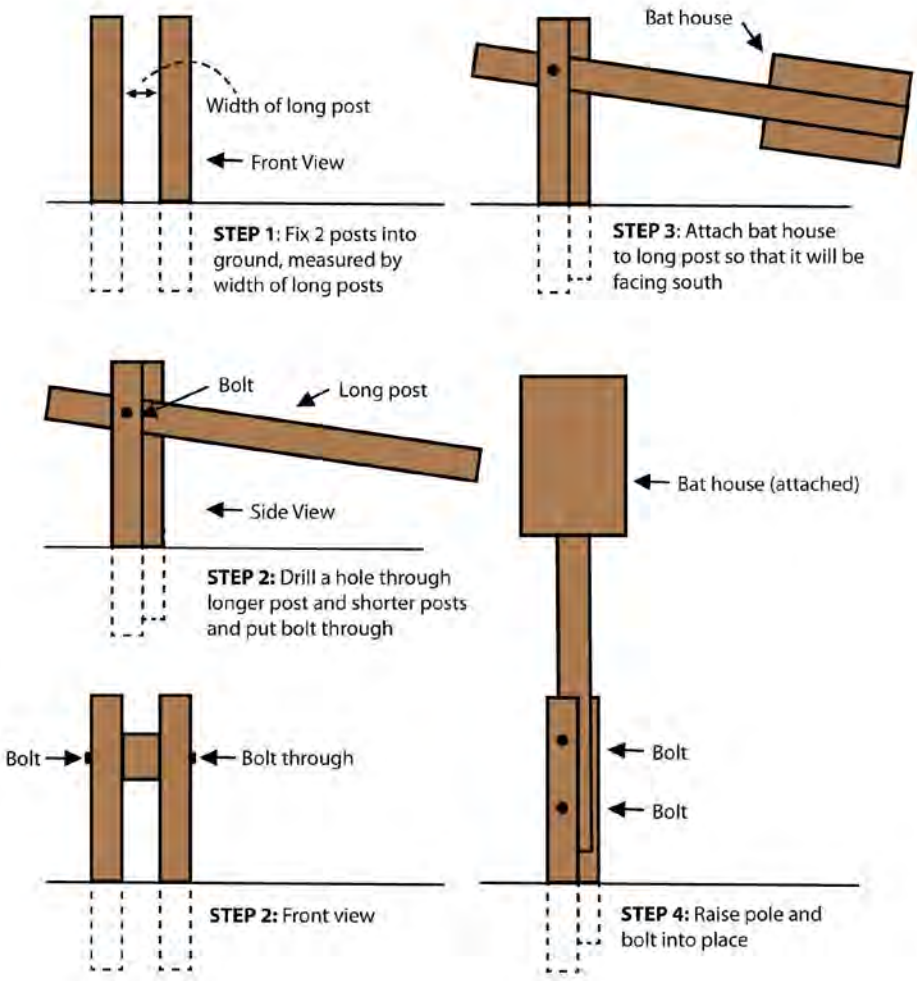


Bat houses mounted on 20' (6 m) poles (wooden, 4' by 4' or metal) put 4' in the ground have been successful since they can be mounted high, face any direction, and placed free of clutter. **An ideal scenario for bat-boxes is to mount two multi-chambered bat houses back to back on a pole** so that one faces north and the other faces south (see diagram) with opportunities for bats to move between then (see *Movement Between Chambers section*). The bottom of the posts can be braced to make them more secure and prevent them from being blown over. Any house mounted on a single post should have the post very securely planted and braced, as swaying of the bat house in wind may make it unappealing to bats, and possibly dangerous to humans!

Trees and snags are not recommended since they are more difficult for bats to find, more vulnerable to predators, and usually receive less sun exposure. However, trees that are significantly de-limbed (to act as poles) are successful. Although power and telephone poles are usually in excellent locations, these structures are not permitted since they prevent maintenance activities.

Tips for installation

To install a pole or a post for a bat house, consider fixing one or two short posts in the ground and then levering a tall pole up (see figure below). Another option is to mount an eye hook to the roof of the bat house and then hoist it into position for securement.



INSTALLATION OF A POLE-MOUNTED BAT HOUSE.

Enhancing Bat Habitat on a Community Scale

Community considerations for bat conservation should emphasize habitat conservation and restoration, including planting of bat-friendly tree species such as cottonwood, in conjunction with discussions about creating supplementary artificial roosting habitat. Communities can take a larger-scale approach, and should definitely consider bat condos. A community event to build many bat houses, a condo, or even a bat barn, can draw upon volunteers for donation of wood, supplying of tools, and labour for construction. These houses can then be erected strategically in the community to ensure a distribution of houses with different microclimates. For example, having two bat houses (e.g. north and south facing) on the same pole may be more beneficial than having each bat house on its own pole away from each other. The community construction of a bat condo should definitely be considered in areas where there is ample foraging habitat to support a large population of bats.

Frequently Asked Questions About Bat Houses

Do all bat species use bat houses?

No, many species of bats in BC only roost in natural structures such as trees, cliffs and caves. However most of the bat species that use buildings, most commonly the Little Brown Myotis, Yuma Myotis and Big Brown Bat, will also use bat houses. One exception is the Townsend's big-eared bat, a rare species in BC that roosts in buildings but requires large cavernous roosts and not the small chambers found in conventional bat houses. In Washington, California Myotis and Silver-haired Bats also regularly use bat houses[14].



TOWNSEND'S BIG-EARED BATS ROOST IN LARGE, CAVERNOUS STRUCTURES. PHOTO BY PAIGE ERICKSON-MCGEE

When should I put up a bat house?

Although a bat house can be installed at any time of year, bats are likely to move into a bat house when they first return from winter hibernation in April or May. If the bat house is being installed in combination with eviction, install the bat house at least two to six weeks before the actual exclusion.

How long until bats move into my bat house?

The success of a bat house depends on the design, location, and whether or not there are bats in the neighborhood looking for a roost site. When a bat house is installed in combination with exclusion of a colony from a building, it has a high chance of being successful. In other situations, it may take time before the bat house is used. Weathering of the wood may influence the suitability of the bat house.

I've had a bat house for years but never had any bats. Why not?

First, check the bat house design. Does it have a landing strip, multiple chambers, and some sort of "grip" for the bats inside? Is it stained an appropriate colour and placed in a high, open location? Is it a good design for this region, meaning that it has multiple narrow chambers and is quite large? If the bat house is a good design and in a good location, then it could simply be that there isn't currently a colony of bats seeking a summer roost site. However, if a colony of bats is evicted from their roost site, either intentionally (e.g. exclusion from a building), or unintentionally (e.g. a large tree falls down, rock feature

[14] Greg Falxa, personal communication.

is disturbed), they may require a new roost site. If the bat house appears to be suitably designed and placed yet still not occupied by bats, then leave the bat house for at least three years before replacing it or moving it to an alternative location.

Are there tricks to attracting bats to bat houses?

Besides ensuring a good design and location for the bat house, there are few other attractants. There is no evidence to support the practice of scenting the bat house with bat guano to improve the likelihood of occupation where a colony is to be excluded. If bats are being excluded from an attic, the bat house could be left inside the attic for several weeks before installing it so that is absorbs the smell of the colony; again, there is no evidence that this is necessary or effective. Guano from other locations should definitely not be applied to new bat houses, in the interest of controlling the spread of any bat diseases or parasites.

How can I tell if bats are using my bat house?

Look under the bat house for guano after several days of dry weather. If it is difficult to see, lay a light plastic sheet or piece of cardboard under the bat house for several days to catch any falling guano. Alternatively, set up a permanent monitoring structure such as a screen platform. Never place a bucket or any other container that bats cannot get out of under a bat house unless you put in a stick or some other object that bats can use to crawl out. If bats are using the bat house as a day or maternity roost, they can usually be observed departing within 30 minutes of dusk in good weather. In summer, watch the bat house for at least fifteen minutes before sunset to 30 minutes after for signs of use. If bats are using the bat house, participate in the **Annual BC Bat Count**





SCREEN TO CATCH GUANO UNDER BAT HOUSE CAN BE USED TO MONITOR THE BAT HOUSE FOR ACTIVITY AS WELL AS COLLECT GUANO FOR GARDENING (LEFT). PHOTO COURTESY OF GREG FALXA. BC RESIDENTS MONITOR BAT HOUSE AT DUSK (RIGHT). PHOTO COURTESY OF JULIET CRAIG.

Should I be concerned about the guano under the bat house?

There are no known health risks associated with bat guano in BC. In some areas of North America, a disease called histoplasmosis is associated with inhalation of bird and bat guano. Fortunately there are no documented cases of locally-acquired histoplasmosis in humans or animals in BC, indicating that the risk of acquiring this disease in this province is minimal. However, surveillance for this fungus in bat guano in BC has been limited so if you do have to clean up bat guano, particularly in an enclosed space, spritzing the area with water to keep the dust down and wearing a mask is suggested. For more information on histoplasmosis see www.ccohs.ca/oshanswers/diseases/histopla.html.

Will having bat houses in my yard interfere with attracting birds?

Bats and birds use different habitats for food and shelter so they do not compete. Installing a bat house does not affect attracting birds to your yard and often swallow boxes and bat houses are used in combination for insect reduction.

Does a bat house require maintenance?

A solidly-built, caulked, and painted bat house will require little maintenance. Wasp nests can be a problem for bats. Limiting the size of chambers to ¾" helps reduce occupation by wasps as does ensuring partitions are built to the roof of the bat house (without a gap at the top). During winter months, check the bat house and remove wasp nests by banging out each chamber using a broom handle or a paint roller extension pole.

Where can I get a bat house?

Check with your local bat project to find out if there is someone locally selling bat houses, or if your community bat project has funding to cover your bat house materials or donate a bat house to you. Look at your local garden, nature, or hardware store to ask if they sell them, but ensure that they meet the criteria of good bat house designs in BC. See the list of "Bat house Sources" in the Resources section of this document. Another option is to build your own bat house or have someone handy build it for you. Bat house plans are found at the end of this document or on the website www.bcbats.ca.

How do I register my bat house?

Please consider registering your bat house to help us learn more about bat preferences! You can find a registration form in Appendix 1, on our website at http://bcbats.ca/index.php/bat-houses/register-your-bat-house, or call the Community Bat Program at 1-855-9BC-BATS (1-855-922-2287). We will be interested in knowing what type of house, what colour, how high you mounted it, what direction it faces, how long it has been in place, and if it is occupied by bats.

How can I participate in the Annual Bat Count?

If you have bats in your bat house or another structure, and you enjoy watching them, please consider counting them as they exit to be a part of the Annual BC Bat Count (Appendix 2). Instructions and data forms can be downloaded from http://bcbats.ca/index.php/get-involved/participate-in-the-bc-bat-count or inquire with your local community bat project.

Resources

BC Community Bat Program

- www.bcbats.ca

Bat house design and placement

- Bat house Builders Handbook
  - http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf
- Bat Conservation International
  - http://www.batcon.org/resources/for-specific-issues/artificial-roosts
- Organization for Bat Conservation
  - http://www.batconservation.org/
- Bat Conservation and Management
  - http://www.batmanagement.com/Batcentral/batcentral.html

Bat house Plans

- Four-chambered nursery bat box: http://www.batcon.org/pdfs/bathouses/FourChamberNurseryHousePlans.pdf
- Single-chambered bat house: http://www.batcon.org/pdfs/bathouses/SingleChamberBHPlans.pdf
- Two-chambered rocket box: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context=icwdmother
- Simple rocket box: http://www.batsnorthwest.org/rocketbox_plans.pdf
- Bat Can (for purchase): http://batmanagement.com/Ordering/batboxes/batcan/batcan.html
- Gable vent cover: http://www.batguys.com/resources/suburban-bat-house.html

Bat house Installation

- http://www.batmanagement.com/Batcentral/boxinstall/install1.html
- https://www.batcon.org/pdfs/bathouses/InstallingYourBatHouseWoodenPostSteel%20Pole.pdf

Bat house Sources

Check with your local community bat project first since there may be a local builder/source.

- Canadian Bat Houses (http://canadianbathouses.com/)
- Urban Nature Store (http://www.urbannaturestore.ca/wild-birding/other-wildlife/bats-bat houses/) – the larger models
- Backyard Bird Centre (http://backyardbird.ca/collections/bat houses) – the larger models
- Natural Insect Control (http://www.naturalinsectcontrol.com/product.php?id=000000307)
- Lee Valley Tools (http://www.leevalley.com/en/wood/page.aspx?p=70692&cat=2,51555&ap=1) – bat house needs to be stained an appropriate colour. Available in-store only at Victoria, Coquitlam and Vancouver
- Amazon Canada (several designs – look for key features) e.g. http://www.amazon.ca/Looker-Bat-Triple-Chamber-House-Triple/dp/B000FLTO6A/ref=pd_sim_86_6?ie=UTF8&dpID=41xeZ3H4huL&dpSrc=sims&preST=_AC_UL160_SR160%2C160_&refRID=0N3BEMVC6NCQ8D3ZZ5P2

APPENDIX 1: Register Your Bat House

Since little is currently known about the optimal characteristics of bat houses in BC, we encourage you to report on the success (or lack of success… these data are important too!) of your bat houses. By registering your bat house and reporting on its success, you can be part of an ongoing project to identify the characteristics of successful bat houses. If you have a bat house, please let us know!

You can fill out this form online at http://bcbats.ca/index.php/bat-houses/register-your-bat-house , or print it, fill it in, and mail to BC Community Bat Program, Attn: Mandy Kellner, Box 8617, Revelstoke, BC, V0E 2S2 or scan and email to info@bcbats.ca .

Your name _____

Your email _____Your phone _____

Nearest town _____ When did you install your bat house? _____

Did you put the house up as part of an exclusion from your own house? Yes ☐ No ☐ Unknown ☐

Have you ever seen signs that your bat house has been occupied? (check for guano (droppings) below the house, listen for squeaks, or watch the house at dusk – you cannot always see the bats inside)
Yes ☐ No ☐ Unknown ☐

How big is your bat house? (e.g. 80cm*8-cm*20cm, 4 chambers) _____

What kind of house is it and how many chambers does it have ? (e.g. 3-chamber maternity)
_____

What colour is your bat house? (e.g. painted or stained black, brown) _____

What direction is your bat house facing ? (e.g. south-west)_____

What is your bat house installed on? (e.g. pole, side of shed, side of house) _____

How high up is the top of your bat house? _____

How much open space is around your bat house (distance to nearest branches, obstacles)? _____

How close is the nearest freshwater body (lake, pond, creek, river)? _____

Has anyone done any testing to determine which species of bats are using your house?
DNA testing ☐ acoustic surveys ☐ mist net surveys ☐ dead bat sample☐ no testing☐

If so, what species were detected?
Big Brown ☐ Little Brown ☐ Yuma ☐ California Myotis ☐ Townsends ☐ I don't know ☐

The Annual BC Bat Count is an important province-wide bat monitoring effort. Volunteers across BC count bats emerging from known roosts 1-2 times between Jun 1 and 21 (before pups can fly) and 1-2 times between Jul 21 and Aug 15 (when pups are flying with their moms). Would you be interested in including your house in the count?
Yes, I would like to participate ☐ Yes, if a Community Bat team member can help ☐
No, my house has never been occupied and is not suitable ☐ No, I do not wish to participate☐
May we contact you by email or phone in the future to get updates on use of your bat houses? Yes ☐ No ☐

Participate in the BC Annual Bat Count

WHAT: A citizen-science program in B.C. to annually monitor bat roost sites.

WHY: Half the bat species in BC are considered to be of conservation concern. Even the common little brown bat is being proposed for designation as an "endangered" species because of high mortality rates from the disease, White Nose Syndrome. The disease is not yet in BC but is predicted to arrive in the next decade. To be able to effectively manage and conserve bats in the face of the many threats, we need to know how their population numbers are doing year to year. The BC Bat Count will contribute towards gathering this important information.

WHO: Anyone who is interested in collecting valuable information to help monitor our bat populations.

WHERE: A roost site (such as abandoned houses, attic, barns, church steeples, bridges, bat-houses and other structures) on your property or somewhere else.

WHEN: Ideally, participants conduct four bat counts per summer - **two between June 1 and 21** (before pups can fly) and **two more between July 21 and August 15** (when pups are flying and exiting the roost). Doing all four bat counts will allow us to best compare data from year to year and between sites. If it is difficult to do four counts, consider the following options:

- Level 1: ***Bat Reporter*** - 1 count over the summer (try between July 21 – August 15)
- Level 2: ***Bat Tracker*** - 1 count between June 1 – 21 and one count between July 21 - August 15
- Level 3: ***Bat Enthusiast*** – 2 counts between June 1 – 21 and 2 counts between July 21 – August 15

HOW:

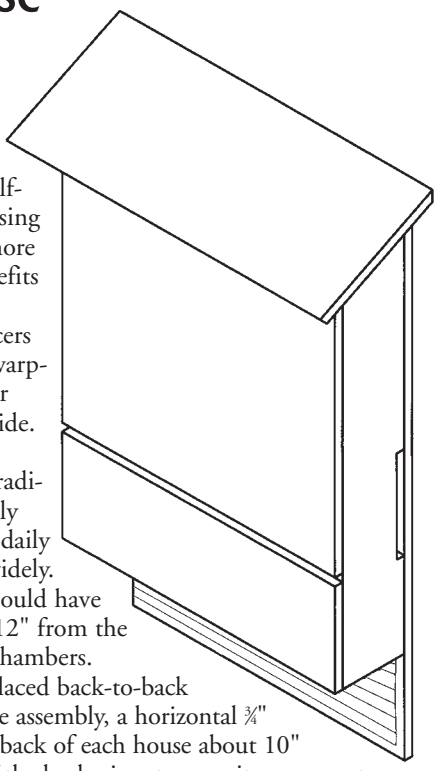
- Check www.bcbats.ca "Get Involved" tab for most recent data forms and instructions.
- Arrive at your bat roost by sunset. Bats may begin to emerge around sunset and so don't be late! Some species may emerge closer to civil twilight so don't worry if it takes a little while to see the first one.
- Count bats for one hour or until it is too dark to see, whichever comes first.
- The air temperature should be at least 12°C with low wind speed. Some bats will not fly if the weather is too cold, windy or drizzly, and roost emergence counts under non-ideal weather conditions will underestimate population size.
- Sit or stand outside so that the bats' exit point is visible from a comfortable distance. More than one person might be needed if bats are exiting from multiple points. Try to have the light sky behind the bats exit point, to make it easier to count.
- Tally the bats as they fly out for their nightly insect-eating. You may wish to use a hand "clicker" to make counting easier, or video the emergence to count later on your screen.

For more information: www.bcbats.ca or 1-855-9BC-BATS

APPENDIX 3: Bat House Plans

Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

Four-chamber Nursery House



Materials (makes two houses) • *Diagrams on pages 12 & 13*

½ sheet (4' x 4') ½" AC, BC or T1-11 (outdoor grade) plywood
½ sheet (4' x 4') ⅜" AC or BC (outdoor grade) plywood
Two pieces 1" x 6" (¾" x 5½" finished) x 8' pine or cedar
One lb. coated deck or exterior-grade screws, 1⅝"
20 to 25 coated deck or exterior-grade screws, 1¼"
20 to 25 exterior-grade screws, 1"
One quart dark, water-based stain, exterior grade
One quart water-based primer, exterior grade
Two quarts flat water-based paint or stain, exterior grade
One tube paintable latex caulk
Black asphalt shingles or galvanized metal
12 to 20 roofing nails, ⅞"

Recommended tools

Table saw or circular saw
Variable-speed reversing drill
Screwdriver bit for drill
Tape measure or yardstick
Caulking gun
1½" hole saw or spade bit
Paintbrushes
Hammer (optional)
Tin snips (optional)
Bar clamp (optional)
Sander (optional)

Construction

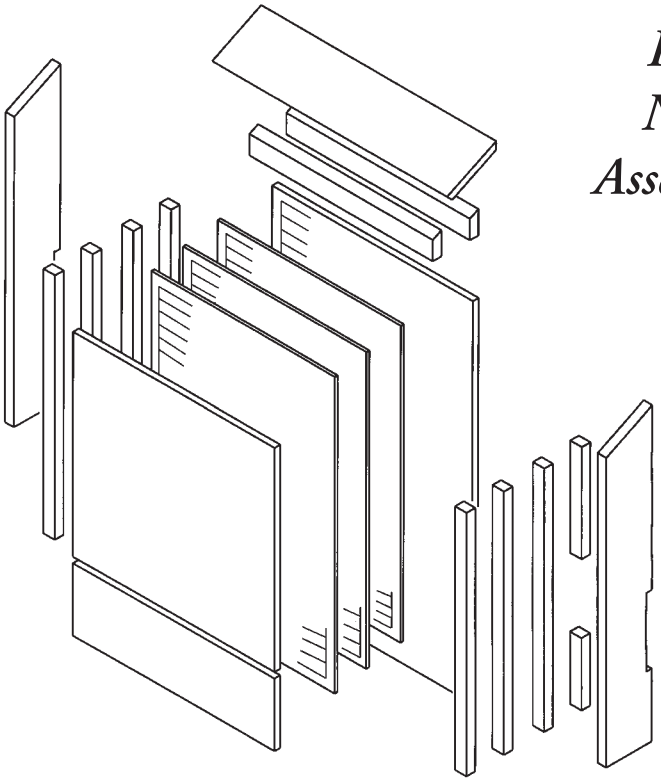
1. Measure, mark and cut out all wood according to the sawing diagrams on pages 12 and 13.
2. Roughen interior and landing surfaces by cutting horizontal grooves with sharp object or saw. Space grooves ¼" to ½" apart, cutting 1/32" to 1/16" deep.
3. IF DESIRED, apply two coats of dark, water-based stain to interior sur-faces. Do not use paint, as it will fill grooves.
4. Attach side pieces to back, caulking first. Use 1⅝" screws. Make sure top angles match.
5. Attach 5" and 10" spacers to inside corners per drawings on page 12. Use 1" screws. Roost chamber spacing will be ¾" (front to back). Do not block side vents.
6. Place first roosting partition on spacers even with bottom edge of roof. Place 20" spacers on partition and screw to first spacers (through partition), using 1⅝" screws.
7. Repeat step 6 for remaining spacers and partitions.
8. Attach front to sides, top piece first (caulk seams). Be sure top angles match (sand if necessary). Leave ½" vent space between top and bottom front pieces. A bar clamp may be useful if sides have flared out during construction.
9. Attach roof supports to the top inside of front and back pieces with 1" screws. Don't let screws protrude into roosting chambers.
10. Caulk around all top surfaces, sanding first if necessary to ensure good fit with roof.
11. Attach roof to sides and roof supports with 1¼" screws. Caulk around roof and side joints to further guard against leaks and drafts. Don't let screws protrude into roosting chambers.
12. Paint or stain exterior three times (use primer for first coat).
13. Cover roof with shingles or galvanized metal.

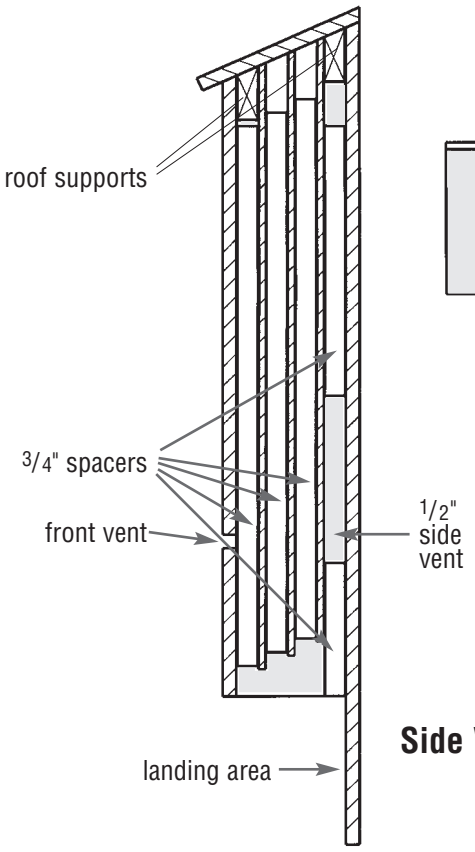
Optional modifications

1. These nursery-house dimensions were chosen to permit construction of two bat houses per half-sheet of plywood. Increasing house width to 24" or more or adding partitions benefits bats and attracts larger colonies. Additional spacers are required to prevent warping of roost partitions for houses more than 24" wide.
2. Taller bat houses provide improved temperature gradients and may be especially useful in climates where daily temperatures fluctuate widely. Bat houses 3' or taller should have the horizontal vent slot 12" from the bottom of the roosting chambers.
3. Two bat houses can be placed back-to-back mounted on poles. Before assembly, a horizontal ¾" slot should be cut in the back of each house about 10" from the bottom edge of the back piece to permit movement of bats between houses. Two pieces of wood, 1" x 4" x 10¾", screwed horizontally to each side, will join the two boxes. Leave a ¾" space between the two houses, and roughen the wood surfaces or cover the back of each with plastic mesh. One 2" x 4" x 40" vertical piece, attached to each side, over the horizontal pieces, blocks light but allows bats and air to enter. Use a 2" x 6" vertical piece if securing houses with U-bolts to metal poles. A galvanized metal roof that covers both houses protects them and helps prevent overheating. Eaves should extend about 3" in front in southern areas and about 1½" in the north.
4. Ventilation may not be necessary in cold climates. In that case, the front of the bat house should be a single, 23"-long piece. Far-northern bat houses may also benefit from a partial bottom to help retain heat. Slope the sides and bottom at an angle of 45° or greater to reduce guano build-up. Leave a ¾" entry gap at the back and be sure the bottom does not interfere with access to the front crevices. A hinged bottom is required to permit annual cleaning.
5. Durable plastic mesh can be substituted for roughening. Attach mesh to backboard, landing area and one side of each partition after staining interior, but prior to assembly. Use ⅛"- or ¼"-inch HDPE plastic mesh [such as Internet product #1672 (1-800-328-8456; www.internetmesh.net)] and attach every two inches with 3/16" Monel® or stainless steel staples.
6. Make partitions removable by attaching small cleats with thumbscrews to the bottom of side pieces for support. Spacer strips are unnecessary if grooves for partitions are cut in the side pieces with a router or dado saw blade.

FIGURE 4

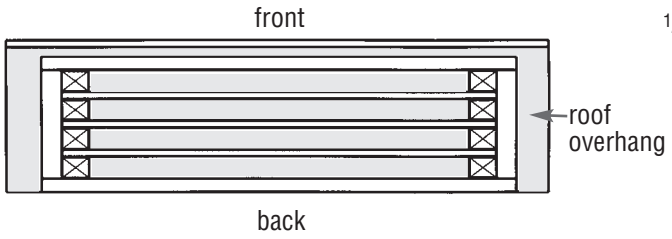
Four-chamber Nursery House Assembly Diagrams

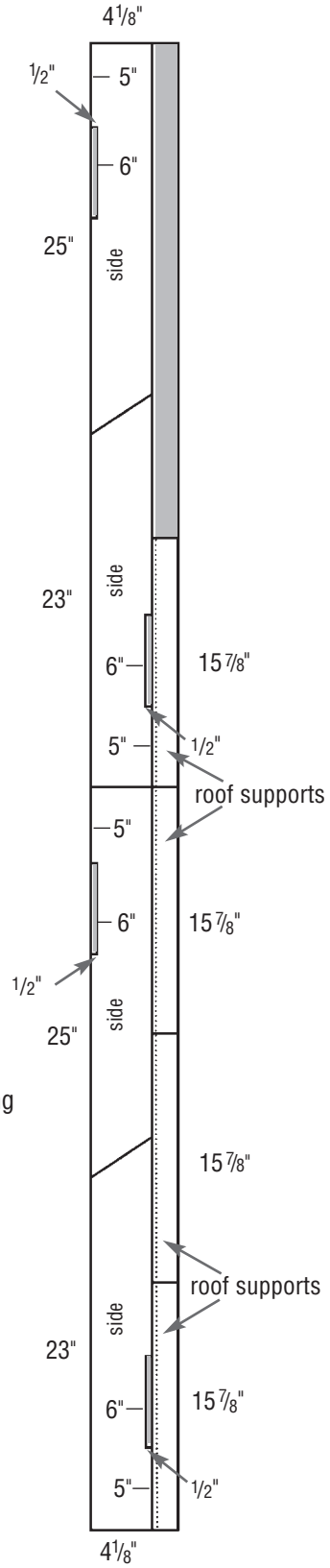




Side View

Bottom View

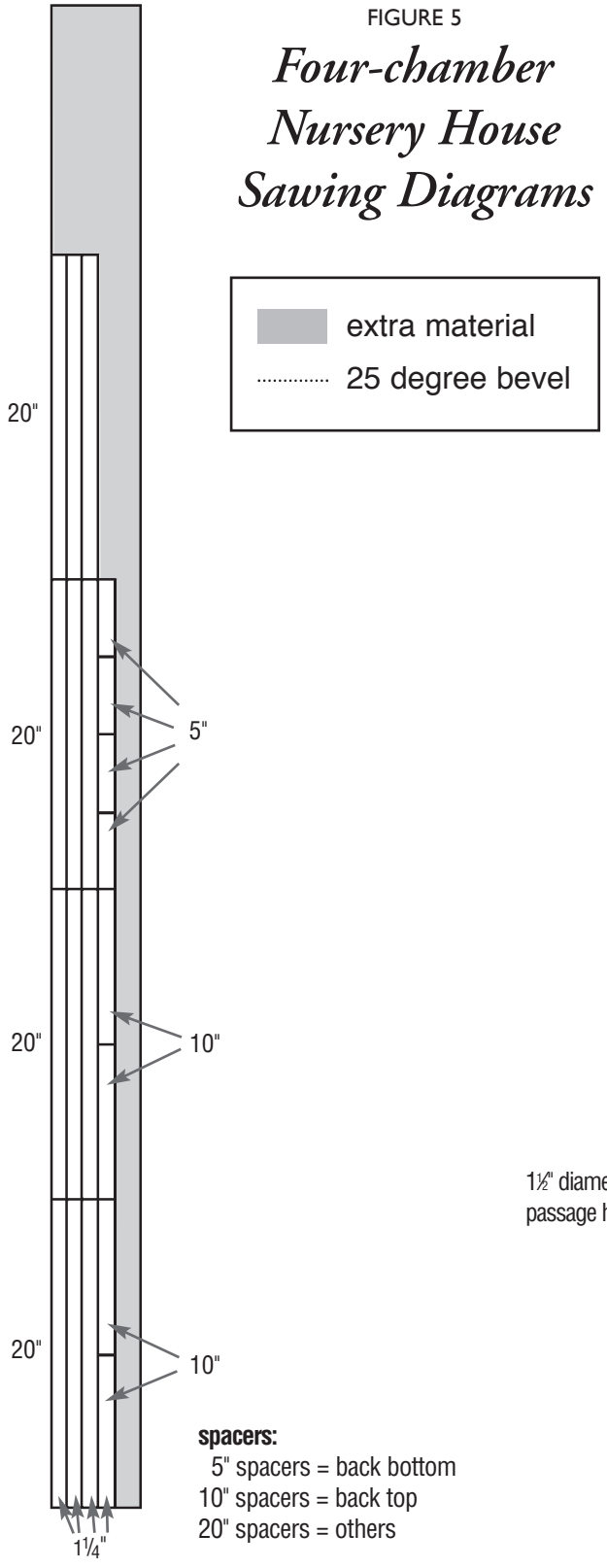




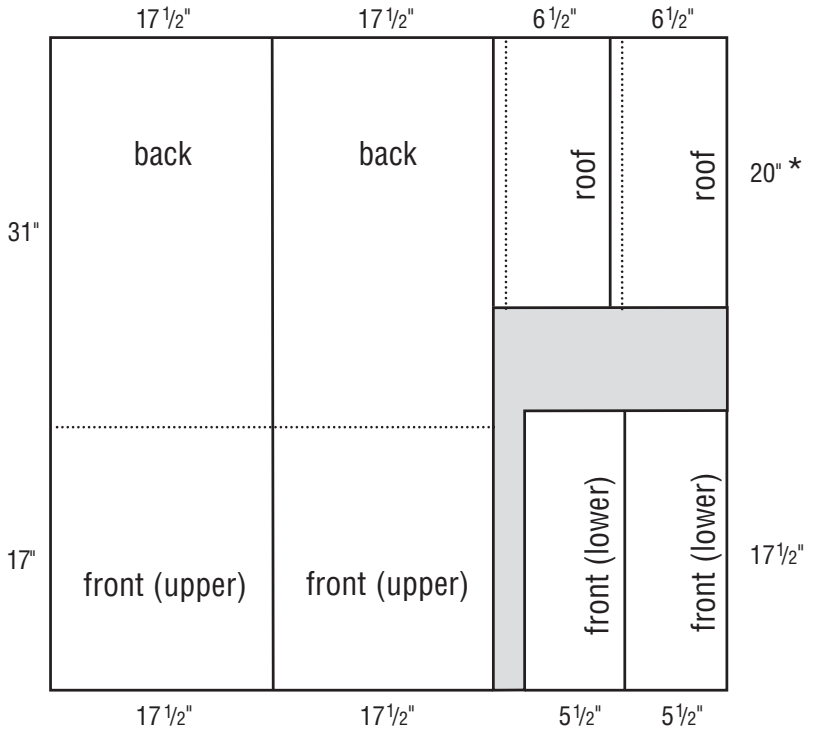
1" x 6" x 8' board

FIGURE 5

Four-chamber Nursery House Sawing Diagrams

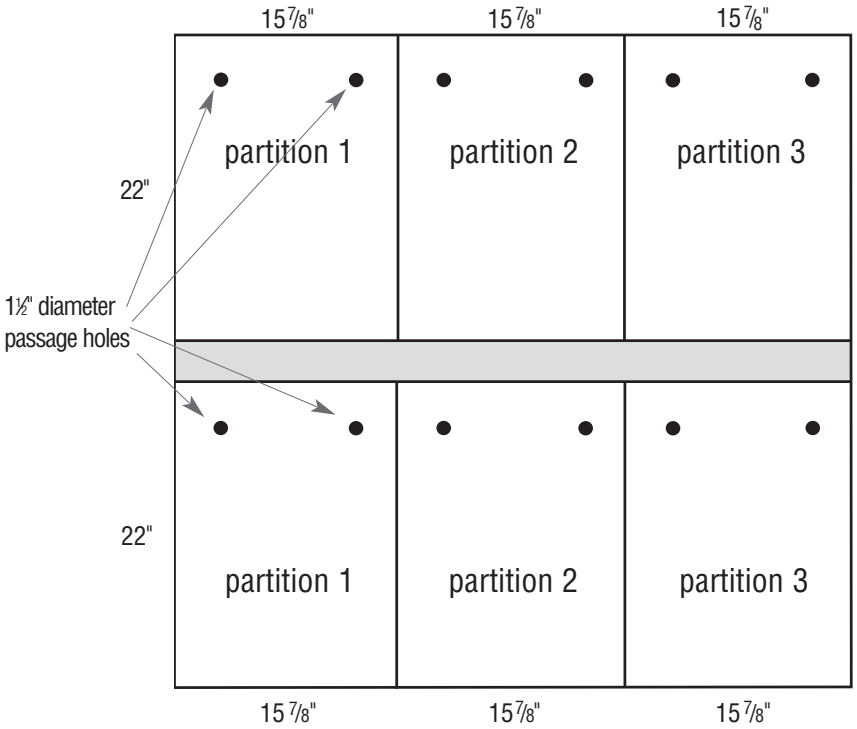


1" x 6" x 8' board



4' x 4' x ½" plywood

* 19" if mounted between two poles



4' x 4' x ⅜" plywood

Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

Two-chamber Rocket Box

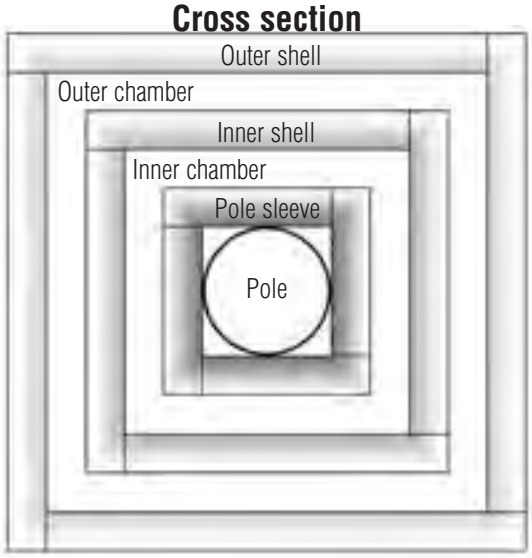
Materials (makes one house)

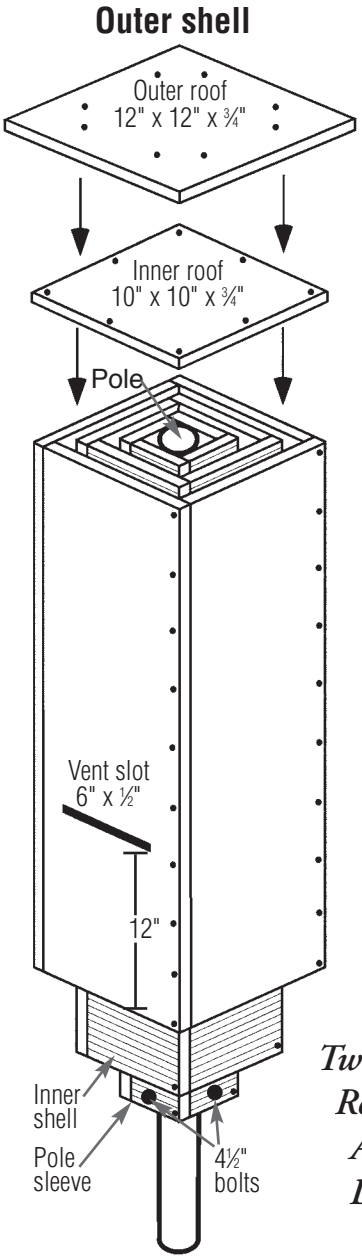
2" diameter (2⅜" outside diameter) steel pole, 20' long
Two 1" x 4" (¾" x 3½" finished) x 8' boards*
Two 1" x 8" (¾" x 7¼" finished) x 8' boards*
Two 1" x 10" (¾" x 9¼" finished) x 6' boards*
24" x 24" x ¾" piece of AC exterior plywood
Box of 100 exterior-grade screws, 1⅝"
Box of 100 exterior-grade screws, 1¼"
16 to 32 exterior-grade screws, 2"
20 to 30 roofing nails, ⅞"
One quart water-based primer, exterior grade
Two quarts flat, water-based stain or paint, exterior grade
Asphalt shingles or dark galvanized metal
One tube paintable latex caulk
Two ¼" x 4½" carriage bolts, washers and nuts

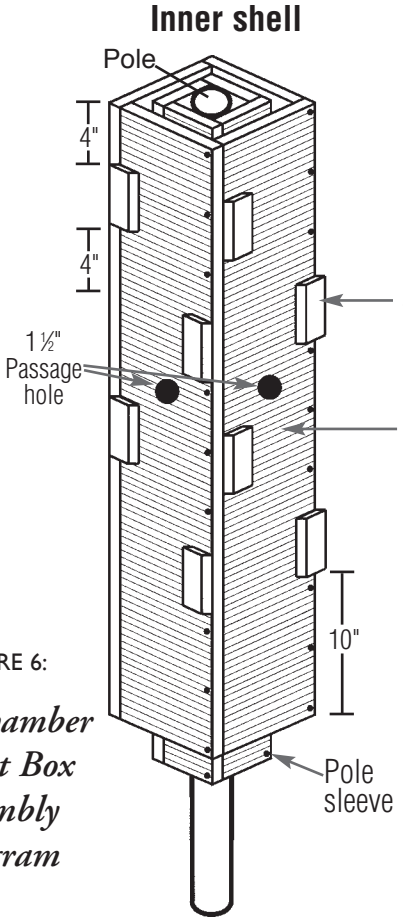
** Western red cedar or poplar preferred*

Recommended tools

Table saw or circular saw
Caulk gun
Hammer
Tape measure
Square
Jigsaw, keyhole saw or router
Sandpaper or sander
Rasp or wood file
Variable-speed reversing drill
1½" hole saw or spade bit
⅛" and ¼" drill bits
Screwdriver bit for drill







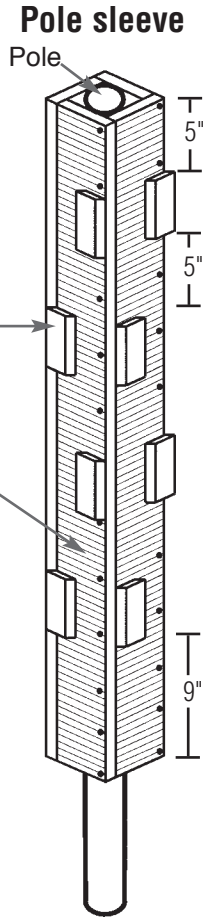


FIGURE 6:

Two-chamber Rocket Box Assembly Diagram

Construction

1. Measure, mark and cut out parts according to Figure 7. Dimensions must be exact for correct fit. Cut out two vent slots and four passage holes as shown.
2. Cut ⅛"-deep horizontal grooves ¼" to ½" apart on one side of all 36" and 45" boards and on both sides of all 42" boards. Sand to remove splinters.
3. Drill two ⅛" holes through each ¾" x 1½" x 4" spacer block to prevent splitting.
4. Assemble four pole sleeve boards into a hollow, square box as shown using 1⅝" screws and caulk. Pre-drill holes to prevent splitting. Countersinking holes may also help.

5. Attach spacer blocks to pole sleeve as shown (four per side) using two 1¼" screws per block. Bottom spacer blocks are 9" up from bottom of pole sleeve. Top spacer blocks are 5" from top. Alternate spacer blocks on left and right sides, 5" apart.
6. Assemble four inner shell boards into a hollow, square box as in step 4.
7. Slide pole sleeve into inner shell until top edges are flush. Bat passage holes will be towards the top. Mark location of spacer blocks. Secure inner shell to pole sleeve with 2" screws through the spacer blocks to ensure no screws protrude into roosting chambers. Pre-drill holes first to avoid splitting spacer blocks (countersinking holes may also help).
8. Attach spacer blocks (4 per side) to inner shell as shown, using two 1¼" screws per block. Bottom spacer blocks are 10" up from the bottom edge of the inner shell. Top spacers are 4" from top. Alternate spacers left and right sides, 4" apart.
9. Assemble four outer-shell boards into a hollow, square box as in step 4. Vent slots are on opposing sides and oriented towards the bottom.
10. Slide finished outer shell over inner shell, so that 6" of inner shell protrudes below outer shell. Mark locations of spacer blocks. Secure outer shell to inner shell as in step 7 (pre-drill holes first). Ensure that no screws protrude into the roosting chambers.
11. Caulking first, attach inner roof to box with 1¼" screws. Carefully drive screws into top edges of shells to prevent screws from entering roosting chambers.
12. Center and attach outer roof to inner roof with 1¼" screws, caulking first.
13. Paint or stain exterior three times (use primer for first coat). Cover roof with shingles or dark galvanized metal.
14. Slide completed rocket box over pole. One inch up from the bottom edge of pole sleeve, drill a ¼" hole all the way through pole and sleeve. Rotate box and pole 90° and drill another ¼" hole, 2 inches from the bottom, through pole and sleeve. Secure box to pole with two 4½" bolts, washers and nuts. Orient vent slots north and south during installation.

Optional modifications to the rocket box

1. For extra mounting height, insert a 4½" bolt and nut about halfway up through pole sleeve after completing step 5.
2. For extra heat-holding capacity, create a compartment in upper half of pole sleeve with a 2½"-square piece of leftover plywood. Fill upper half of sleeve with sand, gravel or dirt, and seal with another piece of plywood flush with top.
3. In warmer climates, a larger outer roof with more overhang can be used for additional shading.

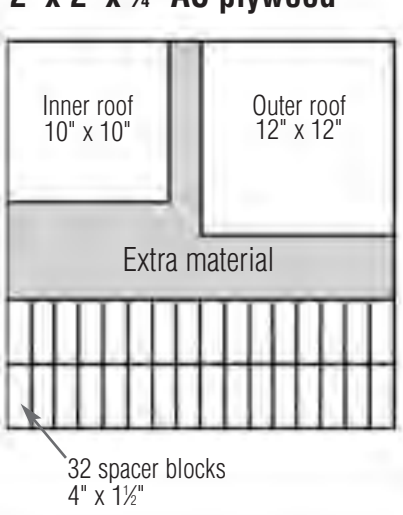
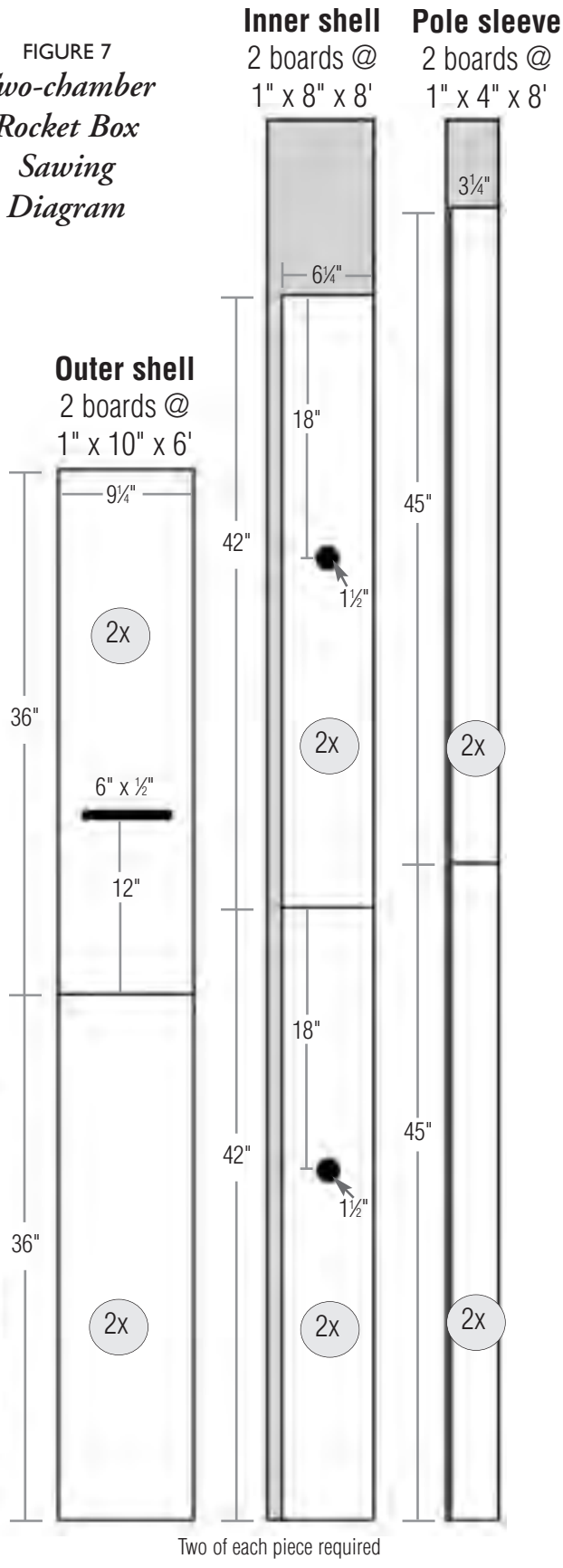


FIGURE 7
Two-chamber Rocket Box Sawing Diagram



Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

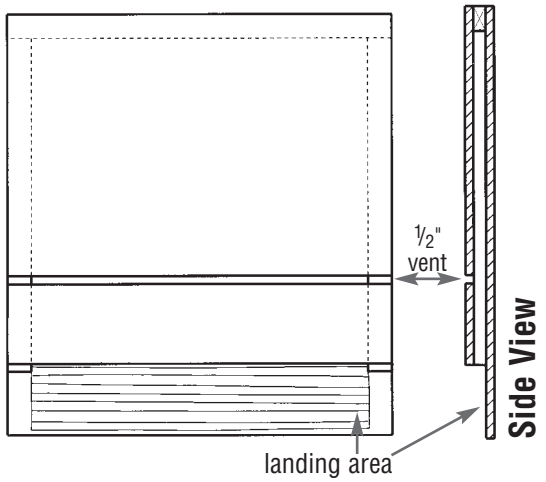
Single-chamber Bat House (wall mounted)

Materials (makes one house)

¼ sheet (2' x 4') ½" AC, BC or T1-11 (outdoor grade) plywood
One piece 1" x 2" (¾" x 1½" finished) x 8' pine (furring strip)
20 to 30 exterior-grade screws, 1"
One pint dark, water-based stain, exterior grade
One pint water-based primer, exterior grade
One quart flat, water-based paint or stain, exterior grade
One tube paintable latex caulk
1" x 4" x 28" board for roof (optional, but highly recommended)
Black asphalt shingles or galvanized metal (optional)
6 to10 roofing nails, ⅞" (if using shingles or metal roofing)

Recommended tools

Table saw or handsaw	Caulking gun
Variable-speed reversing drill	Paintbrushes
Screwdriver bit for drill	Hammer (optional)
Tape measure or yardstick	Tin snips (optional)



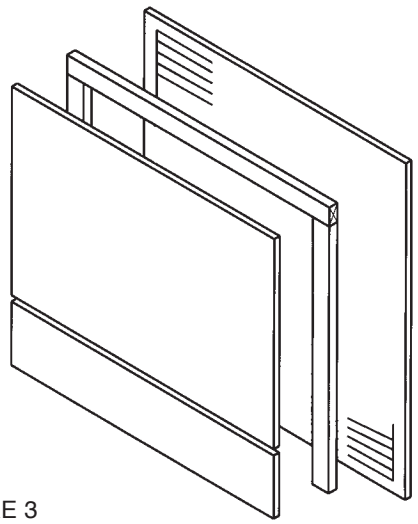


FIGURE 3

Construction

1. Measure and cut plywood into three pieces:
   26½" x 24" 16½" x 24" 5" x 24"
2. Roughen inside of backboard and landing area by cutting horizontal grooves with sharp object or saw. Space grooves ¼" to ½" apart, cutting 1/32" to 1/16" deep.
3. Apply two coats of dark, water-based stain to interior surfaces. Do not use paint, as it will fill grooves.
4. Cut furring strip into one 24" and two 20½" pieces.
5. Attach furring strips to back, caulking first. Start with 24" piece at top. Roost chamber spacing is ¾".
6. Attach front to furring strips, top piece first (caulk first). Leave ½" vent space between top and bottom front pieces.
7. Caulk all outside joints to further seal roost chamber.
8. Attach a 1" x 4" x 28" board to the top as a roof (optional, but highly recommended).
9. Apply three coats of paint or stain to the exterior (use primer for first coat).
10. Cover roof with shingles or galvanized metal (optional).
11. Mount on building (south or east sides usually best).

Optional modifications to the single-chamber bat house

1. Wider bat houses can be built for larger colonies. Be sure to adjust dimensions for back and front pieces and ceiling strip. A ¾" support spacer may be needed in the center of the roosting chamber for bat houses over 24" wide to prevent warping.
2. To make a taller version for additional temperature diversity, use these modifications: From a 2' x 8' piece of plywood, cut three pieces: 51" x 24", 33" x 24" and 12" x 24". Cut two 8' furring strips into one 24" and two 44" pieces. Follow assembly procedure above.
3. Two bat houses can be placed back-to-back, mounted between two poles, to create a three-chamber nursery house. Before assembly, cut a horizontal ¾" slot in the back of each house about 9" from the bottom edge of the back piece to permit movement of bats between houses. Two pieces of wood, 1" x 4" x 4¼", screwed horizontally to each side, will join the two boxes. Leave a ¾" space between the two houses, and roughen the wood surfaces or cover the back of each with plastic mesh (see item 5 below). Do not cover the rear exit slots with mesh. One 1" x 4" x 34" vertical piece, attached to each side over the horizontal pieces, blocks light but allows bats and air to enter. A galvanized metal roof, covering both houses, protects the center roosting area from rain. Eaves should be about 3" in southern areas and about 1½" in the north.
4. Ventilation may not be necessary in cold climates. In this case, the front should be a single piece 23" long. Smaller bat houses like this one will be less successful in cool climates. However, those mounted on buildings maintain thermal stability better and are more likely to attract bats.
5. Durable plastic mesh can be substituted to provide footholds for bats. Attach one 20" x 24½" piece to backboard after staining interior, but prior to assembly. Details on page 11.

Build and Maintain Nesting and Roosting Boxes



Many of Canada's wildlife need trees, especially large ones, that are dying or dead (snags) as safe places to nest in the warmer months and escape poor weather and predators the rest of the year. They are also a key source of food for birds who glean insects along tree trunks and branches.

Where safe, it is best to leave these older trees in your backyard alone. But if it's not possible, or if they were removed before you moved to your home, putting up birdhouses – aka nesting boxes – and roosting boxes can make a big different for bird species that have adapted to these structures.

Tree Cavity Birds in Canada

Tree cavities are formed by either natural decay, an animal or both. Some birds, such as woodpeckers, make their own cavitieswith their strong bills, while others, like owls, nuthatches and chickadees, use these pre-made holes once they are abandoned.

Here's a list of Canadian bird species that have been known to use tree cavities. Many of these birds will use either a bird box and/or a roosting box.



- Eastern Bluebird
- Black-capped Chickadee
- Boreal Chickadee
- White-breasted Nuthatch
- Red-breasted Nuthatch
- Tufted Titmouse
- Pileated Woodpecker
- Downy Woodpecker

- Hairy Woodpecker
- Red-headed Woodpecker
- Northern Flicker
- Red-bellied Woodpecker
- American Kestrel
- Peregrine Falcon
- Merlin
- Barn Owl
- Eastern Screech Owl
- Barred Owl
- Boreal Owl
- Saw-whet Owl
- Northern Hawk Owl
- Pygmy Owl
- Flammulated Owl
- Spotted Owl
- Turkey Vulture
- Great Crested Flycatcher
- Purple Martin
- Tree Swallow
- Chimney Swift
- Vaux's Swift
- House Wren
- Prothonotary Warbler
- Common Goldeneye
- Bufflehead
- Common Merganser
- Hooded Merganser
- Wood Duck

However, according to "Cavity-Nesting Birds of North American Forests" by Scott, Evans, Patton and Stone, the Peregrine Falcon and Merlin no longer had access to big enough cavities with the removal of large trees around the early 1900's and had to adapt to other means of surviving. Some, the western population of Purple Martins have not adapted well to man-made boxes and still need large snags.



Benefits of Putting up Boxes

It is captivating to watch our winged friends building nests, feeding eager mouths and seeing their young take flight. But having cavity nesting birds around our properties is also a huge benefit as they keep insect and rodent populations in check.

It is also satisfying to know that we are helping these important wild neighbours. As more and more people remove the dead or slowly decaying trees from their properties (for various purposes, including firewood, safety, aesthetics and development), there are fewer homes for these important birds.

Removing decaying trees also removes a food source as they forage on insects found on and in dead or dying trees. In fact, experts say that keeping three or four snags (dead or dying trees) per acre of forest is critical for many organisms in that ecosystem, including birds. That's where we can make a real difference!

Some species, like the Eastern Bluebird, once faced serious decline because of the dwindling number of natural cavities available to them, but rebounded because of nesting box programs organized throughout their range.

Where possible, leave dead or dying trees standing. Remove any potentially dangerous branches if near paths, homes or other areas of human activity. If the tree trunk is also a concern (perhaps the top looks weak) consider having a tree company lop the top off to allow the stronger lower portion of the tree to remain standing for several more years. This is especially important for wide trees as larger birds who need bigger homes have less options with fewer mature trees around.

If you can't keep a snag on your property or you want to support these birds, you can put up nesting boxes for the spring and summer and roosting boxes for the rest of the year.



Making Your Own

The dimensions and placement of the nesting box, as well as the size and height of the entrance hole will determine which species will set up house. Check that the species you wish to support lives in your region and that the habitat on your property matches their needs.

Both nesting and roosting boxes benefit from an overhang which prevents rain from going in and makes it harder for predators, like cats and racoons, to reach in. If you are able, cut a groove along the underside of this roof, close to the edge, to channel away any rainwater that could trickle in.

Both boxes should also have a predator guard. You can attach a metal piece fitted around the entrance hole so it can't be chewed wider or, if on a pole, place a baffle below it to prevent animals from climbing up. It's important not to have perches outside the boxes as they make it easier for predators to enter the box.

They will also need a side that can be easily removed or opened for regular cleaning.

When looking to buy or make a nesting or roosting box, keep in mind the main differences between the two kinds of boxes.

MATERIALS

Use woods that resist weathering, such as cedar, pine or redwood. Always avoid pressure-treated lumber as it can be toxic to wildlife. Use lumber at least 2.5 centimetres thick. For roosting boxes, consider using thicker wood to increase the insulation value.

To help the box blend in, use pieces of wood with bark still attached. These slabs are less expensive and can often be found at sawmills and lumber yards.

Consider using screws instead of nails to make it easier to correct mistakes and remove parts in the future if needed. Or use a hinge and latch for even greater access.

It is better not to paint or stain the box. This helps the box blend in, avoiding the attention of predators, and will be healthier for those that use the box. If you do choose to paint, however, follow these tips:

- Use a non-toxic water based paint.
- Paint nesting boxes in the fall for the fumes to dissipate before spring. Paint roosting boxes in the spring, once the coldest days are over.
- Do not paint the inside to prevent paint fumes and flakes from harming young birds.
- Use natural colours that help the box blend in.
- Avoid dark paint colours for nesting boxes, as they can cause the box to hold more heat.

ROOSTING BOXES

- Can have perches inside. They are not necessarily needed as birds have been known to huddle inside but if used, place at different heights and allow sufficient room for moving about.
- Include scuffed sides for gripping.
- Have a low entrance hole so heat rises.
- Do not have ventilation holes in order to contain heat. If your roosting box does have ventilation holes, ensure it is placed on the floor corner and that it is very small.
- Are often larger in size than nesting boxes to accommodate several birds at once.
- Benefit from using thicker wood for added insulation.
- Can be placed in a spot that allows for maximum sunlight, if desired.

DIMENSIONS

These boxes can be any size, as they are known to accommodate varying numbers of birds at one time. You could make them the same size as a nesting box or larger to allow several birds to roost together.

If you have the space, put up a roosting box with a smaller hole (see entrance hole sizes below) and one with a larger hole to attract different species.

CONSTRUCTION

Cut the pieces as specified in the table above, keeping in mind the two side panels should be a bit taller at the back, to allow for a roof that slopes down at the front. (If you are a woodworker or are up for the challenge, you could use two pieces of wood for the roof which slope down at the sides. To do this, you will need to make the front and back pointed at the top to be snugly attached to the roof.)

Whatever box you decide to make, allow extra for the roof to overhang on the front and, if you wish, the sides. If you

are comfortable with woodworking, cut the top of the sides at a slight downward sloping angle and cut the edge of the roof where it meets the backboard to match so it sits snugly.

Drill a hole in the front panel to make an entrance hole using the measurements indicated in the accompanying table (note both the entrance hole diameter and the height of this hole above the floor).

With rough sandpaper, make the inside walls rough enough for young birds to climb out of the box. The higher the entrance hole from the floor, the more help the bird will need. Some species, like ducks, need actual grooves called kerfs.

Attach the pieces with screws or nails. If you choose nails, decide which side you will use to access the inside for cleaning and use screws for that wall, allowing you to undo and reattach each year. You could also use a hinge and latch although raccoons may be able to open it, depending on how loose the latch is.

Drill a few small holes on the sides of the box where you have an overhang to allow hot air to escape. Drill a few small holes (1/4”) in the floor near the walls for moisture drainage. Make the front wall rough on the inside, to help the young climb out as they grow. Some species, such as ducks, will benefit from a few grooves or notches.

Do not attach a platform or perch outside the box. Predators could raid the nest and young birds might venture out of the box too soon.

INSTALLATION

Roosting boxes can be treated very similarly to nesting boxes in terms of placing in a sheltered spot facing away from prevailing winds, being stable even in strong winds, adding protection from predators and located several feet

off the ground. They have different needs in terms of heat, however, as they need the sun's warmth to help survive the colder months, so place on the southern side of a building or tree.

MAINTENANCE

If you think the box is empty, take it down, clean out any droppings and return immediately to the tree. In the spring the box can be cleaned out and disinfected with hot water, as with nesting boxes.

When summer arrives, close the box up or put it away to prevent sparrows and mice from taking up residence.

NESTING BOXES

- Have small ventilation holes near the top to let heat escape.
- Have drainage holes along the bottom to let any moisture drain away.
- Have a roughly textured inside front panel for small birds, and grooves along the inside front panel for larger birds, to climb out once they are old enough.
- Can be placed in a few locations: along a tree trunk to mimic the natural habitat, mounted on a solid metal pole if you are concerned about predators, or mounted on a wooden pole (if you choose a wooden pole, place a baffle – a downward facing cone – just below the box) to prevent predators.
- Should be placed in a spot where it will get shade from nearby trees or building during the hottest part of the day as too much heat can be fatal for young birds. Additionally, face away from prevailing winds.
- Must be well secured so it doesn't move. Even a tiny slant can affect the development of young birds. If it is fixed on a pole, ensure it doesn't sway in the wind.
- May require monitoring for some birds, such as bluebirds. Check out this article for more information.

DIMENSIONS

Below are the measurements for nest boxes of a few Canadian bird species. Keep in mind that the depth (width of the walls) will be less than the height of the walls

and match the dimensions of the floor panel. The roof, if you use one piece of wood and it has an overhang, will be a bit longer than the floor panel.

The floor and roof are attached to the top and bottom edge of the walls, rather than the insides of the walls (which would make the box wider and shorter).

To be most efficient with (buying and) cutting wood, consider copying the method below, adapting the measurements to the species in question.

Species	Entrance hole diameter	Height of hole above floor	Floor panel	Width of wall panels	Height of wall panels	Roof	Height above ground
American Kestrel	7.5 cm (3")	31 cm (12")	25 cm x 25 cm (10" x 10")	25 cm (10″)	40 cm (16")		6-9 m (20-30 ft)
Bufflehead	6 cm (2.5")	30 cm (12")	15 x 15 cm (6" x 6")	15 cm (6″)	37 cm (15")		3 m (10 ft)
Chickadee	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2-5 m (6.5-16 ft)
Downy Woodpecker	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2-3.5 m (6.5-11.5 ft)
Great Crested Flycatcher	5 cm (2")	15 cm (6")	15 cm x 15 cm (6" x 6")	15 cm (6″)	20 cm (8")		3-5 m (10-16 ft)
Hairy Woodpecker	4 cm (1.5")	22-30 cm (8.5-12")	15 cm x 15 cm (6" x 6")	15 cm (6″)	30-35 cm (12-14")		3-5 m (10-16 ft)
House Wren	2.5-3 cm (1-1 1/4")	10-15 cm (4-6")	10 cm x 10 cm (4" x 4")	10 cm (4″)	15-20 cm (6-8")		2-3 m (6.5-10 ft)
Northern Flicker	6 cm (2.5")	35 cm (14")	15 cm x 15 cm (6" x 6")	15 cm (6″)	40 cm (16")		2-5 m (6.5-16 ft)
Nuthatch	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2 m (6.5 ft)

Species	Entrance hole diameter	Height of hole above floor	Floor panel	Width of wall panels	Height of wall panels	Roof	Height above ground
Red-headed Woodpecker	5 cm (2")	25 cm (10")	5 cm x 15 cm (6" x 6")	15 cm (6″)	140 cm (16")		4-9 m (13-30 ft)
Screech Owl	7.5 cm (3")	31 cm (12")	20 cm x 20 cm (8" x 8")	20 cm (8″)	40 cm (16")		4-9 m (13-30 ft)
Wood Duck	7.5 x 10 cm oval (3" x 4")	46 cm (18")	30 cm x 30 cm (12" x 12")	30 cm (12″)	61 cm (24")		2.5-4.5 m (8-15 ft)

CONSTRUCTION

1. Cut one floor panel, one roof panel, two side panels, one back panel and one front panel. If you are comfortable with woodworking, cut the sides at a slight downward sloping angle and cut the edge of the roof (where it meets the backboard) to match so it sits snugly.
2. Cut an entrance hole in the front panel.
3. Nail most of the pieces together, using screws for the removable side that will provide easy access for cleaning.
4. Make several perches out of dowel 0.7 cm or 1 cm in diameter, mounting the perches at varying heights inside the box. (Optional.)
5. Add some wood chips to the floor for added insulation and to help absorb fecal matter. (Optional.)

INSTALLATION

Install the box when the birds you hope to attract return from their migration or, if they remain year round, shortly before nesting time. Putting it up too early can attract species such as the House Sparrow and European Starling which nest early. These introduced species can be aggressive, driving off or killing native species. Alternatively, you can put the boxes up earlier but with a plug in the entrance hole which can be removed when you think the relevant birds are ready to nest. This is especially important in Purple Martin houses.

Mounting nest boxes on metal poles will help prevent predators from accessing the box. Metal T bars are excellent. They should also be placed at a sufficient distance from trees and other structures so that squirrels and cats cannot jump

to the box. An alternative is to use a wooden post and to slip a length of PVC piping around the post to prevent predators from climbing it.

Nest boxes can also be mounted on tree trunks. In this case, cut the back a little longer so it comes above the roof and therefore creates a place to nail to the tree. These spots can leave the nest vulnerable to predators which you can discourage by putting a guard, such as a collar, around the trunk. These tree guards help protect the nest and may also provide a place for some forest-dwelling bat species to roost.

Make sure your box is mounted securely for wind storms. Even subtle movements can affect the development of the young. Also, have the box face away from prevalent winds.

Place in an area that is not sprayed with pesticides as they reduce and contaminate the local insect population.

- Eastern Bluebirds

Place nesting boxes on 1.5 to 1.8 metre poles in quiet open fields, orchards or pastures with some nearby trees for perching. Leave a minimum of about 100 m between boxes. Click here for detailed information. A good idea is to place bluebird boxes in pairs about ten to twenty feet apart. This typically encourages Tree Swallows to take one box and bluebirds the other. These swallows tend to fight off other swallow pairs that are close by but tolerate bluebirds as neighbours.

- Tree Swallows

Situate boxes on 1.5 to 1.8 poles in backyards, front yards, near fields, a river or pond. This species will possibly use boxes that are mounted on the sides of buildings or under eaves. Leave about 15 m between boxes or make sure they are not visible to each other.

- Ducks

Place nest boxes near the shoreline or in a wetland. Use steel poles, dead or live trees to install the boxes 1.2 to 1.8 m above the water or ground. Make kerf cuts

in the wood – grooves that serve as steps and help ducklings to get out of the box.

MAINTENANCE

While there has been the tendency to remove used nests in the fall, some studies suggest that there can be benefits for leaving them. Sometimes birds will choose a clean box while others will choose one with an old nest.

A couple of benefits to keeping an old nest, according to bird expert, David Bird, are that reusing a nest can save a bird time and energy. And for bluebirds, where parasitic wasps actually help these birds by eating harmful blood-sucking blowfly larvae, parasitic wasps will use the old nest to overwinter in until the following year.

Removing nests, however, removes various mites and fleas that could infest adults and their young. It also keeps the height of the current nest lower. This keeps nestlings safer as they are farther away from the entrance hole. It minimizes young birds from accidentally falling out and prevents them from being easy prey for animals reaching in the box.

You may need to be your own citizen scientist and notice from year to year what your birds prefer.

If you choose to clean your nesting box each fall to get rid of parasites, keep in mind that for species like Eastern Bluebirds which typically nest two (sometimes three) times each summer, you might want to clean the nesting box between broods.

When cleaning, it's a good idea to wear a facemask (available at hardware stores and drug stores) to avoid breathing in any potential fungi and parasites. Scrub your box with a stiff brush and bleach. Rinse well with just-boiled water and allow it to air dry thoroughly in the sun.

Thanks to Cliff Bennet for his helpful suggestions with this article.

APPENDIX 6:
Native Plant Salvage Plan

Native Plant Conservation Plan For Lakestone

9678 Benchland Drive, Lake Country

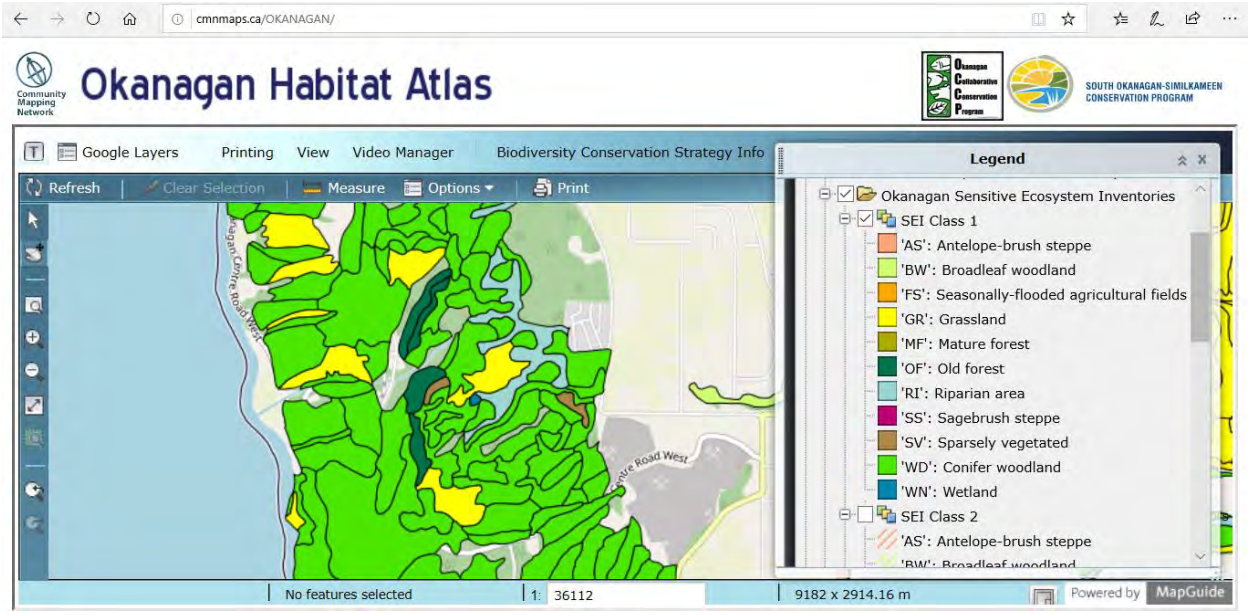
Plan developed by Tanis Gieselman, SeedsCo Community Conservation

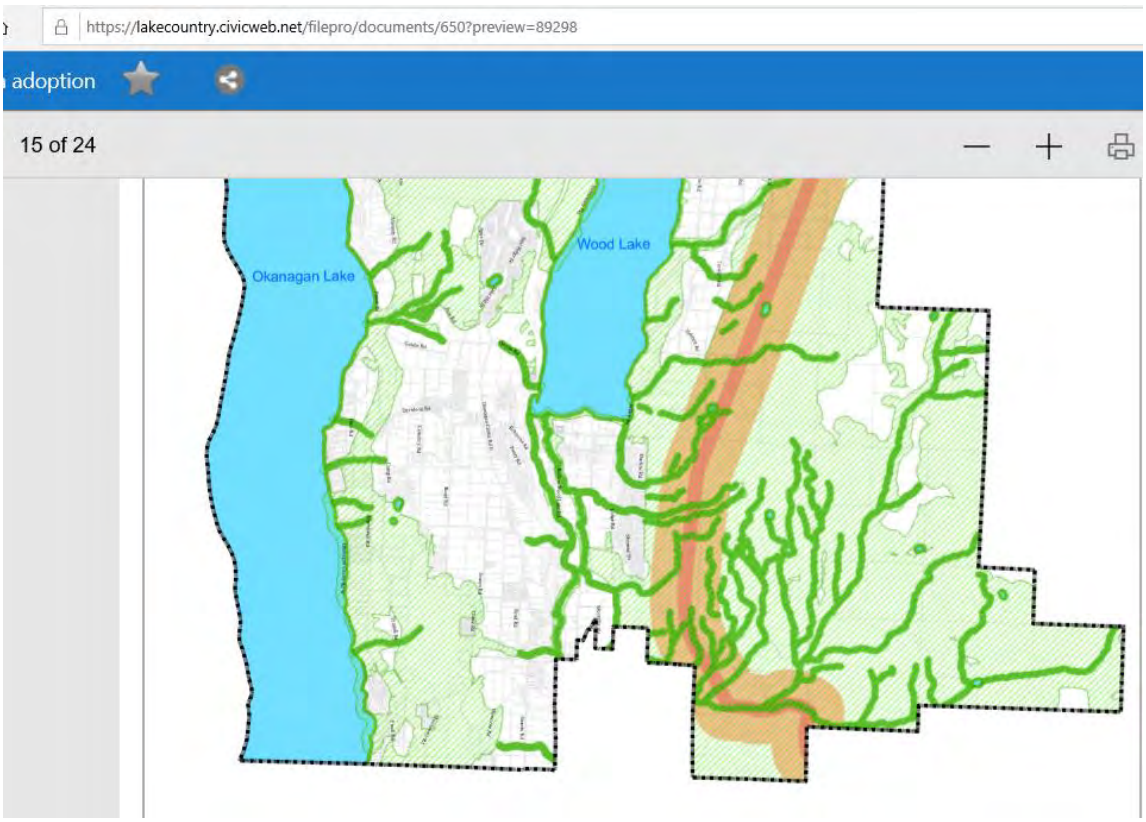
at the request of Ecoscape Environmental Consultants Ltd.

Project Overview

This development is situated in habitat of high value ESAs, so planning to mitigate, restore, and compensate for the destruction of habitat is essential for meeting Federal, Provincial, and local government objectives to:

- Prevent the loss of habitat for rare and threatened species (in Environmentally Sensitive Areas).
- Prevent the loss of green spaces, which reduces flood risk and improves climate resilience.
- Keep remaining habitat well connected to support species migration. For example, there is a network of small riparian corridors and remaining habitat that for a last remaining East-West connection across the valley, connecting Okanagan Lake to the upland Regional Corridor outlined on District of Lake Country OCP Map 15 (Natural Environment Development Permit Area).





SeedsCo Community Conservation – Bringing Conservation to the Construction Zone

- Communities in the Okanagan are all nestled amongst endangered grassland and wetland ecosystems, which are important ecological networks of habitat and migration corridors used by local species.
- Protected areas are the best way to do habitat conservation, but not everything can be set aside. Few systems are currently in place for conservation in developing areas. Meanwhile, native seed resources for reclaiming land that has been developed are limited, especially for large projects.
- Development projects can take an important opportunity to maximize biodiversity conservation by supporting salvaging of native plant species from developing areas, and using these collections to re-plant the landscape post-development.
- SeedsCo Community Conservation has worked over the past seven years to develop strategies for seed salvaging and conservation in partnership with large development projects such as The Ponds, Wilden, and CedarCreek Estate Winery.
- Collections of native plants and seeds are salvaged from each site before it is developed. 10% of the collections are offered for use in restoration or landscaping at the developed site after construction. The remainder of the collections are archived for long-term conservation, and sold to support conservation operations and education programs.

- Seeds salvaged thus far have been distributed back into the community through community partnerships like the Kelowna Nectar Trail, Seedy Saturday and other community events, the Okanagan College Aboriginal Education Department, and the RDCO Parks Volunteer Program. Seeds have also been shared with local native plant nurseries, international botanical gardens, and have been used for restoration initiatives at the En'Owkin Centre, and in Bertram Creek Regional Park.

Pre-development Salvage Collection

- A salvage team visits the proposed development site each week of the growing season. A species list and map of the site is recorded initially. Each subsequent week, several species are chosen for salvage. Species are prioritized for collection according to when their seeds are ripe, and which areas are to be imminently developed.
- Some plant species are also collected by transplanting whole plants to a safe location for propagation, especially for areas where development will occur before a season of seeds can be collected.
- Teams need 8 hours per week for every 2 ha of proposed development area to salvage. The proposed development has an estimated total of 50 ha that will need to be surveyed for salvage, which could be achieved for 10 ha each year over 5 years.

During Development

- Use observation data from pre-salvage collection to identify on a fine scale, and tag important wildlife trees, At Risk plant and animal populations, wetlands, and other important features that are of a high priority to avoid disturbing or for relocation.
- Take whole plants and cuttings from the native vegetation as it is being removed from the development sites. Plants can be potted and grown on site for use in residential and restoration plantings post development.
- If large areas of native plants are desired for landscaping post-development, plants can be pre-ordered, and seeds from previous collections can be grown off-site, to be ready for planting at completion.

Post-development

- 10% of seeds and plants salvaged from the site are provided back to the source for re-planting after development for participating in the conservation partnership.
- 30%-50% of collections are archived for long-term conservation.
- The remaining collections are sold to support the archiving of conservation collections, and for research and other educational initiatives.
- We encourage native species be planted in restoration areas, parks, public greenspaces, street meridians, and private landscaping, and can provide guidance on selection of appropriate species for various applications.

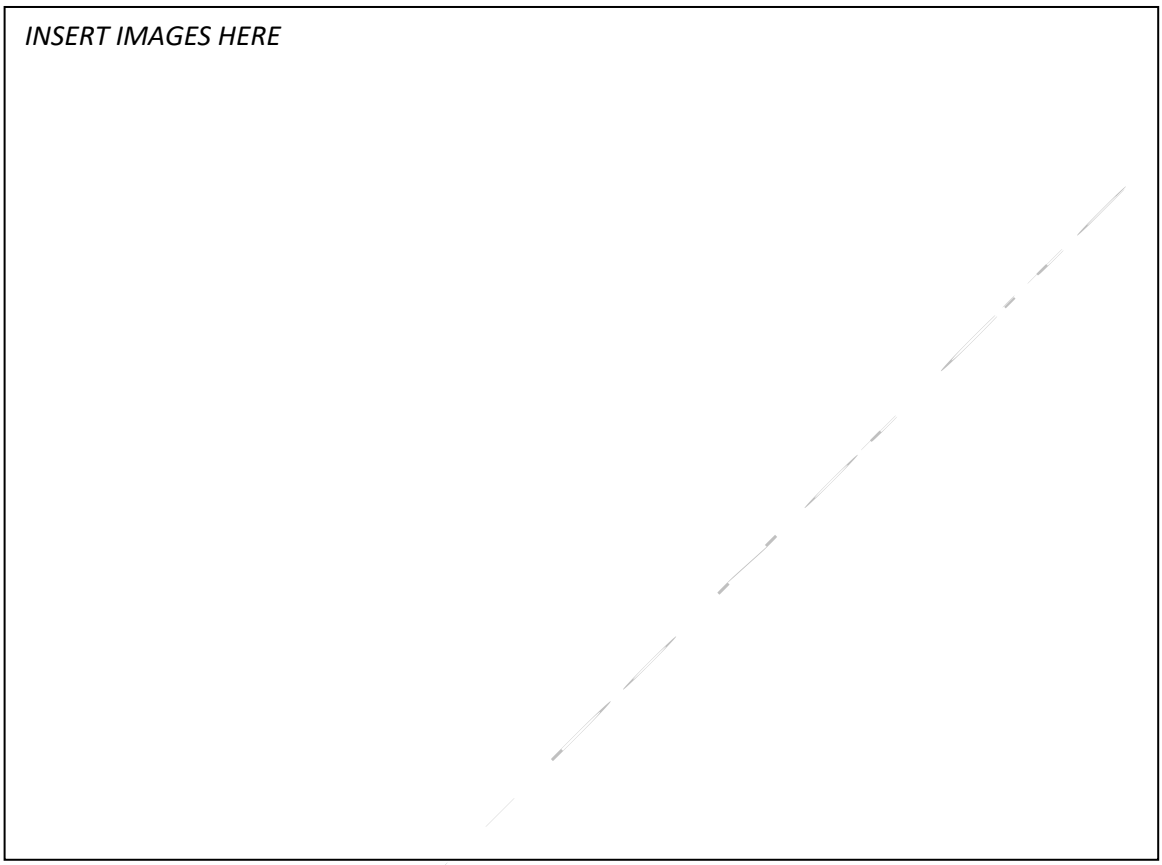
Benefits of Salvaging Native Species

Salvaging native seeds from developing areas enhances the supply of native plants for local projects, and supports biodiversity by maintaining grassland habitat throughout the Okanagan Valley. Okanagan grassland plants are adapted to the harsh Okanagan climate, so they require little additional care or water once they are established, and are ideal for water-efficient urban landscaping. Many of these plants are also essential for supporting local species like bees and other wild pollinators, and are in high demand for conservation and restoration initiatives. Native plant species support wild pollinators throughout the season, in between the limited times when our cherry and apple orchards are blooming, and some wild pollinators even require a particular species of native plant for their survival. Native grasslands support our cattle industry, and provide important winter range for mule deer and bighorn sheep, and even though grasslands cover less than 1% of BC, they support over 30% of our rare and endangered species! The Okanagan is an important biodiversity hotspot, where the arid grasslands of the south meet the northern forests and create a unique and rich community of life that is threatened by intense development pressure. We have already lost 50-75% of our major grassland types, and over 80% of historical wetlands in the Okanagan to development (see Lea, 2007. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=52470). Including native species in all landscaping can help local species survive as developed areas expand around them.



APPENDIX 7:
Guidelines for Amphibian and Reptile Conservation

DRAFT
Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia



DRAFT 5 – Jan. 25, 2019

TABLE OF CONTENTS

Acknowledgements 6
1.0 INTRODUCTION 7
1.1 Background 7
1.2 Purpose 7
1.3 British Columbia Legislative Context 7
Species at Risk Act, 2002 8
1.4 Document Scope and Audience 8
1.5 Document Outline 9
2.0 WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA 11
2.1 Mechanisms of How Roads Can Impact Herpetofauna Populations 12
2.1.1 Habitat Loss 12
2.1.2 Barriers to Movement 13
2.1.3 Road Mortality 14
2.1.4 Attraction to Roadside Habitat 15
2.2 Long-term Impacts of Roads to Populations 16
2.3 Impacts of an Expanding Road Network and Increased Traffic in the Future 18
2.4.1 Road Surface Maintenance 18
2.4.2 Drainage Maintenance 21
2.4.3 Vegetation Maintenance on Roadsides 21
3.0 SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY 21
3.1 Step 1: Identify the assessment area 24
3.1.1 Identify and map species up to 3 km away from your project footprint boundary 25
3.1.2. Identify and map habitat in your project area 26
3.1.3 Inventory species and habitats in your project area 27
3.2 Step 2: Identify the Impacts - Risk Assessment 27
3.3 Step 3: Avoid 29
3.4 Step 4: Minimize and restore on site using BMPs and expert advice 31
4.0 GUIDANCE FOR MITIGATION PLANNING AND DESIGN 31
Where the results of the risk assessment conducted as part of the Screening Tool indicate a “high-risk” road project, a mitigation plan is required. A mitigation plan would also be useful for “medium-risk” projects where mitigation is deemed suitable. 31
4.1 Background information for Developing a Mitigation Plan 31
4.2 Designing crossing structures 32
4.2.1 Bridges and Elevated Roads 33

4.2.2 Tunnels 35
4.2.2.1 Tunnel Design 35
4.2.2.2 Types of Tunnels for Amphibians and Reptiles 38
4.2.2.3 Number of Tunnels, Location, and Spacing 43
4.2.2.4 Retrofitting Existing Drainage Culverts 45
4.2.3 Wildlife Overpasses 45
4.2.4 Fencing for Reptile and Amphibian Crossings 47
4.2.4.1 Fence Design 47
4.2.4.2 Fence Length and Placement 51
4.2.4.3 Fence Maintenance 53
4.2.5 Recommendations by Species Group 53
4.3 Additional Planning and Design Mitigation Measures 61
4.3.1 Influencing Driver Behaviour 61
4.3.2 Influencing Wildlife Movement 64
5.0 GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES 66
5.1 Timing of Construction Activities 66
5.2 Mitigation Measures for Construction Activities 67
6.0 GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES 68
6.1 Assessing and Prioritizing Application of Mitigation Guidelines During Road Maintenance Activities 68
6.2 Road Surface Maintenance Guidelines 69
6.2 Drainage Maintenance Guidelines 69
6.3 Roadside Vegetation and Wildlife Fence Maintenance Guidelines 70
7.0 MONITORING 71
7.1 Compliance Monitoring 71
7.2 Maintenance Monitoring 71
7.3 Effectiveness Monitoring 72
7.3.1 Developing an Effectiveness Monitoring Plan & Study Design 73
7.3.2 Sampling Protocols and Techniques for Effectiveness Monitoring 75
7.3.2.1 Road Surveys 76
7.3.2.2 Monitoring Crossing Structures and Fencing 79
7.3.2.3 Monitoring Population Trends 81
7.3.2.4. Population Viability Modelling 82
7.4 Communication Needs for Adaptive Management 83
8 REFERENCES 84
9.0 APPENDICES 114
Appendix A – Amphibian and Reptile Species, their status (federally SARA listed species are highlighted in bold), and the TRANS region(s) where they occur. (current to June 2018; please check SARA registry and BC Species and Ecosystem Explorer for updates) 114

APPENDIX B – Impacts of Roads on Amphibians and Reptiles (federally listed species are highlighted in bold) 116
APPENDIX C – General Habitat Associations of Amphibians and Reptiles in BC 122
APPENDIX D – Migration, Dispersal, and Movement Distances of Amphibians and Reptiles in BC (federally listed species are highlighted in bold) 124
APPENDIX E – Examples of mitigation projects to reduce road impacts on amphibians and reptiles in BC 130
Appendix F – Instructions for Navigating iMapBC 135

List of Tables and Figures

Figure 1. Effects of roads on amphibians and reptiles. Red arrows indicate animal movements and other arrows show direction of influence of labelled effects. (Based on impacts outlined in Andrews et al. 2008, Beebee 2013, Langen et al. 2015, Marsh and Jaeger 2015.) 12

Figure 2. Flowchart summarizing the use of the Screening Tool and the development of a mitigation plan for road projects. 23

Figure 3. Relative level of risk posed by a road project for amphibians and reptiles based on likelihood of harm and severity of harm. 29

Table 1. The general active/sensitive periods for amphibians and reptiles in BC. *Note:* The timing of life history phases is species- and region-specific, varies annually, and must be confirmed with a QP. 30

Figure 4. Box, arch, and round tunnels buried into the ground and providing an interior height of at least 0.5 m are recommended for ease of movement of amphibians and reptiles under roadways. Interior width will vary with the tunnel design and species (Section 4.3.5). 35

Figure 5. Road crossing locations of adult Red-Legged Frogs (blue dots) and Western Toads (red dots) in spring adjacent to a breeding site near Duncan, BC. Adult movements were more random and widely dispersed than the relatively narrow corridors used by dispersing Western Toad juveniles (pink arrows) in summer after emergence from the breeding site. 44

Figure 6. Design of fencing to exclude amphibians from roadways and/or guide them towards tunnels. 49

Table 2. Fence material options and considerations. See 4.2.5 for species group recommendations. 49

Table 3. Recommended above-ground heights and below-ground depths for fencing for each species group. 50

Figure 7. Fence ends should curve back, by a minimum of 200 cm, towards the shoulder side of the road to deter animals that are moving along the fence from continuing onto the road and, ideally, redirect them back towards the crossing structure. 51

Figure 8. Fencing placement in relation to crossing entryways. Fencing should be continuous between multiple, adjacent crossing structures to increase the “capture” area of migrating individuals. 53

Figure 10. Overview and key elements for planning a rigorous study design that will assess the effectiveness of road mitigation for amphibians and reptiles. 73

Figure 11. Relative level of effort required to collect data to meet different monitoring objectives, including where the monitoring takes place and example sampling techniques used for each. 76

Table 5. Advantages and disadvantages of techniques used to monitor road crossing structures. 80

Acknowledgements

This document was based on *Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario* (Ontario MNRF 2016); we would like to thank the authors for giving us permission to extract portions of text verbatim and images for use in this document. The primary penholders on this document were Elke Wind, Barb Beasley, and Mike Sarell, who prepared the first draft and addressed subsequent reviews of this document with input from B.C. Ministry of Environment and Climate Change Strategy. We would like to acknowledge the contributions of the participants of the 2018 Herpetofauna and Roads Workshop, held the 21st of September in Kamloops, BC, who added pertinent examples, insights, and information that greatly improved this guidance document. We are particularly grateful to the participants that took the time to submit written comments: Steve Beja, David Clough, Jakob Dulisse, Christine Lion, Alison Peatt, Robyn Reudink, David Seburn, and Stephanie Winton.

Kristiina Ovaska and Purnima Govindarajulu were the primary reviewers and editors of this document. Other reviewers include Kendra Morgan, Orville Dyer, Robin Reudink, Jamie Leatham, Manjit Kerr-Upal, and Jemma Green.

1.0 INTRODUCTION

1.1 Background

Amphibians and reptiles are the most at risk species assemblages in British Columbia, with more than 50% of species in each group listed provincially and/or federally as species of conservation concern. Road mortality is identified as a significant threat to amphibians and reptiles, and mitigating this threat is identified as a priority action in the recovery planning documents for most of these species. To address this issue, the first "Herpetofauna and Roads Workshop" was held in Nanaimo in 2011. This workshop brought together qualified professionals (QPs) from within and outside government, academics, and conservation biologists to learn about road mortality issues, share unpublished research, and work together toward more effective solutions.

One of the most significant outcomes of this meeting was the creation of the BC Herpetofauna and Roads Working Group, a network for exchanging ideas. In the years since that first meeting in 2011, some members of the BC Herpetofauna and Roads Working Group and others conducted substantial new research, both in mitigation project design and in effectiveness evaluation. However, the results are not widely available and standard guidance is still lacking. This guidance document fills that need and is based on a similar document produced by the Government of Ontario in 2016 (Ontario MNRF 2016). This document is updated with BC-specific information and the most recent literature.

1.2 Purpose

The purpose of *Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia* (hereafter referred to as Guidelines) is to provide road authorities, and the qualified professionals advising them, with a comprehensive knowledge base to avoid, minimize, and mitigate road impacts on amphibians and reptiles in BC. Road authorities include all levels of government, industry, and private landowners who build, manage, and maintain roads in BC. The information in this document follows the mitigation hierarchy set out in the Government of British Columbia's ***Procedures for Mitigating Impacts on Environmental Values*** and provides information for mitigating impacts arising from road building and upgrading, as well as from maintenance activities on existing roads.

1.3 British Columbia Legislative Context

The information and procedures described in this document do not create new legal requirements or supersede any statute. However, they are intended to serve as a decision support tool to inform the implementation of existing legislation and regulatory requirements improve awareness and understanding of the best available science, and allow for flexible, well informed, and balanced solutions. Some legislation that might have implications for road building and maintenance activities and their impact on herpetofauna is listed below.

Provincial Legislation

Wildlife Act, 1996

In BC, all native wildlife, including amphibians and reptiles, are protected under the BC *Wildlife Act*. Under the Act it is an offence to kill, harm, collect, transport, or trade in native wildlife species. An exemption permit may be issued when all avenues to avoid impacts to wildlife have been examined and deemed not feasible.

Forest and Range Practices Act, 2002

The *Forest and Range Practices Act* provides for management of forest and range practices on Provincial Crown lands for the habitat of species at risk identified in the *Identified Wildlife Management Strategy* (see Appendix A for amphibians and reptiles listed as Identified Wildlife). Part of the protection for these species includes limited or no road building within designated Wildlife Habitat Areas. For a list of approved Wildlife Habitat Areas, visit: http://www.env.gov.B.C..ca/wld/frpa/iwms/wha.html.

In addition to these existing laws, the Government of B.C. is in the process of drafting BC-specific Species at Risk legislation. Requirements under this act will be updated in this document once they become available.

Federal Legislation

Species at Risk Act, 2002

The *Species at Risk Act* provides the legislative framework for the protection of species at risk in Canada. The purposes of the *Species at Risk Act* are to prevent wildlife species in Canada from disappearing; to provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity; and to manage species of special concern to prevent them from becoming endangered or threatened. The Act provides for the development of recovery and management planning documents for species listed under the Act. These documents prioritize recovery and threat mitigation actions, including the identification of Critical Habitat—defined by the Act as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or action plan for the species"—and the listing of activities likely to result in the destruction of Critical Habitat. For example, Table 3 of the *Recovery Strategy for the Western Rattlesnake (*Crotalus oreganus*), the Great Basin Gophersnake (*Pituophis catenifer deserticola*) and the Desert Nightsnake (*Hypsiglena chlorophaea*) in Canada 2017* lists road building and road maintenance as activities with the potential to result in destruction of critical habitat. This Guidelines document, along with recovery planning documents and others, provide guidance on preventing and mitigating the impacts of roads.

What is Mitigation?

The ***Procedures for Mitigating Impacts on Environmental Values*** (Environmental Mitigation Policy; EMP) defines a "mitigation measure" as a tangible conservation action taken to avoid, minimize, restore on-site, or offset impacts on environmental values and associated components, resulting from a project or activity.

[*From:* Version 1.0, May 27, 2014]

"There is no universally accepted mitigation design that is effective for every socio-economic roadway situation or wildlife species. The effectiveness of mitigation depends on the level of commitment and dedication of all stakeholders."
(Colley et al. 2017.)

The location of approved Critical Habitats for species at risk that occur in BC can be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en.

1.4 Document Scope and Audience

Preventing the impacts of roads on amphibians and reptiles is a science that continues to evolve as new solutions are implemented and tested. As such, it is not possible at this time to provide specific or directive best management practices that can be applied universally across diverse road projects. Instead, this document offers guidelines for developing site-specific mitigation based on current peer-reviewed and grey literature (e.g., websites and conference proceedings), government documents,

academic theses, and questionnaire-based surveys of experts in road ecology and other areas of relevance (e.g., engineering, species biology). When knowledge gaps are identified, the recommendations include a range of options based on the best available science and expert opinion, as well as interpretation based on species-specific needs and life-history traits.

The intended audience of this guidance document is primarily the qualified professionals who advise the road authorities that build and maintain roads in BC, to support professional reliance and adherence to the precautionary principle. This document is equally relevant to government staff reviewing development applications and providing advice to the statutory decision-makers. Finally, this document will also be useful for academics interested in assessing the effectiveness of, and improving, mitigation measures, and addressing knowledge gaps in current road ecology as it pertains to amphibians and reptiles.

This document presents current information, as of the date of publication. It is intended to be updated as new information becomes available. The members of the BC Herpetofauna and Roads Working Group will be the community of practice that prioritizes and guides the development and updating of these Guidelines going forward.

1.5 Document Outline

Much of the information in this document is subject to ongoing research and is evolving rapidly. It is strongly recommended that the services of a QP with experience in the geographical region, and with the species of concern and the mitigation techniques required, are engaged to ensure that the most biologically sound and cost-effective solutions are developed and considered early in the project planning cycle. Citations and links for further information are provided throughout the document to enable QPs to access the latest developments, updates, and data from previous and ongoing projects.

This document is organized into the following sections:

Section 1 (INTRODUCTION) provides information on the purpose of the document in relation to regulations associated with the protection of amphibian and reptile species in BC.

Section 2 (WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA) provides background information on the diverse and complex impacts of roads on amphibians and reptiles that go beyond simple road mortality. Recent information on these more subtle and indirect effects provides the background against which to assess the need for, and development of, road mitigation measures.

Section 3 (SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY) provides step-by-step guidance for assessing whether mitigation is needed as a result of anticipated effects of a project on amphibians, reptiles, or their habitats.

Section 4 (GUIDANCE FOR MITIGATION PLANNING AND DESIGN) describes how to develop a mitigation plan for new and existing roads taking into account landscape-level considerations for habitat protection and connectivity. It provides details on road designs to reduce impacts, amphibian and reptile crossing structures and fencing systems. Options for influencing driver and wildlife behaviour to reduce impacts are also discussed.

Section 5 (GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES) provides considerations for reducing impacts from road construction including timing construction activities to avoid construction-related

impacts, and considerations regarding the use of temporary measures to minimize impacts during construction.

Section 6 (GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES) describes how various maintenance activities can affect amphibians, reptiles, and their habitats and outlines mitigation strategies to reduce those potential impacts.

Section 7 (MONITORING) highlights the importance of filling knowledge gaps related to the effectiveness of mitigation measures for reducing road impacts on amphibians and reptiles. Monitoring requirements for compliance, maintenance, and evaluating the effects of mitigation on population viability are described. Study design and monitoring techniques for measuring crossing structure and fencing effectiveness to assist in adaptive management of these structures are discussed.

REFERENCES, PERSONAL COMMUNICATIONS and APPENDICES summarize resources and provide more detailed information about the status, geographic location, home range, and dispersal distance of amphibian and reptile species in BC, the road impact assessments for these species, and examples of amphibian and reptile crossing structures implemented across BC.

2.0 WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA

Roads are a critical part of BC's transportation infrastructure, underpinning a strong and vibrant provincial economy. In 2018, BC had approximately 719,000 km of roads (Environmental Reporting B.C. 2018). The majority of these roads (92%) are unpaved industrial (forestry, mining, etc.) roads and the remainder are paved highways and municipal and local roads. Decisions affecting road construction and maintenace need to consider many important factors, including public safety, cost, and timing. In recognition that the importance of roads needs to be balanced againt their known impacts on wildlife, there is a growing field of study focused on mitigating the potential ecological impacts of road networks (Forman et al. 2003, Coffin 2007). While paved roads amount to only a fraction of the total road network in BC, they may have a disproportional impact on herpetofauna because they are associated with higher traffic volumes, and are often wide with multiple lanes, which increase the risk of road mortality (Jochimsen et al 2004).

Reptiles and amphibians are particularly vulnerable to roads because of their need to move between different habitats for their various life-history requirements. Frogs, salamanders, and turtles migrate regularly between aquatic and terrestrial habitats as part of their annual life cycle. Roads often intersect their travel routes, as roads are commonly built along valley bottoms and follow the shorelines of water bodies. Most large snakes undertake long-distance seasonal movements, which brings them in contact with the roads that crisscross their home range. Hobbs (2013) calculated that almost half (49%) of the 368 confirmed Western Rattlesnake dens in BC's arid interior were within 1 km of a road.

Amphibians and Reptiles are Particularly Vulnerable to Roads

The threats to herpetofauna extends beyond BC and Canada:

- Globally, a higher proportion of amphibian and reptile species are declining compared to mammals or birds. Within BC, 67% of native reptile and 55% of the native amphibian species are at risk.
- Roads are a greater threat to amphibians and reptiles than for other vertebrates.
- Some roads are assessed in the highest threat category in provincial and federal recovery documents.

(References: IUCN 2010, Rytwinski and Fahrig 2012, COSEWIC 2013, COSEWIC 2015a, BC Species and Ecosystems Explorer 2018, see Appendix A and B)

Roads can result in the following impacts on amphibians and reptiles (Fig. 1):

- Habitat loss
- Barriers to movement leading to habitat fragmentation and isolation of populations
- Road mortality of individuals hit by vehicles
- Habitat pollution from runoff resulting in reduced fitness or increased mortality
- Increased predation
- Habitat degradation resulting in reduced survival and reproductive success
- Attraction to poor-quality roadside habitats

These impacts can lead to reduction of body condition of animals, a reduction of genetic diversity as populations become fragmented, and ultimately, population declines and potential extirpation. Individual and population-level responses can occur more rapidly when impacts combine to produce a **cumulative effect** (see Section 2.3, Box 1).

An understanding the various ways in which roads can impact herpetofauna is essential for planning avoidance and mitigation measures for future projects. In this section, examples of past projects from

B.C. provide context and lessons learned, including what has worked and what has not worked. Drawing attention to both the positive and negative aspects of past projects helps to reveal how impacts were assessed and solutions implemented, where solutions were either too costly and/or logistically not feasible, and where adjustments are needed in the future.

Photo x. Roads are cited as the most significant threat to Western Rattlesnake populations (COSEWIC 2015a).

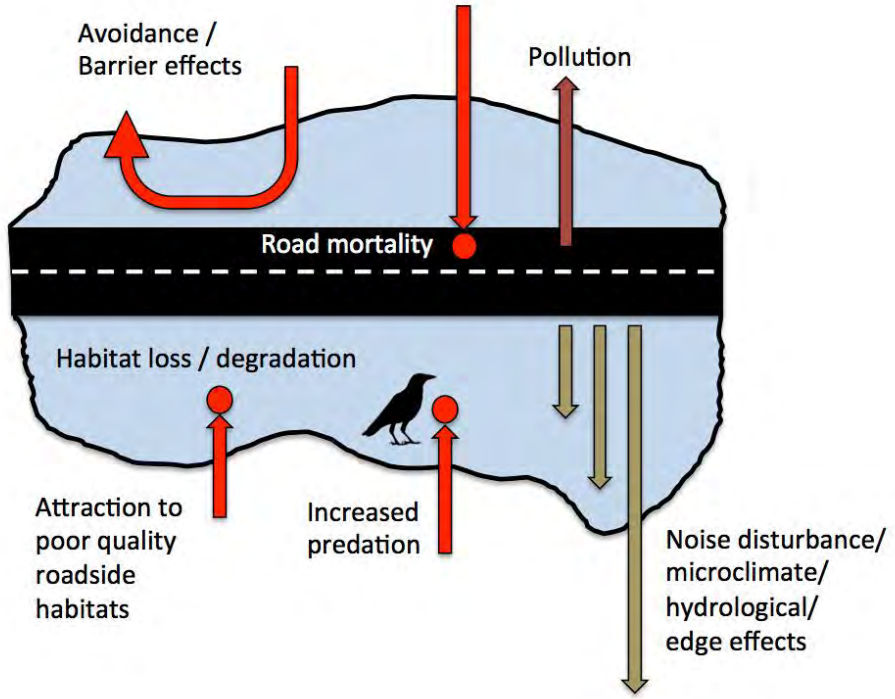


Figure 1. Effects of roads on amphibians and reptiles. Red arrows indicate animal movements and other arrows show direction of influence of labelled effects. (Based on impacts outlined in Andrews et al. 2008, Beebee 2013, Langen et al. 2015, Marsh and Jaeger 2015.)

2.1 Mechanisms of How Roads Can Impact Herpetofauna Populations

2.1.1 Habitat Loss

The construction and widening of roads may remove habitat that is important to amphibians and reptiles (Beebee 2013, Marsh and Jaeger 2015). The footprint of a road itself may destroy breeding sites, foraging areas, hydration sites, overwintering hibernacula, and migratory/dispersal routes. Habitat along the side of the road and/or downstream may also be lost or severely degraded by contaminants from the road, compacted soil, altered hydrologic regimes, sedimentation, human garbage and disturbance, edge effects such as increased sun and wind exposure, altered plant and animal communities, and increased exotic invasive species (Langen et al. 2015). The width of the habitat area impacted by a road, known as the "road-effect-zone," may be many times the road's actual width (Forman and Alexander 1998, Jochimsen 2004).

Two recent road projects highlight the impacts that roads can have on amphibian and reptile habitat loss, and the challenge of avoiding and mitigating those impacts. The Highway 99 upgrades from Horseshoe Bay to Whistler, completed in preparation for the 2010 Winter Olympics to accommodate increased traffic volumes, resulted in a 1.9-km highway realignment through a wetland complex at Pinecrest. Several wetlands used by Northern Red-legged Frogs (*Rana aurora*) and other species were partially or completely filled, and a permeable retaining wall at the wetland-highway interface increased drainage that led to further wetland habitat loss (Malt 2012) (Figure x). The project implemented a number of mitigation measures, but the effectiveness of these mitigation measures is uncertain and the subject of continued research. Another example is the 2017 highway expansion near Williams Lake that inadvertently exposed a garter snake den at a time when the snakes were in the den. The den was destroyed during construction, leading to an emergency salvage of hibernating snakes (Steciw 2018). A replacement den was constructed; however, the effectiveness of this mitigation measure remains uncertain as follow-up effectiveness monitoring has not been completed.

2.1.2 Barriers to Movement

Roads disrupt normal movement patterns of amphibians and reptiles. Paved and gravel road surfaces and mowed right-of-ways have different microclimates and provide less protective cover from predators compared to the surrounding landscape (Langen et al. 2015). Amphibians have permeable skin, which makes them vulnerable to desiccation (drying out) while on paved roads, which rapidly lose surface moisture to evaporation. During dry weather, many amphibian species rarely cross roads, even though they continue to move through moist, vegetated habitats (Ervin et al. 2001, Gravel et al. 2012). Some snake species avoid crossing roads because the open space exposes them to predators (Shine et al. 2004, Andrews and Gibbons 2005, Kingsbury 2011). In some situations, roads include steep roadside verges, concrete barrier structures, and curbs that physically prevent some amphibian and reptile species from crossing (e.g., curbs on a road at Waterton Lakes National Park Reserve obstructed movements of Long-toed Salamanders (*Ambystoma macrodactylum*), B. Johnston pers. comm.). In addition, collision with vehicles causes road mortality (see Section 2.3), which alters the abundance of animals moving across the landscape. When animals avoid or are prevented from crossing roads, their habitats can become fragmented into isolated patches. This can have detrimental impacts on individuals, populations, species, and ecosystems (see Box below) (Hocking and Babbitt 2014, Cosgrove et al. 2018).

Consequences of Roads as Barriers to Movement at Various Scales

- **Restricted home range and resource access** on a daily or seasonal basis can result in poor health and reduced survival and reproductive output, which can ultimately lead to population decline.
- **Impediments to dispersal affect demographics** because they make it more difficult both for declining populations to be rescued via immigration and for unoccupied patches to be recolonized. Limited dispersal can also increase competition among individuals that would otherwise live further apart spread out to find resources.
- **Population isolation** over several generations results in low genetic diversity and higher risk of extinction (e.g., Timber Rattlesnakes (*Crotalus horridus*) in hibernacula that were isolated by roads had lower genetic diversity that resulted in morphological abnormalities, low survivorship, and greater susceptibility to disease compared to non-isolated populations).
- **Blocked or restricted flow of energy and nutrients** may affect food webs within and across ecosystems (e.g., the high number of amphibians moving from land to water to lay their eggs can result in substantial energy subsidies to ponds).

(References: Regester et al. 2006, Marsh et al. 2008, Clark et al. 2010, Clark et al. 2011, Rouse et al. 2011, Robson and Blouin-Demers 2013, Hocking and Babbitt 2014, Cosgrove et al. 2018)

2.1.3 Road Mortality

Amphibians and reptiles are forced to cross roads when they move between seasonal breeding, foraging, and overwintering habitats. Road mortality is primarily a function of traffic volume, regardless of road surface (paved or unpaved), road width, traffic speed, or other road characteristics. Road-killed amphibians tend to be concentrated on roads near wetlands, usually during warm, rainy weather, as adults make seasonal migrations to and from breeding wetlands over late winter and spring, and as metamorphosed juveniles emerge and disperse over the summer and fall. On the coast, where temperatures are mild, the active period for amphibians can extend from as early as February to as late as November (e.g., Beasley 2006, Wind 2014); the active period is shorter in other parts of the province (e.g., Crosby 2014; see Table 1). Hatchling turtles are killed as they disperse from nests in spring (beginning in March) and adult female turtles are killed in summer (June to July) when they leave the water and seek terrestrial nesting sites (Engelsoft et al. 2011, Killburn et al. 2011). Snake road mortality mainly occurs near dens and gullies during the active period (April to October); road mortality is especially high during summer and fall (July to September), when snakes are breeding and returning to hibernacula (Pickard et al. 2009, Winton 2017).

When herpetofauna cross roads, they are extremely vulnerable to being run-over by vehicles for a variety of reasons:

- Most species cannot recognize and avoid the threat of oncoming vehicles (Bouchard et al. 2009).
- Many species are too small for drivers to see and avoid, especially amphibians, which are active at night (Beckmann and Shine 2012, B. Beasley, pers. obs.).

- Turtles, salamanders, and some snakes move very slowly and may immobilize (i.e. "freeze") in response to passing vehicles, increasing their likelihood of being killed (Aresco 2005, Mazzerolle et al. 2005, Andrews and Gibbons 2005). For example, Gophersnakes use slower rectilinear movement (versus fast sinusoidal movement) in open areas such as roads, possibly to avoid detection by avian predators (M. Sarell, pers. obs).
- Amphibians will linger on roads after rains in order to readily absorb water through their more permeable ventral skin.
- Snakes and toads can be attracted to paved roads for thermoregulation, lingering on the warm surfaces in order to raise their body temperature, thereby increasing the time they are at risk of being run over (Waye and Shewchuk 2002, Wind 2018).
- Some drivers deliberately run over reptiles. Ashley et al. (2007) reported that 2.7% of motorists in their study in Long Point, Ontario intentionally hit snakes and other reptiles on the road. Drivers have been observed deliberately targeting snakes in B.C. as well (M. Sarell, pers. obs.).

Species that move shorter distances or move less frequently are less prone to road mortality (Carr and Fahrig 2001). There are several species in B.C. that are infrequently found dead on roads (see Appendix B). Terrestrial-breeding salamanders, tailed frogs, lizards, and some small snakes, including Sharp-tailed Snake (*Contia tenuis*), have small home ranges and are therefore less likely to encounter roads unless roads bisect their prime habitats. Unfortunately, the few individuals that are killed on roads are potentially dispersing to other populations, and are therefore especially important for maintaining genetic diversity across populations.

2.1.4 Attraction to Roadside Habitat

Roads and roadside habitats often attract amphibians and reptiles to their detriment. For example, turtles nest in gravel substrates on road shoulders (Evelyn 2018); frogs and salamanders breed in warm, shallow water in roadside ditches and stormwater ponds (Ostergaard et al. 2008, Karraker and Gibbs 2011); some snakes and toads bask on roadsides for thermoregulation (Waye and Sewchuk 2002, Andrews et al. 2008, Crosby 2014, Wind 2018); Great Basin Spadefoots in B.C.'s arid interior have been observed hydrating themselves in puddles that form on roads after rain (P. Govindarajulu, pers. obs.); Western Toads have been observed on roads eating earthworms, which can be numerous on rainy nights (J. Dulisse, pers. obs.); and frogs are known to be attracted to road surfaces with streetlights where insect prey are abundant (Perry et al. 2008, Davies et al. 2012). Some species may also use roads as travel corridors.

Roadside habitats may be of poor quality in many ways:

- Increased exposure to traffic increases chances of mortality from vehicles and maintenance equipment (e.g., mowing).
- Contaminants from the road, such as de-icing salts and dust control agents, accumulate in roadside ponds and lower the survival of eggs and larvae of some species (Sanzo and Hecnar 2006, Karraker 2008, Collins and Russell 2008).
- Roadside ponds and ditches may have short hydroperiods that leave egg masses and larvae desiccated when water recedes (Ostergaard et al. 2008).
- Traffic noise can disrupt choruses of breeding frogs (Nelson et al. 2017).
- Artificial light may interfere with navigational cues and the visual capabilities of some species (Perry et al. 2008).

Studies show considerable variation in the quality of roadside ponds; some potentially provide source habitat while others act as sink habitats or ecological traps (McCarthy and Lathrop 2011, Le Viol et al. 2012, Gallagher et al. 2014). Source habitat produces a large enough number of juveniles to that survive and increase adult populations, while sink habitats and ecological traps attract breeding adults but do not produce sufficient juveniles to contribute to overall population stability or increase. Researchers suggest that roadside stormwater ponds may provide source habitat, especially in areas where natural wetlands are scarce, but caution that further study and management is needed to prevent them from becoming traps (Le Viol et al. 2012). For example, Karraker and Gibbs (2011) found that Spotted Salamander (*Ambystoma maculatum*) egg masses were smaller near roads than away from roads. Additionally, they found that road mortality shifted breeding populations toward smaller, younger individuals with lower reproductive capacity.

2.2 Long-term Impacts of Roads to Populations

Populations of amphibians and reptiles have been known to decline as a result of road mortality and population isolation (Aresco 2005, Eigenbrod et al. 2008a, Fahrig and Rytwinski 2009). Such declines usually take years to detect (Marsh and Jaeger 2015). Aquatic breeding amphibian species typically experience large annual fluctuations in population size, so long-term data collection over at least ten years is needed to detect a trend (Pechmann et al. 1991). Similarly, it can take time to see a cumulative effect where annual mortality of reptiles is low (Pike et al. 2008). Findlay and Bourdages (2000) detected road-related losses in amphibians and reptiles in Ontario decades after roads were built.

Modelling can be used to forecast the effects of road mortality on populations. Models require information about the probability of survival and reproduction, and the average number of offspring produced (i.e., fecundity) in a population that experiences road mortality. This information is used to calculate whether the population size will change over time.

Examples of Population Models that Estimate the Impacts of Road Mortality

- Northern Red-legged Frogs (*Rana aurora*) along Highway 99 at Pinecrest, B.C., experienced a high rate of mortality because the highway bisected important wetland habitats. A population model predicted a high probability of local extinction within 40 years given the observed rate of 16-28% road mortality per year (Malt 2012).
- A model was used to assess the effects of road mortality on Blotched Tiger Salamanders (*Ambystoma mavortium*) at White Lake, BC, based on 240 road killed juveniles in 2013 and an estimate that 7200 young were produced in 1997. The model indicated that the population would be able to sustain the annual loss of juveniles. However, the road mortality of only a few breeding females when population numbers were low, could quickly lead to a population decline (Southern Interior Reptile and Amphibian Working Group 2016; Dyer 2018).
- Row et al. (2007) modeled the effects of roads on Black Ratsnakes (*Elaphe obsoleta*) in Ontario and predicted that the probability of extinction of the population would rise from 7.3% to 99% over 500 years (based on only 0.026 deaths per crossing), illustrating the long-term effects of sustained, low rates of road mortality on a species with low reproductive output (fecundity).
- Winton (2018) used detailed population viability analysis (PVA) paired with refined road mortality estimates to evaluate the persistence of a Western Rattlesnake (*Crotalus oreganus*) population threatened by road mortality at White Lake, BC. Overall, an estimated 6.6% of the population was killed on the road annually and the PVA indicated that although the population was likely to persist for the next 100 years, it would be in continual decline as a result of road mortality. Any increases in road mortality rates resulted in increased probability of extinction.

Modelling can be used to forecast the effects of road mortality on populations. Models require information about the probability of survival and reproduction, and the average number of offspring produced (i.e., fecundity) in a population that experiences road mortality. This information is used to calculate how the population size will change over time based on different levels of mortality of various life-stages on the road. Models show that population declines vary among species and is based on the species behaviour or life-history traits that increase exposure to traffic, the proportion and life-stage of the population that encounters traffic, traffic volumes, and the ability of the population to sustain high rates of mortality (Marsh and Jaeger 2015).

Species behavioural traits that increase exposure to traffic include:

- frequent long-distance movements (i.e., most individuals in the population make daily movements, migrate, and/or disperse, versus being sedentary or territorial);
- attraction to habitats on or near roads; and
- slow road-crossing speed.

Road and landscape conditions that result in high road and traffic encounter rates include:

- high road density within home ranges;
- roads (low/moderate/high traffic volume) that intersect migratory or dispersal paths;
- roads (low/moderate/high traffic volume) that are immediately adjacent to important habitats (e.g., dens or breeding ponds); and
- consistently high volumes of traffic.

Traits of species most vulnerable to ongoing or high rates of mortality include:

- low fecundity and long generation times (long life spans and late sexual maturity), as among turtles and snakes;
- small population sizes, such as naturally/currently rare or endangered species (e.g., Sharp-tailed Snakes and Nightsnakes);
- populations that fluctuate and experience periods of low population numbers (e.g., tiger salamanders during long-term drought);
- sex-specific behaviour or life-history traits that cause adult females to be particularly vulnerable to road mortality (e.g., females may migrate longer distances than males)—the loss of reproductive females is more significant for population persistence than the loss of males or juveniles (Photo x);
- isolated populations; and
- populations within which reduced competition for resources does not cause a rebound in population size (i.e., road kill is not like a “sustainable harvest” that is compensated by higher survival and / or reproductive rates among the survivors, or by immigration).

Photo x. Traffic kills female Western Pond Turtles more than males because females make overland movements to nesting areas.

2.3 Impacts of an Expanding Road Network and Increased Traffic in the Future

Between 2000 and 2005, the amount of paved and unpaved roads in B.C. increased by 23%, from an estimated 570,000 km to 702,574 km (Austin et al. 2008). Road expansion has been low since then, and was estimated at 719,000 km in 2018 (Environmental Reporting B.C. 2018). As human populations grow, and as development and resource extraction continues, there will be further increases in traffic volume and pressure for road expansions and repair. B.C.'s population increased by 56% from 1986 to 2015 (B.C. Environmental Indicators), and it is expected to grow to nearly 6 million people by 2031 (Austin et al. 2008). These population projections are important to consider because even if there are no new roads constructed, traffic volumes on existing roads may increase with increasing population density and therefore increase road impacts on amphibians and reptiles.

> ***What is a Cumulative Effect?***
> The Government of British Columbia defines cumulative effect as "Changes to environmental [or other] values caused by the combined effect of past, present and potential future human activities and natural processes." The legacy and ongoing impacts of existing roads combine with the impacts of new road construction and present and future road maintenance to produce cumulative effects that amplify detrimental changes to herpetofauna population health and biodiversity in BC. Therefore, it is important to assess and manage cumulative effects when mitigating the impacts of road management activities on herpetofauna.
>
> (Reference: Government of B.C. 2016)

Herpetofauna in BC are likely to be differentially impacted by paved and unpaved roads; however, there are no known studies to quantify the differences. Paved and unpaved roads may present similar levels of habitat loss and degradation, barriers to movement, and attraction of amphibians and reptiles to poor roadside habitats. Nevertheless, road mortality for many species is likely to be higher on paved, multi-lane highways than smaller paved and unpaved roads because the number of animals killed increases with traffic volume for most species (Fahrig et al. 1995, Mazzerolle et al. 2004, Gibbs and Shriver 2002, Jochimsen 2004). In the case of forestry roads and other unpaved resource roads, effects may be temporary, as these roads may be decommissioned to reduce their long-term impacts.

2.4 Impact of Ongoing Road Maintenance Activities

In addition to the construction of new roads and upgrades to existing roads, roads need to be maintained in order for them to be safe and accessible. The cumulative impacts of mandatory road maintenance activities on herpetofauna can be significant because they are continuous in nature and occur across the entire road network. A number of road maintenance activities can have direct (e.g., mortality) or indirect (e.g., habitat loss/degradation) impacts on amphibians and reptiles. Ongoing road maintenance activities may disproportionately impact amphibians and turtles, which are often found breeding in habitats adjacent to roads.

2.4.1 Road Surface Maintenance

Various chemicals are used to suppress dust and stabilize the base of the road surface. The chemicals commonly used for this purpose are calcium chloride and magnesium chloride, although in some cases water or water mixed with oil or other agents can be used (B.C. MOTI 2019, USDA n.d.). The larvae of some aquatic-breeding amphibians experience

> ***Road placement within the surrounding landscape is one of the most important factors determining the severity of road impacts on amphibians and reptiles.***
>
> (Andrews et al. 2008)

reduced survivorship when exposed to these chloride-based chemicals (Dougherty and Smith 2006, Harless et al. 2011). The effect of these chemicals on reptiles is not well understood but impacts may occur for species that spend a significant amount of time in the water (e.g., turtles).

The objective of snow removal and ice control practices are to remove winter accumulations from roadside, overhead, and pedestrian-accessed infrastructure, and to restore traction. Anti-icing, de-icing, and/or pre-wetting materials are used for this purpose. Inputs of melt water carrying these chloride-based chemicals contaminate roadside aquatic habitat with sand, salt, and chemicals; amphibian larvae that are exposed experience reduced survivorship (Dougherty and Smith 2006, Collins and Russell 2009, Harless et al. 2011). Disposal of accumulated snow into roadside aquatic habitats used by amphibians for breeding may cause delayed breeding due to cold water temperatures. Temporary wildlife fencing can also be crushed by snow plows or damaged under the weight of snow piles.

Chloride Contamination from Dust Control and Road De-Icers (extracted from Copan 2016)

Canada applies 5 million tonnes of road salts annually (Environment Canada 2012). Chlorides are commonly used in de-icing agents due to their low price and abundance. Of these, sodium chloride (NaCl) is the most frequently used. Some chlorides, such as magnesium chloride flakes (MgCl), are used for both road de-icing and dust control.

Ecologists consider the application of chlorides to roads to be one of the leading anthropogenic factors affecting amphibians in northern climates (Environment Canada 2001, Environment Canada 2012). Amphibian species that breed early in the year are subject to the highest toxicity levels of road de-icers because their breeding season coincides with ice and snow melt (Collins and Russell 2009, Helmreich et al. 2010). In addition to direct impacts, the use of chlorides along roadways could affect the distribution of amphibians within the landscape. For example, Karraker et al. (2008) found that Spotted Salamander and Wood Frog egg mass density declined significantly with proximity to roads, with increased salinity having a small but detectable negative influence on egg mass density.

Environment Canada (2012) released a Code of Practice in response to concerns over road de-icers. The code seeks to regulate the use of salt-based de-icers, as well as to promote the use of "green" alternatives, such as urea, formates, and acetates, that are considered more environmentally friendly than the road salts currently used (Environment Canada 2012). However, some of these alternatives also have issues or limitations (e.g., some cannot be applied at low temperatures and/or have corrosive effects on concrete and metals, etc.). Calcium-magnesium acetate (CMA) is of interest as an alternative de-icer because it has relatively low toxicity and is non-corrosive. However, it depletes oxygen levels in aquatic systems as it breaks down, which can be harmful to aquatic life, such as developing amphibians. Also, it is considered to be less effective and requires more frequent applications (approximately 1.2-1.6 times more) when applied alone to achieve the same results as sodium chloride (Manning and Crowder 1989, Transportation Research Board 1991). Its primary use currently is to supplement salt-based de-icers (Fay and Shi 2012).

Copan (2016) compared acute toxicities of a traditional road de-icing chloride agent (NaCl) to a non-chloride alternative (CMA). She found that acute exposure to ecologically relevant levels of NaCl was detrimental to the survival of Wood Frog tadpoles. The 96 hour LC50 values for tadpoles (the concentration that causes tadpole mortality after 96 hours of exposure) ranged from 85.77 mg/L to 1406.96 mg/L depending on the tadpole's site of origin and developmental stage. This response is concerning, given that Environment Canada (2001) reported higher chloride concentrations for ponds within 50 metres of roadsides, with many exceeding 4000 mg/L. In comparison, the 96 hour LC50 values for CMA toxicity was 2588.45 mg/L for Wood Frog tadpoles in aerated tanks, and 465.17 mg/L in non-aerated tanks. These values fall outside the typical 10-100 mg/L range of CMA found within roadside ponds and wetlands (Horner 1988, Transportation Research Board 1991); however, direct sampling of road runoff has been known to yield concentrations as high as 5000 mg/L (Horner, 1988; Transportation Research Board, 1991).

INSERT IMAGE OF DUST CONTROL APPLICATION BESIDE WETLAND HABITAT

Roads are cleaned periodically to remove debris such as pieces of tire, discarded auto parts, and other debris. Disposal of this debris on the side of the road could contribute to water contamination, destroy habitat structures, or affect the structural integrity of mitigation structures such as guiding fences for crossing structures.

2.4.2 Drainage Maintenance

The objective of drainage maintenance is to provide effective drainage on and along road surfaces for driver safety and to protect roads and supporting infrastructure from erosion. Maintenance work in and along ditches containing water, and removal of obstructions such as beaver dams, may strand eggs and impact larval amphibians. Direct impacts may come from machinery use, while indirect impacts may relate to changes in hydrology, such as a drop in water levels that strands eggs or larvae. Amphibians can be inadvertently captured in the spoil during roadside ditch cleanout work where standing water occurs.

Shore, bank, and watercourse maintenance is carried out to prevent scour and erosion damage to roadways at shores and banks of watercourses. Debris and potential obstructions that threaten to damage highways, which may be a considerable distance upstream or downstream, are removed. This could inadvertently affect amphibians if the obstructions had created pooled water ideal for amphibian breeding. Removal of these obstructions when amphibian eggs and larvae are present could result in stranding if the removal of obstructions results in water draining, or the animals being washed away if removal of the obstruction results in high flow volumes. In some cases, rip-rap is installed to prevent water flow over road surfaces or to stabilize the shoreline. Depending on the size of the rip-rap boulders, these installations could act as barriers to movement of amphibians and turtles.

2.4.3 Vegetation Maintenance on Roadsides

The objective of vegetation control is to improve visibility for road users and facilitate drainage. This relatively exposed, open habitat with shorter vegetation may attract certain amphibian and reptile species, inadvertently putting them at risk of predation and road mortality. Vegetation maintenance activities, such as mowing, can lead to direct mortality of amphibians and reptiles occupying the shoulder environment, especially during periods of migration. In addition, if mowers and other machinery are not properly cleaned between sites, it could result in invasive plants and diseases agents (e.g., *Batrachochytrium dendrobatidis*, ranavirus) being introduced to new habitats or wetlands, causing degradation of habitat for amphibians and reptiles. In some cases, herbicides may need to be used to control vegetative growth. Some of these herbicides are known to be hazardous to amphibians and reptiles.

Wildlife fencing, including fencing to direct amphibians and reptiles towards a safe crossing structure, has been installed along some stretches of highways and other paved roads in BC. The mowers and weed snippers used for vegetation control can damage these fences by inadvertently slashing them, creating gaps in the fencing. Amphibians and reptiles can escape through these gaps and end up on the road surface, where they are again at risk of road mortality.

3.0 SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY

The Government of British Columbia's ***Procedures for Mitigating Impacts on Environmental Values*** (2014) establishes the mitigation hierarchy to guide development and application of measures to mitigate impacts on environmental values and associated components. The levels of the mitigation

hierarchy are: (1) Avoid, (2) minimize, (3) restore on site, and (4) off-set. Although set out as a hierarchy with the expectation that all feasible measures at one level are considered before moving to the next, in practice, the levels within the mitigation hierarchy will often be considered as a whole. The feasibility of measures at each step of the hierarchy should be considered iteratively to reach the most cost-effective solution to achieve maximum ecological benefit.

This screening tool enables the gathering of information and assessment of the first three levels of the mitigation hierarchy. The screening process may be used as a decision support tool that makes the process by which the final decision was made transparent and defendable. **The expectation is that the screening tool will be used primarily by the QPs advising proponents on the project**, to gather and evaluate the scientific information necessary to provide the rationale for the required mitigation level for amphibians and reptiles in the project area. The screening tool may also help QPs communicate the necessity of mitigation measures for herpetofauna in the project area to road engineers and planners. The screening tool can be applied for one-time projects, such as road construction and expansion, as well as for regular road maintenance activities.

The Screening Tool and Mitigation Planning process are outlined in Figure 2. The results generated from the Screening Tool will guide proponents and their QPs to activity-specific guidelines in sections 4, 5, and 6.

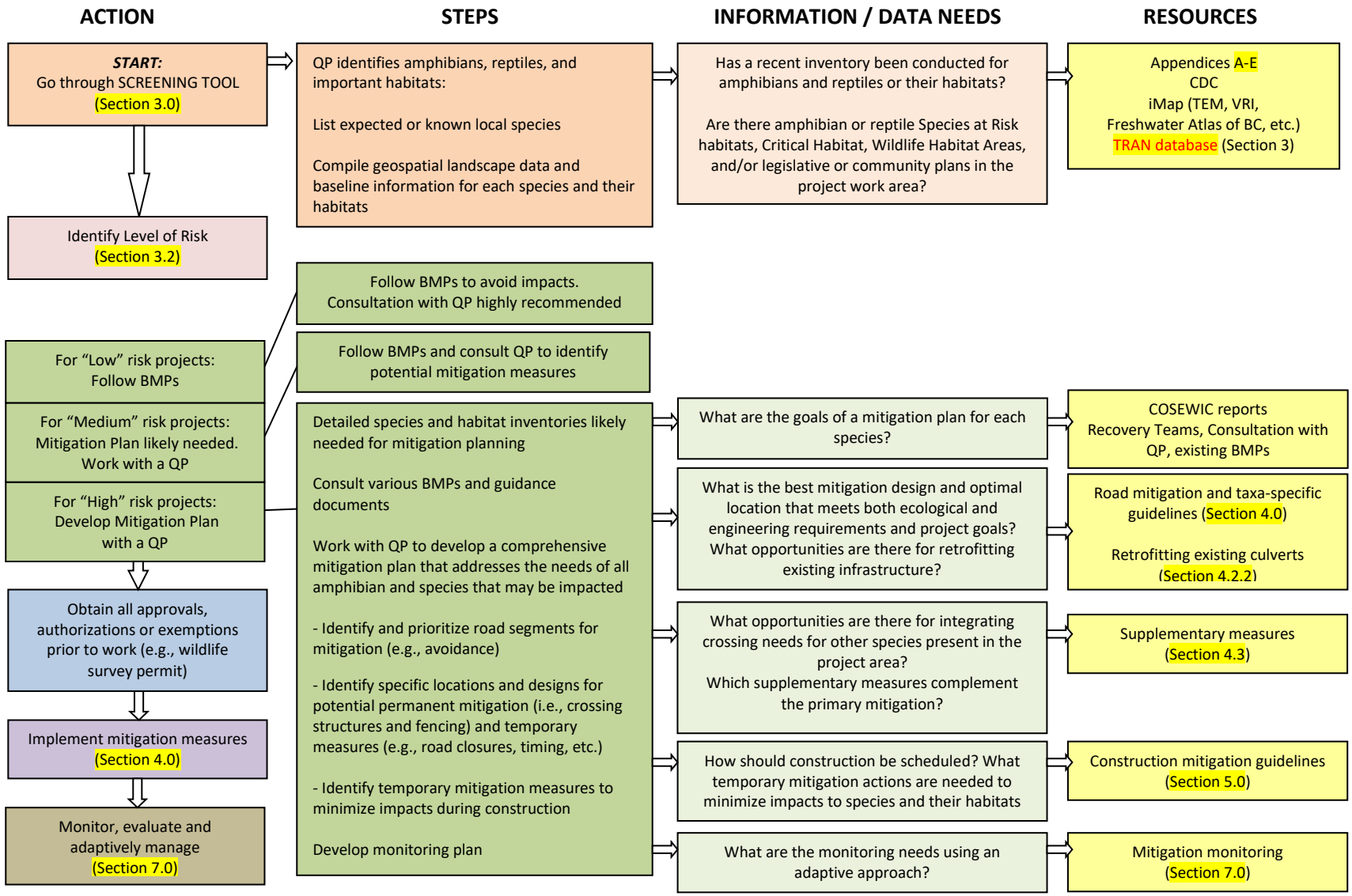


Figure 2. Flowchart summarizing the use of the Screening Tool and the development of a mitigation plan for road projects.

3.1 Step 1: Identify the assessment area

To identify whether amphibians and reptiles may be impacted by a project, it is necessary to identify the boundaries of the assessment area. This area needs to include the ***project footprint*** (physical works required; construction area) as well as the ***area of influence*** of the project on the target species (e.g., important habitats such as dens or breeding sites, movement corridors, and movement distances of amphibians and reptiles). Consideration of the impacts on amphibians and reptiles at local and landscape levels is a vital component of effective mitigation planning for transportation projects (Semlitsch 2008). Animals move within habitats to access resources (local scale), and move between habitats during migration (e.g., to breeding or overwintering habitat) and dispersal (landscape scale).

BC's amphibian and reptile species vary in their home range size and dispersal distances (Appendix D). Examples of highly mobile species in BC include Western Toads, which have been tracked dispersing over 7 km in less than 24 hours during spring migration on Vancouver Island (Davis, unpubl. data cited in COSEWIC 2012d), and Western Rattlesnakes, which have been tracked moving over 3.5 km between summer foraging areas and overwintering dens (Gomez et al. 2015). Western Painted Turtles have been recorded travelling a straight-line distance of 2 km in the Lower Mainland, traversing four sloughs and ending at a small wetland (Kilburn and Mitchell 2011). It is important to consider road placement early in the planning stages of all new developments, so that they can be placed where they pose the least risk of road mortality and isolation of habitat.

Identification of the area of influence is not as straightforward as for the project footprint. In order to determine the area of influence of the project on amphibians and reptiles, first identify the local species and important habitats that may occur within 3 km of the project footprint (or further, when highly mobile species are recorded in the area). This value is based on recorded movement distances of amphibians and reptiles away from dens, breeding sites, and hibernacula in BC or the Pacific Northwest (see Appendix D). For road maintenance activities, the area of influence will be the area directly impacted by the action (e.g., road surface and shoulders, roadside mowing swath) and also the adjacent area that might be indirectly impacted by that action (e.g., roadside ditches and wetlands that may be impacted by runoff of dust control and de-icing chemicals, herbicides, or sediment, or whose hydrology may be affected by drainage maintenance activities).

3.1.1 Identify and map species up to 3 km away from your project footprint boundary

A. Using Appendix A, identify which species are likely to occur within the project footprint. Include confirmed or potential non-native species in order to factor them into the salvage/management plan (i.e., where details of humane euthanasia of American Bullfrogs, Green Frogs, and Pond Slider turtles may be needed).

B. Further refine your species list by consulting the government databases listed below to identify known and potential amphibian and reptile occurrences and important habitats in the project area. Refer to section 3.1.3, below, for project areas where few to no species records are included in government databases.

iMapBC

1) Go to https://maps.gov.bc.ca/ess/hm/imap4m/
2) Select the tab titled "Data Sources"
3) Click "Add Provincial Layers"
4) Select "Fish Wildlife and Plant Species", under which you should search within the following data sources:
    - BC Frogwatch Amphibians (Select all species in your region, based on Appendix A)
    - BC Frogwatch Reptiles
    - BC Frogwatch Turtles
    - Species and Ecosystems at Risk – Publicly Available Occurrences – Conservation Data Centre (includes publicly available data and masked secured data – see below)
    - Wildlife Species Inventory – Incidental Observation Points – Nonsensitive
        - WSI- IO – Reptiles and Amphibians – Nonsensitive
    - Wildlife Species Inventory – Survey Observation Points – Nonsensitive
        - WSI- IO – Reptiles and Amphibians – Nonsensitive
    - Telemetry Observation Points – Nonsensitive
        - WSI- TO – Gopher Snake - Nonsensitive

Note: Shapefiles can be requested from iMapBC (e.g., for use in ArcMap).

Data-sensitive species and ecosystems

Occurrence data are not made publicly available for elements that are considered "sensitive" (e.g., species at risk, den sites, hibernacula), and are masked (buffered) in the iMapBC and CDC sites (i.e., presented as a polygon). This is to protect species from persecution or harm, for proprietary reasons, or to protect government interests. However, secured records are released on a need-to-know basis if a project location overlaps a secured element occurrence and the details of the element occurrence are relevant to decision making. If the species of interest is included in the list of Species and Ecosystems Susceptible to Persecution or Harm, or if the mapping exercise above reveals the occurrence of masked secured data in your area of assessment, contact the Conservation Data Centre or Species Information Database (sometimes referred to as the Wildlife Species Inventory) using the information below; include your reasons for requiring the data, details related to project/activities, and the precise area of interest:

- All Wildlife (including Species at Risk and WHA): SPI_Mail@gov.bc.ca
- Species and Ecosystems at Risk: cdcdata@gov.bc.ca/250-356-0928

An online training module must be completed, and a Confidentiality and Non-Reproduction Agreement signed and submitted by all personnel that will have access to the data before secure data can be released. For more information on this process, consult the Species and Ecosystems Secure Data and Information Procedures.

Example of How to Further Refine Your Species List:
Appendix A provides a species list for each region in the province. Additional information may be gleaned from Biogeoclimatic Zones (BEC zones) and elevations within 3 km of the project area. Species accounts can help determine if the project is likely within the habitat range for the initial species list from Appendix A. For example, looking at the snake species listed in Appendix A for Region 3, if the road project is situated in the Montane Spruce between 1100-1400 m elevation, species account information states that some snake species are possible but less likely and that the project is likely above any hibernacula. In that scenario, you are likely only dealing with possible summer habitat for snakes.

3.1.2. Identify and map habitat in your project area

Use Appendix C and the government databases listed below to identify and map important habitats for the amphibian and reptile species in your region/project area, such as breeding and hibernation sites, and corridors that connect important habitats (e.g., streams connecting forest patches, forests and meadows connected to wetlands, etc.; see Section 4.1.1). In BC, important habitats for amphibians and reptiles include, but are not limited to:

- Old/mature forest stands and patches (e.g., terrestrial salamanders)
- Grasslands/shrub-steppe (e.g., snakes, tiger salamanders, spadefoots)
- Streams and creeks and associated riparian areas (e.g., tailed frogs, giant salamanders)
- Rock outcrops (e.g., snakes, lizards)
- Talus slopes (e.g., snakes, lizards)
- Small, ephemeral (temporary) ponds and surrounding upland areas (e.g., aquatic-breeding amphibians)
- Wetlands and lakes and associated riparian areas (e.g., turtles, aquatic-breeding amphibians)

Habitat databases and other habitat resources:

1) **iMapBC** (See Appendix F for instructions):
    - **Critical Habitat** for Federally-Listed Species at Risk – Posted;
      For the most up-to-date information, mapped **Critical Habitat** (proposed and approved) for federal species at risk that occur in BC can also be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en
    - **Wildlife Habitat Areas** – Approved, Proposed, and FRPA
    - **Terrestrial Ecosystem Mapping** (TEM)
    - **Vegetation Resources Inventory** (VRI)
    - **BC Freshwater Atlas**

2) Government of Canada **Species at Risk Public Registry** has links to up-to-date **Status Reports and Recovery Strategies**, including a description of critical habitat.
3) **BC Species and Ecosystem Explorer**:
    - Provides reports and detailed information on the annual habitats utilized by each species in BC.
4) **B.C. Species at Risk Recovery Planning** documents
5) Existing **models** for amphibians and reptiles, for example:
    - Okanagan (using TEM) - Warman et al. 1998 (updated version available)
    - Merritt Forest District (using VRI) - completed by Keystone for the Nicola Valley Innovative Forestry Society (2008)

    For more information, visit https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-habitats/wildlife-habitat-mapping or contact:
    Calvin Tolkamp
    Ecosystem Information Section (ECOINFO)
    Phone: 778-698-4018
    Email: Calvin.Tolkamp@gov.bc.ca

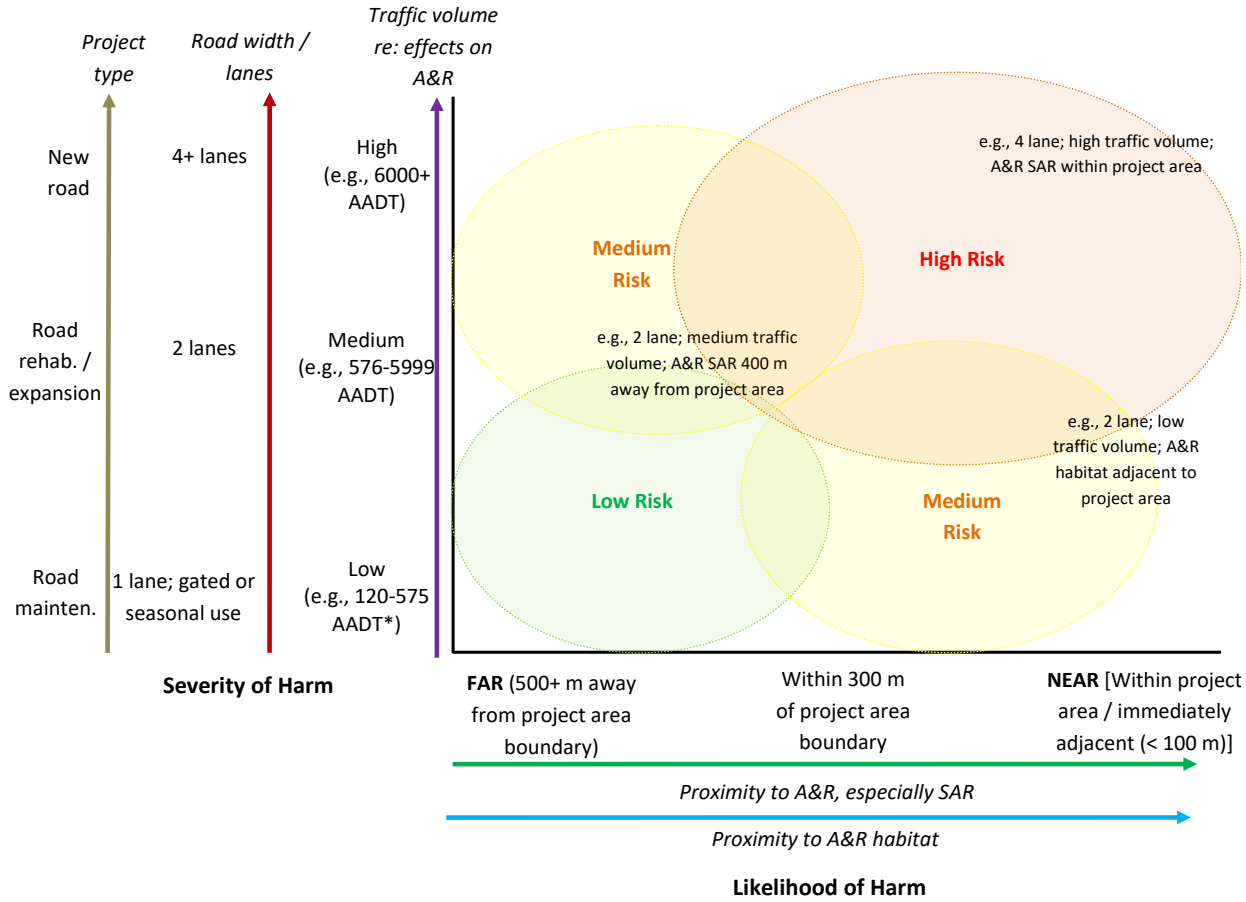
Provincial databases of amphibian and reptile occurrences provide a critical first step for assessing potential impacts. Unfortunately, for most herpetofauna species, existing data is rarely adequate to develop effective mitigation. It may be necessary for additional baseline data to be obtained by a qualified professional biologist (QP) to meet provincial and federal environmental mitigation standards.

3.1.3 Inventory species and habitats in your project area

Do not consider the lack of records for a certain species as evidence that it is not present. If there is no information in the databases listed above, a field inventory by a qualified professional biologist (a QP with previous experience working with the species of interest) is necessary to confirm whether amphibian or reptile species or their habitats are present. This is especially if the project area is located within the range and habitat of amphibian and reptile species at risk for which roads have been identified as a threat in assessment and recovery documents. A field inventory may not be necessary if recent and appropriate surveys indicate no amphibian or reptile species have been detected in the area. "Recent" is suggested to be within the past five years and is based on average lifespan of many herpetofauna. An "appropriate" survey is defined as one that follows provincial inventory guidelines (e.g., Resources Information Standards Committee (RISC) standards) in terms of the appropriate survey season(s), sampling techniques, and level of effort for the expected species in the area (Appendix A). Surveys conducted within the project footprint and area of influence would be the most appropriate based on average home ranges and dispersal distances of herpetofauna.

3.2 Step 2: Identify the Impacts - Risk Assessment

For the purposes of this document, **risk** is defined as exposure to harm. The level of risk that a road project poses to amphibians and reptiles is influenced by two main components: (1) *likelihood of harm*, determined by the proximity of the project/road to amphibian and reptile species (especially species at risk), and/or their habitats; and (2) *severity of harm*, which considers short-term (determined by factors such as timing and duration of construction; e.g., road maintenance) and long-term (determined by factors such as road width/number of lanes and traffic volume; e.g., new road construction) impacts. Severity of harm for amphibians and reptiles in relation to roads is influenced by:



- **Project type:** Some projects result in habitat loss or degradation in addition to risk of collision/mortality (e.g. new road construction).
- **Road width**: Wider roads expose crossing individuals to greater risk compared to narrower roads and may be a movement barrier for some species; potential traffic volume increases with the number of lanes.
- **Traffic volume**: Traffic volume can affect the density of local frog and toad populations, especially when amphibian and reptile migration/active periods coincide with peak traffic times daily or seasonally (e.g., in spring, summer, and / or after sunset).

Figure 3 provides an understanding of the many factors that act together to determine the relative level of risk that a project poses to local amphibian and reptile populations.

Traffic Volume/Intensity

Traffic volume is considered the most significant risk factor for wildlife along roads (Charry and Jones 2009). Fahrig et al. (1995) found fewer live and dead frogs and toads (anurans), a higher proportion of dead anurans, and reduced anuran density (as measured by breeding chorus intensity) with increasing traffic intensity along two 2-lane roads near Ottawa, Ontario. Estimates of the potential effect of traffic volume on amphibians and reptiles should consider differences on both a daily and seasonal basis, as most amphibians and reptiles are most active in spring and summer and at night.

* AADT = Average Annual Daily Traffic; based on data compiled by Charry and Jones 2009 relating traffic volume to impacts on amphibians and reptiles. Note: Estimates of traffic volumes in spring and summer would be more accurate in terms of their impacts on amphibians and reptiles.

Figure 3. Relative level of risk posed by a road project for amphibians and reptiles based on likelihood of harm and severity of harm.

It should be noted that the need for action is not determined by risk of the project alone but also by vulnerability of the affected species/population, which may be increased by cumulative effects of other road management activities, other human activities (e.g., resource extraction, development), and natural processes (e.g., disease). Endangered species/populations might trigger mitigation measures even from low-risk projects, while mitigation may be minimal for medium-risk projects when species/populations are stable. The mitigation effort required must be judged at a project-specific level taking both risk and species vulnerability into consideration.

ACTIONS associated with relative level of risk:

- **High Risk – Mitigation is necessary**
    1. Conduct further species and habitat inventories, if necessary, at a fine scale (e.g., field surveys) to determine exactly where mitigation is required.
    2. Consult BMPs for guidance: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/best-management-practices.
    3. Develop mitigation and follow-up monitoring plans in consultation with a QP with appropriate species and local experience.
        - Provincial guidelines for mitigation planning can be found at: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/policy-legislation/environmental-mitigation-policy.
- **Medium Risk – Some mitigation is likely necessary**
    - Consult BMPs and, if necessary, additional experts and QPs to identify need and extent of potential mitigation measures.
- **Low Risk – Minimal mitigation required**
    - Consult BMPs and, if necessary, additional experts and QPs to avoid and/or reduce impacts.

3.3 Step 3: Avoid

Regardless of the assessed risk, due to the sensitivity of herpetofauna to roads, avoidance is the most effective mitigation approach and should always be considered. Information and assessments from Step 1 and 2 can be used to follow the provincial guidelines for mitigation planning, with avoidance being the first step in the mitigation hierarchy.

The most effective conservation strategy for protecting wildlife, including amphibians, reptiles, and their habitats, is to avoid impacts. Impacts can be avoided either spatially or temporally or by using both strategies. Spatial avoidance includes not working in important habitats and travel

Avoidance Challenges

Although measures can be taken to avoid important terrestrial habitats, such as known or potential hibernacula/dens, the locations of these important habitats are largely unknown. As such, project managers should be aware that construction or maintenance work that involves removing or disturbing ground cover (e.g., large downed wood, stump, or rock removal), could uncover hibernating amphibians and reptiles (e.g., snake dens). See guidelines below for actions required under this scenario.

corridors. Temporal avoidance includes conducting work during periods when the animals are less vulnerable (e.g., not clustered at den sites or breeding ponds). Avoidance is often more feasible when amphibians and reptiles are considered early in the planning process (see Section 3.0).

For new road projects, overlay the proposed road location with the spatial data on species occurrences and habitats collected in Step 1. Where possible, alter the alignment to avoid known occurrence records and important habitat features, such as wetlands, rock outcrops, and talus slopes. Ideally, allow a buffer of at least 300 m from these important habitat features. Spatial avoidance may be much more challenging for road improvement projects, such as road widening, creation of medians, and installation of shoulder barriers. In these cases, temporal avoidance may be considered during the project. Road improvement projects may offer a valuable opportunity to retrofit mitigation measures where significant amphibian and reptile migration and dispersal routes have been identified (e.g., where occupied breeding sites or dens occur near the road alignment).

When possible, road maintenance and rehabilitation activities, such as culvert or bridge improvements/replacements/removals, repaving, ditch cleaning, and other maintenance activities, should be avoided at times of the year when herpetofauna are clustered at important habitat features (e.g., when reptiles are at hibernation sites or when amphibians are congregated at breeding ponds; Table 1). When impacts are unavoidable, appropriate mitigation measures should be incorporated into the project design.

Table 1. The general active/sensitive periods for amphibians and reptiles in BC. *Note:* The timing of life history phases is species- and region-specific, varies annually, and must be confirmed with a QP.

Amphibian & Reptile Group	**Breeding / Active Period (Sensitive)**	**Migratory / Active Period (Sensitive)**	**Relatively Inactive Period (Hibernation, summer inactivity)**
Terrestrial Salamanders	Spring and Fall (e.g., Feb–June; Sept –Nov)	Not applicable	Winter; Summer (on land/subsurface) (e.g., Dec–Jan; Jun–Aug)
Pond-breeding Amphibians	Later winter/spring (e.g., Jan–May on the south coast; Apr–June in the interior and north)	(1) Late winter/Spring and Fall (e.g., Oct–June on the south coast; Mar–May in the interior and north) (2) Late summer/Fall (metamorphs disperse; e.g., June–Sept, or later in interior)	Fall/Winter (some on land/subsurface, some underwater) (e.g., Nov–Jan on the south coast; Oct–Mar in the interior and north)
Stream-breeding Amphibians	Summer (e.g., June)	N/A	Fall/Winter (in water and riparian areas)

			(e.g., Oct–Feb)
Turtles	Spring–Summer (females nesting) (e.g., May–July)	Spring–Fall (e.g., March–Oct)	Fall/Winter (underwater) (e.g., Oct–Feb)
Snakes and Lizards	Summer (July)	Spring, Summer, and Fall (e.g., Apr–Oct)	Fall/Winter (on land/subsurface) (e.g., Oct–Mar)

3.4 Step 4: Minimize and restore on site using BMPs and expert advice

If the project cannot avoid all impacts to amphibians and reptiles or their habitats, seek expert advice to develop a mitigation plan and implement the guidelines below for minimizing impacts, restoring habitat on-site, and where necessary, offsetting. Where complete mitigation cannot be implemented (i.e., avoid, minimize, restore on-site), offsetting is recommended by the B.C. Environmental Mitigation Procedures (B.C. MOE 2014). This may include the restoration or creation of habitat outside of the project area, such as wetland or den construction in an area occupied by a species at risk. Additional monitoring and adaptive management requirements may be included in project-specific plans.

In addition to the guidelines below, the B.C. Environmental Mitigation Procedures, the Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia, and the Best Management Practices for Amphibian and Reptile Salvages in British Columbia provide a good foundation for developing a mitigation plan.

4.0 GUIDANCE FOR MITIGATION PLANNING AND DESIGN

Where the results of the risk assessment conducted as part of the Screening Tool indicate “high-risk” or “medium-risk” then planning for mitigation measures becomes necessary. A fully developed mitigation plan is necessary in the case of “high-risk” projects to design and monitor effective measures to reduce impact on amphibians and reptiles. While a fully developed mitigation plan may not be essential for “medium-risk” projects, assessing opportunities for reducing the impact on amphibians and reptiles is recommended.

4.1 Background information for Developing a Mitigation Plan

The data compiled from the Screening Tool (Section 3.0), in combination with data collected during field inventory work (if applicable), will support the development of an effective mitigation plan, the steps of which are outlined in Figure 2. These data can be compiled into a geographic information system (GIS) that can be overlaid with georeferenced project layers. The following considerations and resources support project planning:

- Consider the local (daily or within-season) and landscape (from season to season between habitats) movement patterns of the species identified to be potentially present in the project area and map these potential movement corridors.
- Consider a multi-species perspective to ensure that a strategy for an individual species does not create unintended negative impacts on other amphibians and reptiles or other wildlife species.
- In the case of larger road projects, the duration of the environmental assessment (EA) process can last for multiple years, especially if there are time lapses between the preliminary assessment, detail design, and construction. This provides opportunities for inventories and

other data collection within the project study area that can better inform mitigation planning and provide important data for post implementation effectiveness monitoring (Before-After-Control-Impact (BACI) design).

- Other useful data that may be available to support project planning include existing and future road network and other infrastructure, such as existing barriers (e.g., median and shoulder barriers) and passageways (e.g., culverts), and adjacent railroads and local or private roads.
- Identifying and considering existing and future land use, status, and ownership may also prove useful while designing a mitigation plan. For example, the condition and ownership of land adjacent to a project may provide opportunities for maintaining connectivity and protective buffers. Most Official Community Plans map environmentally sensitive areas and areas for development at a regional scale. Provincial and Regional Parks, ecological reserves, Wildlife Management Areas, Wildlife Habitat Areas, and other areas designated for conservation are mapped at a provincial scale (see Section 3.0, Step 1 for details).
- Effective communication is also important, from the planning to the implementation phase of mitigation measures. It is important for all individuals involved in construction and maintenance projects, including road crews, to be made aware of the mitigation measures to be implemented for the project (e.g., the need for additional, dry culverts with fencing; the need for fences to be buried properly, without gaps that allow animals to move through to the road). Communicating and coordinating with other jurisdictions (e.g., municipalities and conservation authorities) that own or manage adjacent infrastructure and land is also important.

4.2 Designing crossing structures

Specifically-designed crossing structures (e.g., elevated roads, under- and overpasses) with fencing are often the most effective mitigation strategies to reduce road mortality and enhance habitat connectivity (Dodd et al. 2004, Aresco 2005, Cunnington et al. 2014, Baxter-Gilbert et al. 2015, Rytwinski et al. 2016). This section provides a summary of current knowledge of best crossing structure and fence designs that allow amphibians and reptiles to move between habitats bisected by roads, with an emphasis on BC. Different species preferentially use different types of crossing structures and we are still learning about the requirements of many of BC's species. This document provides the minimum and/or an acceptable range of recommended design specifications (e.g., height, length, and width for crossing tunnels and fencing) based on the best available information. Illustrations, relevant examples, photos, references, and caveats are provided throughout.

It is important to weigh the potential detrimental effects of installing crossing structures and fencing against the benefits. Channelling animals through narrow crossing structures could increase predation pressure (Little et al. 2002) and the transfer of disease. Restricting movements across the landscape with fences could slow the escape of animals from wildfire, introduce invasive plants by disturbing soil, and alter ecological processes that rely on open dispersal (e.g., pollination, decomposition, germination, etc.). Furthermore, any individuals or species that will not use crossing structures are effectively blocked by fencing. Very little research has been done to test these effects. For example, Little et al. (2002) found no studies that specifically examined predation rates in or near crossing structures compared to areas further away; there was only scant anecdotal evidence of predation events at some wildlife passages. Without the science to guide us, careful consideration is needed to decide whether mitigation crossing structures and fencing can be installed in ways that would have minimal detrimental effects that are outweighed by the benefits.

Elevated roads and bridges most effectively mitigate the impacts of roads on amphibians and reptiles for a variety of reasons (see Section 4.3.1). The next best option is to install a series of discrete crossing structures or underpasses, hereafter referred to as tunnels (see Section 4.3.2). Tunnels with associated fencing are the most common form of mitigation and have been applied broadly across BC. Wildlife overpasses that are used to connect habitats for larger wildlife species, such as deer, caribou, and bears, may also be used by amphibians and reptiles (Grift et al. 2009). Certain features that accommodate amphibians and reptiles must be incorporated into wildlife overpasses in places where this kind of multi-species approach is deemed appropriate (see Section 4.3.3).

Crossing structures alone are not sufficient for mitigating road impacts (Schmidt and Zumbach 2008, Rytwinski et al. 2016); they must be used in conjunction with fencing (see Section 4.3.4), which is essential for two purposes: guiding animals to the entranceways of crossing structures and preventing animals from accessing the road surface where they risk being killed. Fencing designs, in combination with crossing structures, must be tailored specifically to the terrain at mitigation sites and to the behaviour and movements of target species (see Section 4.2.5).

The majority of amphibians and reptiles do not naturally want to move through crossing structures. Specific designs and fences are needed to guide (encourage) them to move through these structures.

Installation of crossing structures and fencing during new road construction provides the greatest opportunity for creating functional passages because roads can often be designed to accommodate the recommended sizes of crossing structures (i.e., engineers can plan for appropriate grades and amounts of fill). Road improvement and rehabilitation projects are more challenging because the existing road profile often constrains what can be done. Despite these constraints, there are numerous examples in BC of the addition of new crossing structures to existing roads during upgrades (Appendix E). There are also examples of retrofitting of existing drainage structures to facilitate wildlife passage (see Section 4.2.2).

4.2.1 Bridges and Elevated Roads

Rivers and valley bottoms form natural movement corridors for amphibians, reptiles, and other wildlife. The best solution when a road cannot avoid crossing a river or wetland, or avoid following a shoreline for a long distance, is to install a bridge or elevated road with an appropriate span distance to allow free water flow and maintain the continuity of the natural shoreline habitat (Beben 2016). These larger structures make it possible for various species to move freely under the road and access resources without being constrained to narrow crossing structures. Bridges and elevated roads are particularly important on wider roads (e.g., more than two lanes) because animals are more reluctant to move through long, narrow tunnels than to move under more open bridges of the same length (e.g., turtles; Yorks et al. 2011).

A variety of frog, lizard, snake, and turtle species have been shown to cross under bridges (Smith 2003). Design details vary, but the width of the bridge crossing should be wider than the width of the stream at high water to allow dry passage for terrestrial animals along its banks (Lesbarreres and Fahrig 2012). Planting herbaceous vegetation and shrubs that extend from the edge of the road to beneath the bridge, or adding other cover objects, will provide safety cover. It is important to install ramps that allow animals to cross over abutments if they extend from the shoulder to the riverbank, otherwise they form barriers for animal movement (Figure x).

Bridges and Elevated Roads	
Description • Larger multi-span bridges, arches, viaducts, and elevated roads.	
Advantages • Maximizes connectivity of migratory routes along creeks, shorelines, and throughout wetland habitats • Maintains ecological and physical properties and processes • Allows for the integration of terrestrial pathways at creek and river crossings	
Disadvantages • Expensive compared to smaller crossing structures.	
Application	• Deck on piles or columns
Engineering Considerations	• Engineering measurements and road design will determine best options for bridge or elevated road
Maintenance Considerations	• Natural substrate and cover objects must be maintained

Example Bridges and Elevated Roads	
Photo of bridge structure with connected guiding fences – Highway 4 Lost Shoe Bridge	Photo of elevated road over wetland
Photo x.	Photo x.

4.2.2 Tunnels

In this document, the term tunnel is used to distinguish crossing structures intended for amphibian and reptile use from culverts, which are designed to transport water under the road. Box tunnels, arch tunnels, and round tunnels (Fig. 4) buried into the ground are the primary recommended tunnel types because they provide a natural, relatively flat or horizontal (versus rounded) crossing substrate, and sufficient air, light, and clearance for hopping amphibians (frogs and toads). If the edge between the ground and lateral wall is concave rather than a 90° angle, amphibians will attempt to climb the walls and are less likely to move through the tunnel (Schmidt and Zumbach 2008). The interior height of tunnels retrofitted to existing roads will be constrained by the depth of the ditch relative to the road height, but the minimum interior height should be at least 0.5 m. The interior width will vary with the tunnel design and species (see below and Section 4.3.5). The tunnel should be as wide as possible within the constraints of the materials used to fit the road bed. Longer tunnels (i.e., under more road lanes) will need to be wider and higher to maintain ambient light and temperature throughout the span of the tunnel.

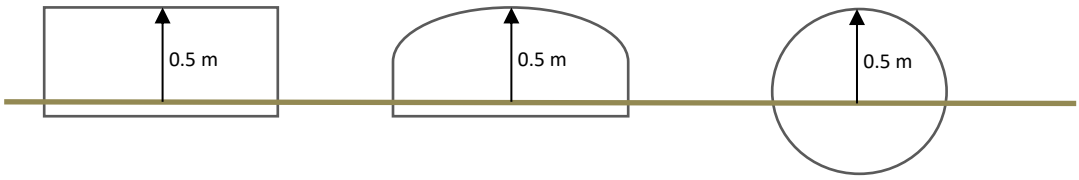


Figure 4. Box, arch, and round tunnels buried into the ground and providing an interior height of at least 0.5 m are recommended for ease of movement of amphibians and reptiles under roadways. Interior width will vary with the tunnel design and species (Section 4.3.5).

4.2.2.1 Tunnel Design

Tunnels need to have particular moisture, temperature, and light conditions to be readily used by amphibians and reptiles (Andrews et al. 2008). In general, tunnels should have an interior width as wide as possible and an overall length as short as possible to allow airflow and keep temperatures inside similar to those outside of the tunnel (Woltz et al. 2008, Yorks et al. 2011). For example, Smith (2003) observed that amphibians and reptiles in Florida used tunnels more often if they were at least 1.5 m wide and 0.6 m high internally, compared to smaller tunnels. In addition to suitable temperatures, amphibians prefer tunnels with high moisture levels due to the permeable nature of their skin and their vulnerability to water loss. Some species tend to avoid structures that are too dark. Design elements can be used to create suitable microclimates in and near crossing structures (e.g., the use of natural substrates, inclusion of cover objects). For example, artificial (e.g., fluorescent lighting) and ambient lighting inside a culvert has been shown to encourage tunnel use by turtles (Yorks et al. 2011) and speed up movements through tunnels by an eastern species of salamander (Jackson 1996). However, artificial light may alter the vision of frogs and have other detrimental impacts (Perry et al. 2008).

General tunnel design recommendations to facilitate amphibian and reptile use (for tunnels < 3 m inner width) are outlined below based on the literature and expert opinion. Specific requirements for individual species or taxonomic groups are summarized in Section 4.3.5.

Design Specifications

- Tunnels should be as open (internally wide and tall) as possible to maximize air flow and ambient light inside the tunnel.
    - Suitable microclimate and light conditions may be achieved by designing tunnels with larger (typically wider) openings, using two structures connected with fencing when a median is present (Photo x), or with an open-top or partial open-top tunnel (Photos x and x).
- At locations where tunnels will be relatively long (e.g., under roads wider than two lanes), consider the following:
    - A bridge or large underpass (> 3 m inner width)
    - Elevating the road (especially when new highway alignments will bisect critical habitat for species at risk)
    - A wildlife overpass
    - Separate, shorter tunnels under each of the opposing traffic lanes with an open median between. Ensure the two tunnels are connected with appropriate fencing in the median. Head walls may help prevent animals from climbing over or around the entrances of each tunnel (Photo x).
- On divided highways, crossing structures should never end in the centre median (Photo x) unless they are connected to other structures with fencing.
- When possible, include "skylights" or fenced gaps at medians and shoulders. Skylighted/grated tunnels can be used along roads that receive snow (e.g., they have been successfully used in Waterton Lakes National Park in Alberta, and in Killbear Provincial Park and the Long Point Causeway in Ontario).
- Where existing culverts are being replaced, increase the size of tunnels to at least minimum design specifications, and use the tunnel type guidelines summarized in Section 4.2.2.2; incorporate specific recommendations for each applicable species or taxonomic group (refer to Section 4.2.5).
- For all species, tunnel entryways should be flush with the terrain.

Microhabitat and Cover

To encourage use by amphibians and reptiles, all terrestrial crossings should have a natural substrate on the tunnel floor that consists of soil, sand, branches and other natural materials (Photos x and x). The use of local, moisture-holding soil (i.e., soil with high organic matter content, such as wood and humus, often referred to as "overburden") in crossing structures is widely recommended for amphibians (e.g., Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013). For example, Woltz et al. (2008) observed that fewer frogs crossed through tunnels containing bare concrete or PVC compared to natural substrate. Substrate selection should be informed by the following considerations:

- Soils should be from the local area to maintain the composition of the local soil microfauna and avoid introducing invasive species.
- Soils that consist of large stones should be avoided because these typically have lower moisture-holding capacity.
- Sediment baffles (e.g., open plate) may be used to "hold" natural substrate in place if water flows through the tunnel (Photo x).
- Cover objects (flat rocks and/or woody debris) should be placed throughout larger tunnels to provide security cover and shelter from predators. These cover objects should not block sightlines or impede individuals from crossing straight through the tunnel.

- Sufficient cover objects (e.g., one relatively large boulder/log or 2-3 cobbles/pieces of wood per 10 m) should be present near the entrances of all terrestrial crossing structures to provide shelter and safety cover.
- Retain as much natural vegetation at the entranceways as possible during construction; where needed, additional planting should occur after construction.

Other Design Considerations

- The amount of desired water within the tunnel will vary across the province depending on local species and conditions. Some species will utilize tunnels containing water (e.g., turtles) while others will not (e.g., lizards). It may be desirable to allow rainwater to enter tunnels in drier interior locations where precipitation is rare/low compared to wetter coastal environments where precipitation can be heavy and lead to frequently flooded tunnels. Where it is deemed suitable to have some water in wildlife tunnels (e.g., designed for aquatic amphibians or turtles), the water should be standing or have low flow rates. Except for tailed frogs and giant salamanders, few amphibian and no reptile species will move through tunnels filled with fast-flowing water. Wildlife tunnels should never be fully submerged (e.g., Caverhill et. al. 2011, Photo x), as amphibians and reptiles require access to surface oxygen.
- Terrestrial tunnels should be as level as possible for the entire length of the structure so that any water that enters the tunnel will move through at a low flow rate. One exception to this is tunnels with grated tops, which can fill with water; these tunnels should be installed with a slight slope to allow for drainage and natural cleaning of the tunnel. The slope of tunnels with grated tops can follow the natural contour of the land or be highest in the middle and slope downwards towards either end to make it level with the ground at both entrances of the tunnel.
- Tunnel entrance bottoms (including the soil level inside the tunnel) should be at ground level so animals do not need to “step up” or “step down” to enter the structure (Photo x).
- At terrestrial tunnels, most runoff water should be diverted away from the entrances with drainage ditches or sloped excavation (Photo x). However, it is important to allow some rainwater to enter the tunnel to keep soils moist for amphibians (Malt 2012, B. Beasley pers. obs.).
- If they are large enough, culverts intended for drainage and tunnels with water flow can be made suitable as crossing structures for some species by creating a bench that allows dry passage through the tunnel. The bench can be integrated into the culvert or tunnel design (e.g., attached to the side wall), but it must be situated above the high water mark and connected (extended) to dry ground at both tunnel entryways to be effective (Photo x).
- When arch tunnels are used at road-stream crossings, terrestrial corridors should be retained along the stream riparian zone by using wider tunnels that extend beyond the high water mark (Photo x). This design can better accommodate seasonal high water and flooding events (Lesbarrères and Fahrig 2012).
- When dealing with multi-species issues and variable site conditions, a mixed array of tunnel types and sizes should be provided. Structural diversity of tunnels can provide an experimental setting to test species-specific crossing preferences (see Section 7).
- Many crossing structures become ineffective over time due to lack of maintenance (Iuell et al. 2003). Regular maintenance is required for long-term effectiveness of all tunnels to ensure that the microhabitat is intact, passageways are clear of debris, and that suitable substrate remains. Maintenance needs to be factored in to the original design and budget of mitigation structures.

4.2.2.2 Types of Tunnels for Amphibians and Reptiles

<table>
<tr><th colspan="2">Box Tunnel</th></tr>
<tr><td colspan="2">Description
Traditionally used for drainage, concrete box culverts can be modified specifically to serve as tunnels for amphibian and reptile passage.
Tunnels up to 3 m wide or high are typically made from precast concrete.
The maximum recommended tunnel length is 25 m (i.e., to fit under a 4-lane road) because amphibians and reptiles are reluctant to use longer structures.
Variations include open-top or open-grate, open-bottom, and variations of these.</td></tr>
<tr><td>Open-top</td><td>Achieved with slots or grooves along the top or open-grate, set upon two concrete footings.
Allows for internal moisture, light, and temperature conditions more similar to ambient conditions.
Possible concerns with influx of road debris, pollutants, or traffic noise.
Installation at a downward incline from middle of road to edge of road to allow for drainage and natural cleaning of the tunnel.
The use of larger tunnel entryways in small tunnels facilitates maintenance.</td></tr>
<tr><td>Open-bottom</td><td>Three-sided structures.
Allows natural topography and substrate conditions to be retained (e.g., streambed or grass floor).</td></tr>
<tr><td colspan="2">Advantages
Lower road cover requirements for concrete box tunnels compared to arches or round metal tunnels allows them to be set higher in the roadbed.
Provide more cross-sectional area, or openness, than round or elliptical tunnels of the same width. The amount of light and airflow (microhabitat conditions) in a smaller-sized open-top tunnel may be equivalent to that of wider/taller tunnels that are enclosed.
Straight (vertical) walls are easy for animals to follow continuously from straight-walled fencing, and they may be perceived by target species to provide increased openness.</td></tr>
<tr><td colspan="2">Disadvantages
Interior opening is smaller, darker and potentially colder compared to passages under bridges and elevated roads.</td></tr>
<tr><td>Application</td><td>Open-top grate tunnels have previously been used on low-use roads or roads in protected areas (e.g., cattleguards; M. Sarell pers. comm.).
The tunnel floor should be buried and covered with natural substrate and cover objects.
An open-top in the road shoulder and a closed-top along the road pavement may be more suitable for high volume roads.
For divided highways with two structures that end in the median, tunnels should be connected with a fence.
Headwalls may be used at the entrance to shorten the length of the structure or to create a seamless join to a concrete guide wall.</td></tr>
<tr><td>Engineering Considerations</td><td>Open-top tunnels must be at grade with the road surface.
Road must be constructed with a vertical road profile that will allow for the height of the tunnel and adequate cover for structural stability. The necessary elevational relief will vary depending on the size of box tunnel and</td></tr>
</table>

Box Tunnel	
	road loading requirements. For a concrete box culvert with a vertical opening of 0.5 m, there will need to be at least 1 m between the elevation at the surface of the road and the elevation at the bottom of the ditch or where animals enter the tunnel. • Design variations may require special design drawings if not prefabricated.
Maintenance Considerations	• Natural substrate and cover objects must be maintained. • Open-top tunnels may have to be periodically flushed with water (e.g., with a fire hose) to clean build-up of road pollutants. • Smaller tunnels will be more difficult to keep clear of debris. • Larger structures allow better maintenance accessibility while having relatively minor cost increases relative to the cost of the road project. • Open-top tunnels are thought to interfere with snow removal; however, this has not been the case in tunnel installations in cold countries (Langton 2014). • The top of the tunnel wears away at the same rate as the road surface (see review in Langton 2014).

Examples of Applications of Box Tunnels	
Photo 1. Precast concrete box tunnel filled with material (like the one at Ryder Lake) (photo taken from side of road).	Photo 2. Open-top tunnel with a grate near road shoulder (photo taken from above from side of road).
Photo 3. Open-top tunnel with a manhole grate at centre of road (photo taken from above road).	Photo 4. Interior of tunnel with manhole grate at centre of road.
Photo 5. Open-top tunnel with slots at Waterton Lakes National Park (manufactured by ACO Systems Ltd.) (photo taken from above road).	Photo 6. Interior of open-top tunnel with slots for light and air flow.
Photo 7. Open-bottom concrete box tunnel with natural substrate continuous with outside substrates (shown from above at roadside).	Photo 8. Open-bottom and open-top tunnel with grate set on two concrete footings (shown from above at roadside) allows natural substrate to be retained.

Photo 9. Adding soil to bottom of concrete box culvert along Highway 4 near Uclulet (Photo: B. Beasley).	Photo 10. Cover objects placed on soils in bottom of concrete box tunnel (Photo: B. Beasley).
Photo 11. Box tunnels meeting in the median should be connected with fencing (Photo: Kari Gunson).	Photo 12. Box tunnel with headwalls connected to guiding fences at entrance.

Arch or Round Tunnel	
Description • Made of concrete, corrugated steel, aluminum, or plastic. • Arch tunnels have open bottoms and are recommended for tunnel widths greater than or equal to 1.5 m in diameter (common widths: 1.8 m, 2.4 m, and 3.0 m). • It is also possible to make the shape of an arched tunnel by compressing a round pipe. • The maximum recommended tunnel length is 25 m because amphibians and reptiles are reluctant to use longer structures. • Recommended sizes for arch tunnels are slightly larger than box tunnels to compensate for the loss of openness as a result of tunnel shape.	
Open-top	• Slotted open-top or vertical skylight risers along the length of the tunnel to provide natural light.
Open-bottom	• Achieved by using arch tunnel, or by placing sufficient natural substrates into bottom of round tunnels to increase the floor width (at least 2 m in diameter).
Advantages • Round tunnels work well in aquatic conditions for turtles and semi-aquatic snakes. • Increasing the width of the tunnel allows for the retention of terrestrial corridors alongside the stream or creek bed.	
Disadvantages • Interior space is smaller, darker and potentially colder compared to passages under bridges and elevated roads. • Higher road cover requirements for arches or round metal tunnels requires them to be set lower in the roadbed. • Provide less cross-sectional area or openness than box tunnels of the same width. • Rounded vertical walls are not as easy for animals to follow continuously from straight-walled fencing.	
Application	• Arch structure may be preassembled and dropped in place or assembled at site. • Corrugated steel arch or concrete side slabs are placed on footings.
Engineering Considerations	• Footings are required for arch tunnels. • In terrestrial conditions, round tunnels should be filled with local soil and

	debris to create a level crossing surface for amphibians and reptiles. The recommended tunnel substrate depth depends on tunnel diameter—0.1 to 0.2 m can be adequate as long as it raises the height of the bottom to a level that will not be flooded. The minimum diameter of a round tunnel is 2 m to compensate for the internal height lost with the addition of substrate material. • Buried tunnels may be more suitable when tall footings are required.
Maintenance Considerations	• Natural substrate and cover objects should be maintained. • Larger structures allow better maintenance accessibility while having relatively minor cost increases relative to the cost of the road project.

Examples of Applications of Arch/Round Tunnels	
Photo 13. Arched tunnel with natural stream crossing.	Photo 14. Aluminum arch culvert on metal footings.
Photo 15. Pipe culvert with slotted top installed for Timber Rattlesnakes in Illinois, U.S.	Photo 16. Zoom-in of open-top pipe culvert at road for Timber Rattlesnakes in Illinois, U.S.
Photo 17. Corrugated metal culvert crossing Highway 97.	Photo 18. Very large corrugated metal culvert crossing Sea to Sky Highway at Pinecrest.

4.2.2.3 Number of Tunnels, Location, and Spacing

The following considerations are outlined to assist with site selection for the optimal placement and number of crossing structures:

Location

In general, crossing structures should be placed where the road bisects habitat used by the target species (e.g., aquatic features and wetlands), where the road is between important, adjacent seasonal habitats used by a species (e.g., aquatic breeding habitat and upland overwintering habitat), and where the road bisects a movement corridor (e.g., natural linear pathway, such as a riparian area, hedgerow, or gully). Tunnels and fencing are best located where movement paths cross existing and proposed roads, as determined from field surveys or spatial analyses (see examples in Gunson et al. 2012, Persello et al. 2011, Beasley 2013, Grods and Garner 2018, Neilson 2018). Field surveys over at least one year are likely needed to account for different species and seasonal differences. Examples of predictable movements include annual spring migrations of adult amphibians between upland forests and breeding ponds (e.g., Wind 2014), snake migrations to and from overwintering hibernacula (e.g., Winton 2017, Fortney et al. 2013), and female turtle terrestrial nesting migrations and inter-wetland movements (e.g., Evelyn 2018). Road mortality hotspots, or areas where the highest number of animals are killed, are often used to guide placement of crossings (reinforcing the need for comprehensive pre-construction wildlife surveys). For rare or long-lived species with low reproductive rates, any location with a road-killed individual may reflect a location that requires long-term mitigation, as even small numbers killed on the road each year may be unsustainable.

In cases where past road mortality has reduced populations, road kill numbers may be low even at sites with high traffic volume.

Priority should still be given to high-traffic locations where habitats are near and straddling the road. These sites are particularly important locations for recovering depressed populations.

Exact locations for crossing structures depend on the terrain at the specific site:

- Crossing structures should be integrated with the natural landscape. Gullies and ravines are often used as movement corridors and are ideal positions for placing crossings under roads if there is sufficient elevation relief for installing a structure of appropriate height.
- Vertical alignment and location should be based on water level. For example, terrestrial tunnels should be placed in the roadbed just above the high water mark defined by the maximum water level in the ditch during stormy periods.
- Hydraulic and engineering information should be used to predict the amount of water that will flow through the tunnel at its proposed location during migration and dispersal seasons. This can then be used to decide whether the proposed location is appropriate for the target species. Refer to taxonomic-specific recommendations for aquatic and terrestrial crossing types in Section 4.2.5, in addition to site-specific conditions measured in the field.
- Modify existing or planned man-made features (e.g., ditches, retaining walls) that can act as barriers to amphibians and reptiles moving along the right-of-way (parallel to) or towards (perpendicular to) roads, so that they do not block animals from accessing crossing structures (Gartner Lee and Ecoplans 2009).

Number and Spacing

The number of crossing structures and spacing between them will depend on the length of the section of road that animals interact with (preferably measured with road encounter data, see Section 7.2.1) and the distances that individuals of the species are willing to move along guiding fences to where they will encounter crossings. For example, Long-toed Salamanders moved an average of 29 m along fences monitored in Waterton Lake National Park (Pagnucco et al. 2012). Crossing structures that are not encountered will not be used. On this basis, Schmidt and Zumbach (2008) recommend that tunnels for amphibians be spaced no more than 50 m apart along the core road encounter length, but this distance will vary by species. In BC, distances of up to 250 m between tunnels have been used for some snake species in some areas, although ideal distance may be no more than 150 m apart within high road-encounter zones (M. Sarell, pers. comm.).

- Appendices C and D provide a general summary of movement distances, home range areas, and habitat used by each species, but more detailed species- and site-specific information gathered at mitigation locations should be used to inform the number and spacing of tunnels.
- When roads bisect large expanses of continuous habitat (e.g., forest), several small, evenly distributed crossing structures will increase connectivity more than a single, large crossing structure (Karlson et al. 2017).

The young of some species (e.g., Western Toads) and species in some locations of BC (e.g., dry interior habitats) may move en masse to or from important habitats (e.g., during infrequent rain events). On the coast, amphibians and reptiles typically move away from breeding sites or hibernacula individually and randomly in space and time to access resources in ways that reduce competition and predation (e.g., Fig. 5). In this latter scenario, providing several crossing structures instead of a single structure will better maintain natural distribution patterns.



Figure 5. Road crossing locations of adult Red-Legged Frogs (blue dots) and Western Toads (red dots) in spring adjacent to a breeding site near Duncan, BC. Adult movements were more random and widely dispersed than the relatively narrow corridors used by dispersing Western Toad juveniles (pink arrows) in summer after emergence from the breeding site.

4.2.2.4 Retrofitting Existing Drainage Culverts

Some species of amphibians and reptiles use culverts that have historically conveyed water under roads (e.g., Caverhill et al. 2011). Road improvement and rehabilitation projects provide opportunities to retrofit or enhance existing drainage culverts to facilitate use by these animals. In some cases, existing drainage culverts may already be located and designed correctly for use by the target species and may only require guide fencing to facilitate crossing use and reduce road mortality (Caverhill et al. 2011, Beasley 2012; see section 4.2.4 and Photo X). Existing culverts need to be carefully evaluated for their potential as passages for the intended species before directional fencing is installed. If culverts become frequently inundated with water, some amphibians and reptiles may not be able to swim through them. Retrofitting water-carrying culverts with shelves (benches) attached to the inside of the walls, above the high water line, can make them viable passageways (Photo X).

Photo X. Existing culvert retrofitted with fencing

Photo X. Existing culvert retrofitted with shelf/bench

4.2.3 Wildlife Overpasses

Overpasses are primarily designed for larger animals, such as large carnivores and ungulates, but they can serve as both passageways and intermediate habitats for amphibians and reptiles (Jackson and Griffin 2000, Grift et al. 2009). Wildlife overpasses are sometimes referred to as "green bridges" because they are typically planted with vegetation to form a continuation of the natural landscape. Modifications for amphibians and reptiles include cover objects and ponds for hydration (e.g., in the Netherlands: Grift et al. 2009; see photos x and y). The advantages of overpasses are that they are less confining, quieter, maintain ambient conditions of rainfall, temperature, and light, and serve as passageways for large and small wildlife (Glista et al. 2009). The main drawback is their expense.

Wildlife Overpass	
• A large, multi-species crossing structure that is not usually prefabricated or precast. • Integrated as a multi-species strategy for both large and small animals. • Design includes a bridge deck that spans the road. • Requires a natural landscape planting strategy and drainage system on top of the structure. • The slope of approach ramps should be minimized for greatest visibility. • Overpass width varies from 20 m to > 70 m.	
Application	• Large structures provide greater opportunity to provide cover objects, such as flat rocks, vegetated mounds composed of branches and logs and covered with sod, or rock piles (Photos x and x). • Design enhancements for amphibians and semi-aquatic reptiles include small ponds as "stepping-stones" along the length of the structure. Natural or artificial substrate may be used to retain pond water or rainfall (van der Grift et al. 2003; Figure y). • For multi-use structures, wildlife and human use should be separated or human use should be mitigated. For example, the Rt. Hon. Herb Gray

Wildlife Overpass	
	Parkway in Ontario has incorporated a crossing structure for Butler's Gartersnake and Eastern Foxsnake into the multi-use trail system to minimize disturbance impacts from recreational trail users. • Multi-species fencing designs should be used. For example, the fencing along the Highway 69 overpass in Ontario combines ¼ inch mesh with a 2.4 m-high large animal mesh fence (Photo x).
Engineering Considerations	• Overpass decks can integrate natural footings, such as rock cliffs (Photo x).
Maintenance Considerations	• Maintenance checks for initial establishment of vegetation on overpass structures are required. • Irrigation for pools and vegetation may be required.

Examples of Wildlife Overpasses	
Photo 19. A 30 m-wide overpass installed near Sudbury on Highway 69 in Ontario (view from above).	Photo 20. Brush piles on top of an overpass on Highway 69 in Ontario.
Photo 21. Rock cliff footings on overpass on Highway 69 (view from road).	Photo 22. Multi-species fencing guiding animals to overpass.

4.2.4 Fencing for Reptile and Amphibian Crossings

Crossing structures are not likely to be used by amphibians and reptiles unless they incorporate fencing (Cunnington et al. 2014, Rytwinski et al. 2016). However, careful consideration must be given to the potential detrimental impacts of fencing on non-target species and the ecosystem (see Section 4.3). If the potential benefits to the target species outweigh negative impacts, then fences can be installed balancing benefits to target species against maintaining landscape connectivity for other species. Primarily, limit use to mortality hotspots and between key habitats. Fence lengths will depend, in part, on the species, terrain, and number and spacing of crossing structures. Care must be taken to avoid leaving fencing and crossing structure gaps at amphibian and reptile movement hotspots, as these gaps may have the adverse effect of funneling animals onto the road (e.g., Baxter-Gilbert et al 2015).

Fencing serves two purposes: 1) directing animals towards structure entrances and 2) providing a barrier to exclude animals from the road (e.g., Wilson and Topham 2009). Fencing can be used with crossing structures or as a stand-alone measure to prevent mortality along roads where connectivity is not a concern (e.g., when suitable habitat is adjacent to, but not bisected by the road, or where animals are unlikely to cross successfully due to high traffic volumes; Jackson et al. 2015).

The following recommendations are divided into fencing design, placement, and maintenance considerations and are generally applicable to all amphibians and reptiles. Species-specific details are provided in Section 4.3.5.

4.2.4.1 Fence Design

These recommendations focus on designing and installing high-quality, gap-free fencing, which may have higher initial costs but will be less expensive in the long run, compared to the ongoing maintenance required for lower-quality fencing. A number of projects have experimented with fencing effectiveness for amphibians and reptiles (e.g., Beasley, unpubl. data, Crosby 2014, Dulisse et al. 2018, Langen 2011, Smith and Noss 2011), and new, cost-effective designs are continually being engineered and tested.

Fencing should have a solid, durable framework (stakes, posts, and sheeting) to provide an effective barrier for the target species and to withstand the weight and impact from snow removal. General considerations for fence design are as follows (see Figure 6 for further illustration):

- *Posts:*
    - Steel posts will not break with snow load.
    - Posts that are closer together (e.g., spaced 2-3 m apart) will prevent both fence sag and collapse during severe weather events and snow removal.
    - Stakes or posts should be placed along the road-facing side of the fence to deter climbing and should be buried at least 30 cm into the ground to prevent burrowing.
- *Materials:*
    - The choice between recommended fencing materials listed in Table 2 depends on the target species.
    - Use materials that allow drainage through or beneath the fence at wet sites to avoid pooling at or near a crossing structure (Smith and Noss 2011, Photo x).
    - Use opaque fence materials, especially where snakes or turtles occur.
        - Recent studies on the effects of hardware cloth fences on snakes (Eye et al. 2018) and chain link fencing on tortoises (Peaden et al. 2017) have shown that these animals will repeatedly attempt to get through the fence if they can see

the other side, causing injury or death. In contrast, turtles were found to move more quickly along fences that were opaque (Yorks et al. 2011).

- Fence material should not be flammable in areas that experience frequent wildfires.
- Mesh should not be used as fencing material. Several species of amphibians can climb plastic ¼" mesh fences (Beasley, unpubl. data) and some small snakes can pass through or get stuck in ¼" mesh (Photo x; Smith and Noss 2011, S. Marks, pers. comm.).

- *Fence Depth and Height:*
  - The fence should be buried to a minimum depth of 10 cm, with a fold 10-20 cm wide to create a lip that is directed away from the road (Fig. 6). This is to deter animals from digging under the fence and to reduce the risk of the fence material being pulled out of the ground when bumped.
  - If fences have the potential to be inundated by spring runoff, the fence height should be at least 0.5 m higher than the high water level in spring to prevent animals from jumping or climbing over it.
  - When more than one species is targeted for mitigation, fence height should be the tallest height recommended for all target species (Table 3). The use of an overhanging lip along the top of the fence can allow for the fence to be shorter (see next point).
  - The fence should include an overhanging lip along the top (Fig. 6). This lip should extend 6 cm outwards, away from the road (horizontally), and then 4 cm downwards (vertically).
- *Additional Considerations:*
  - Backfill or ramps installed every 3 to 5 m on the road side of the fence can help trapped animals escape to the safe (shoulder) side of the fence (e.g., Highway 4 wildlife fence, Lost Lake toad fence manufactured by ACO Systems Ltd.; Photo x).
  - Fence ends should be curved or installed in a 90° "U" design to direct amphibians and reptiles away from the road (Fig. 7). This curved section should be a minimum of 200 cm long, though longer is better (D. Seburn, pers. comm.).

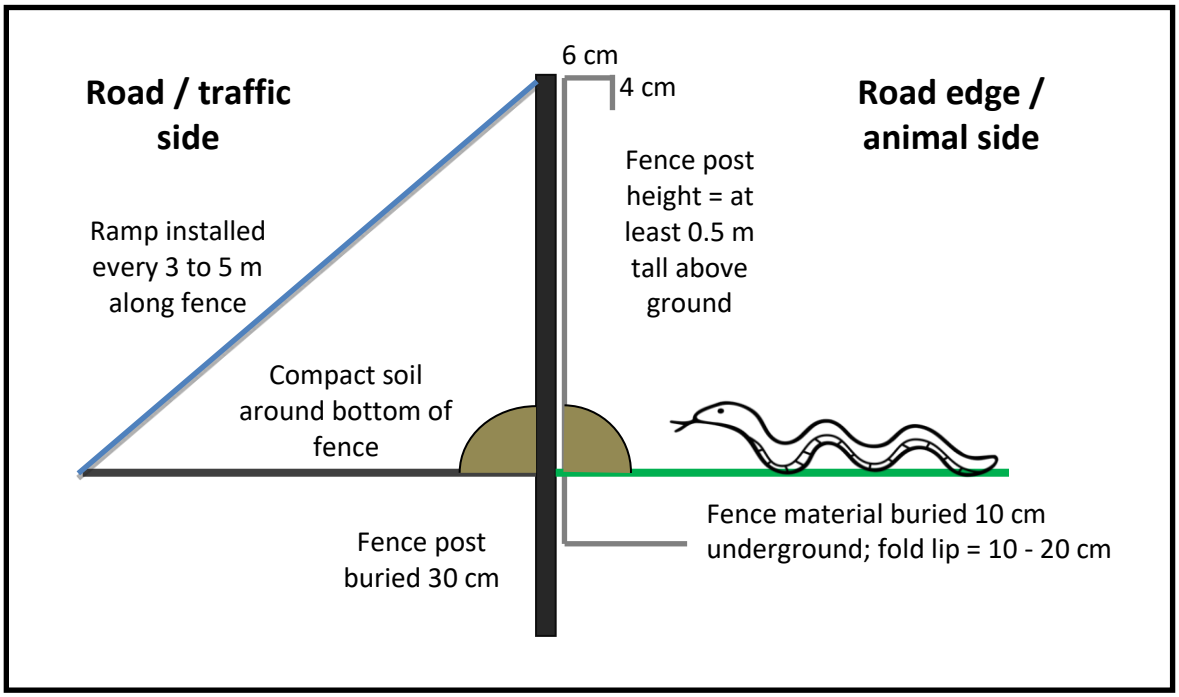


Figure 6. Design of fencing to exclude amphibians from roadways and/or guide them towards tunnels.

Table 2. Fence material options and considerations. See 4.2.5 for species group recommendations.

Material	Use	Recommended?
Hardware cloth or rigid plastic mesh	Durable fence material that allows drainage	Only if drainage is required. Not for turtles or snakes.
Chain link fencing	Standard chain link used for large animals (e.g., 2.5 m high wildlife exclusion fencing with 4" mesh); does not work for many amphibians and reptiles, as individuals can pass through the large mesh holes	Only if additional fencing material, such as heavy-duty plastic fencing, is attached at the base for amphibians and reptiles (Photo x)
Metal (e.g., sheeting)	Durable fence material	Yes
Vinyl	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Wood	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Concrete	Durable fence material	Yes

Heavy duty UV-resistant polymer fencing designed for wildlife	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Light duty geotextile (Photo x)	Temporary fence material (lifespan up to 1 year)	Not for long-term use
Heavy duty geotextile fence	Temporary fence material (2-3 years)	Not for long-term use
Wood lath snow fencing	Temporary fence material (< 3 years)	Not for long-term use
Nylon mesh fencing or erosion materials	Should not be used, as snakes and other species can become entangled and die in this material	No

Photo X. Amphibian and reptile fencing attached to the bottom of large animal chain link fencing.

Photo X. Light duty geotextile fencing—not recommended for long-term use.

Photo X. Waterton Lakes National Park's plastic fencing before & after the 2017 fire, and replacement metal fencing.

Photo X. Use materials that allow drainage under the fence.

Photo x. ¼" mesh fencing being climbed by a frog.

Photo x. The bottom fold of the fence should be 10-20 cm wide and buried 10 cm below ground.

Table 3. Recommended above-ground heights and below-ground depths for fencing for each species group.

Species Group	Recommended depth of buried fence, excluding bottom lip (10 - 20 cm; see Fig. 6)	Recommended height of fence, excluding top lip (6 cm + 4 cm; see Fig. 6)
Turtles	10 - 20 cm	60 cm
Frogs and Toads	10 - 20 cm	50 cm
Snakes	10 - 20 cm	100 cm
Lizards	10 - 20 cm	unknown
Salamanders	10 - 20 cm	30 cm

Photo x. Backfill or a ramp on road side of fence.

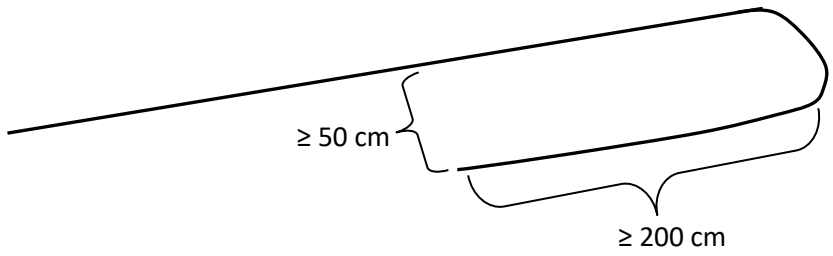


Figure 7. Fence ends should curve back, by a minimum of 200 cm, towards the shoulder side of the road to deter animals that are moving along the fence from continuing onto the road and, ideally, redirect them back towards the crossing structure.

4.2.4.2 Fence Length and Placement

Fence length depends on the species' movement abilities as well as the interface of the surrounding habitat with the road. Spatial analyses of where species are found can help determine how much fencing is required and where it should be placed (Gunson and Teixeira 2015). However, when roads bisect continuous expanses of habitat, fencing is often required along the entire stretch of road to prevent mortality. The following should be considered when evaluating fence and crossing structure placement:

- Data collected from inventory work, road surveys, expert opinion, and other sources should be used to understand species presence, habitat use, and movements in relation to the road (see Appendices A-D).
- Maximum movement distances of the target species along fences should be used to inform fencing length. For example, salamanders generally will not move distances greater than 50 m along fences (Schmidt and Zumbach 2008), while frogs, turtles, and snakes may move much farther (see Appendix D). Some species will move considerable distances along the fence and access the road at the fence ends; this can only be avoided if the fence is longer than the distances that the species will move, or if the fencing is extended back away from the road at each end (see Fig. 7 above).
- Solid rock areas should be avoided when possible; if rocky areas cannot be avoided, dirt or mortar can be used to hold the fence in place and infill irregularities in the rock surface to create a seal (Photo x).
- Wherever possible, the fence should direct wildlife, without impediment, towards the crossings.
- To be effective in guiding animals, fencing must connect to the tunnel entrances smoothly and without gaps. Connections should follow a 'V' pattern (Fig. 8a) or span between multiple crossing structures in a 'W' pattern (Fig. 8b) to funnel animals. Many factors, such as land ownership, terrain, limitations of the fencing material, road maintenance requirements, ditch

drainage, etc., must be included in the design. Where wildlife fencing is constrained by road right-of-ways and existing fencing, a 'W' pattern may not be possible; in these cases, 'V' patterns should be used in proximity to the crossings to funnel animals.

- Effective fencing requires regular, planned maintenance (see Section 4.3.4.3 below).

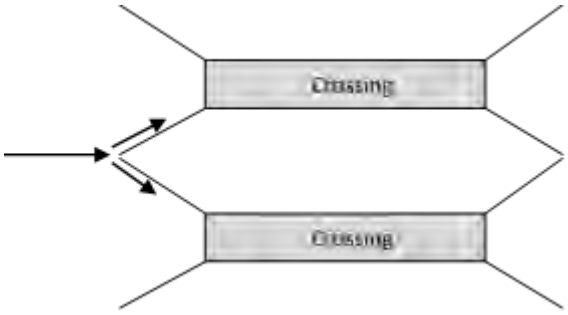
Right-of-way considerations:

- Fencing should be placed as far as possible from the road edge to minimize impacts from snow removal, mowing, or other roadside maintenance practices.
- Fencing cannot interfere with road interchanges or driveway access.
- Fencing cannot interfere with ditch drainage or any watercourse flows that intersect the road.
- Permissions and permits must be obtained from the road authority.
- When the fence extends beyond the right-of-way, permission must be obtained from property owners.

Photo X. Dirt or gravel keeping fence in place along rocky areas.



a. "V" formation of fencing is used to guide amphibians and reptiles towards a crossing structure.



b. "W" formation of fencing is used to guide amphibians and reptiles towards multiple crossing structures.

Figure 8. Fencing placement in relation to crossing entryways. Fencing should be continuous between multiple, adjacent crossing structures to increase the "capture" area of migrating individuals.

4.2.4.3 Fence Maintenance

All fencing requires routine checks and maintenance which should be planned and budgeted for (see Section 7.2). The frequency of maintenance checks and repairs will vary with the durability of the fence and the rate of vegetation growth and mammal activity along it. After snowmelt, a thorough survey and immediate fence repairs are essential before amphibians and reptiles emerge from hibernation. The following are recommended considerations for fence maintenance:

- Regular maintenance is required to clear vegetation and debris from all fences. Woody vegetation, leaves, thick grasses, and other debris that pile up along the fence may provide a "ladder," or puncture the fence, allowing animals to access the road. Clearing of vegetation and debris also helps to reduce fuel loads to protect fencing materials that may be flammable.
- Fences should be marked with tall posts and flagging tape to alert maintenance crews to their presence, especially where mowing and snow removal will occur.
- Routine fence surveys should be done using a checklist approach to identify where repairs are required, including the location and description of any damage (see Section 7.2). The survey checklist should include monitoring for potential carcasses along the fence and on the road during the active season (Table 1) to ensure that the fence materials and design are effective (not allowing animals onto the road) and not negatively affecting any local amphibian and reptile species (e.g., entangled snakes).
- Repair crews need to fix the fence in a timely manner (e.g., before and during the active season) to minimize fence breaches by amphibians and reptiles.
- Amphibian and/or reptile carcasses on the fence or adjacent road may be an indication of a failure of fence design, signalling a need for immediate fence repairs, modification or replacement.

Fence Maintenance Checklist:

Prior to the active season

- ☐ Fence is standing (has not collapsed)
- ☐ Fence links to the crossing structure with no gaps
- ☐ Fence is vegetation free
- ☐ No holes or gaps in or under the fence

During the active season

- ☐ No carcasses along fence
- ☐ No carcasses along the road

4.2.5 Recommendations by Species Group

In addition to the general design considerations for reptiles and amphibians that are outlined above, the following are specific recommendations that are unique to each group. The following recommendations are based on species that have been observed using tunnels. It is unknown how effective the specifications below are to other reptile and amphibian species, or for overpasses, in BC. This underscores the importance of conducting effectiveness monitoring for mitigation projects (Section 7.0).

In general, tunnel design recommendations are made with the assumption that as tunnels get longer, an increase in width is more important than an increase in height in order to maintain suitable climatic conditions (see Box 1).

SPECIFICATIONS FOR TURTLES

Type of structure and minimum size based on tunnel length

Tunnel Length	Box Tunnel (w x h)	Arch Tunnel (w x h)	Round Tunnel (diameter)	Other Structure Recommended
15 m	1.5 m x 1.0 m	1.8 m x 0.9 m	1.5 m	
15-25 m	1.8 m x 1.0 m	2.0 m x 1.0 m	1.8 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Terrestrial and aquatic structures are suitable for most turtle species.
- Open and closed-top tunnels have been used by turtles; however, open-top tunnels may increase crossing success.
- Do not install rip-rap at entranceways, along footings, or leading into the crossing structure.
- Concrete fabric can assist in allowing turtles to climb into or out of culverts that have steep hills.
- A minimum of 150 m (Appendix D) of fencing (60 cm high, buried 10-20 cm into ground; Table 3) on either side of the crossing structure is recommended to funnel turtles to entranceways and keep them off the road/highway.
- Fencing should be opaque.
- Substrate type may not be as important in terrestrial tunnels for turtles as with other amphibians and reptiles.

Rationale

Use of culverts has been documented for Western Painted Turtles in BC. For example, after a couple of years and several design modifications, turtles were observed going through a large culvert installed under Highway 97 where the road was expanded to four lanes, south of Williams Lake (Bings and Steciw 2018).

Several studies have demonstrated relatively high use of large (> 1.5 m width) crossing structures by species of turtles outside of BC:

- The Port of Portland Authority built turtle culverts for Western Painted Turtles, which, although not scientifically studied, appear to work (Kintsch and Cramer 2011).
- In Ontario, a drainage culvert 1.8 m in diameter that was approximately half-full of water (Caverhill et al. 2011) was used regularly by Blanding's Turtles and was also used by Snapping Turtles.
- Multiple Spotted Turtles were confirmed to cross through a tunnel 1.8 m x 1.8 m (Kaye et al. 2005).
- Aresco (2005) documented over 200 turtle crossings through a 3.5 m-diameter drainage culvert.
- Wood Turtles continued to use a stream that passed through a culvert that was 3 m in

diameter and 26 m long (Parren 2013).

Caverhill et al. (2011) found that turtles will cross through tunnels 25 m long, although crossing success may be lower as length increases (Yorks et al. 2011).

In a simulated tunnel experiment, more turtles crossed through a tunnel that let in at least 75% ambient light through the top (Yorks et al. 2011).

Turtles have used closed-top tunnels (e.g., Dodd et al. 2004, Aresco 2005, Kaye et al. 2005, Caverhill et al. 2011) and Wood Turtles (Photo 54) and Snapping Turtles (Whitelock 2014) have crossed through open-top tunnels in Ontario.

Blanding's and Spotted Turtles have been documented to cross through tunnels with natural substrates (e.g., Kaye et al. 2005, Caverhill et al. 2011), but in a simulated crossing structure experiment, Painted and Snapping Turtles did not demonstrate a substrate preference (Woltz et al. 2008).

Photo x. Turtle in terrestrial tunnel.	Photo x. Turtle in aquatic tunnel.

SPECIFICATIONS FOR SNAKES AND LIZARDS				
Type of structure and minimum size based on tunnel length				
Tunnel Length	**Box Tunnel (w x h)**	**Arch Tunnel (w x h)**	**Round Tunnel (diameter)**	**Other Structure Recommended**
15 m	1.0 m x 1.0 m	1.5 m x 0.75 m	1.0 m	
15-25 m	1.5 m x 1.0 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Open and closed-top tunnels have been used by snakes. Open-top tunnels may increase crossing success for some snake species while allowing others to access road surfaces through the opening.
- Depending on the tunnel material and shape, lizards may be able to access the road surface through open-top tunnels.
- Aquatic tunnels are not recommended for some BC snakes and all BC lizards. Existing culverts with intermittent flows are likely to be used by snakes and should be considered during project design.
- Do not install rip-rap at crossing entranceways.
- A minimum of 250 m of fencing (1 m high, buried 10-20 cm into ground; Table 3) is required on either side of the crossing structure (Appendix D) to funnel snakes to entranceways and keep them off the road/highway.
- Fence height and length are unknown for lizards.
- Fences should be opaque and the tops and bottoms should be folded over as per Figure 6.
-).

Rationale

Note: BC-specific data are not available. These recommendations are adapted from the *Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario* (2016) and other publications and reports from outside the province.

Snakes (e.g., Taylor and Goldingay 2003, Laidig and Golden 2004, Roberts 2010, Eads 2013) and lizards (e.g., Taylor and Goldingay 2003, Painter and Ingraldi 2007, Arizona Game and Fish 2010) have used a variety of crossing structures under roads. However, compared to other taxa, there is less certainty about crossing structure design preferences for these species.

Snakes have crossed through tunnels as small as 0.25 m in diameter (Roberts 2010), but tunnels 1.0 m in diameter had a greater crossing success than smaller tunnels for the Eastern Gartersnake and Eastern Ribbonsnake in an experiment by Eads (2013).

Both closed-top (Taylor and Goldingay 2003, Laidig and Golden 2004, Roberts 2010, Eads 2013) and open-top (Pagnucco et al. 2011, Colley et al. 2017) crossing structures have been used by snakes.

Wandering Garter Snakes in Waterton Lakes National Park, Alberta, moved through open-top tunnels manufactured by ACO Systems Ltd. that have interior dimensions of 0.50 m wide x 0.33 m high (Pagnucco et al. 2011).

Open-bottom box tunnels with cross-sectional dimensions of 1.0 x 1.0 m in Killbear Provincial Park, Ontario, were used by many (11) Massasaugas and 2 Eastern Foxsnakes in 2014 (Colley et al. 2017).

Timber Rattlesnakes have crossed through concrete-bottom structures (Laidig and Golden 2004), but

natural substrate or habitat conditions may enhance use (Laidig and Golden 2004).	
Photo # Snake in terrestrial tunnel.	Photo # Snake fencing.

SPECIFICATIONS FOR SALAMANDERS				
Type of structure and minimum size based on tunnel length				
Tunnel Length	**Box Tunnel (w x h)**	**Arch Tunnel (w x h)**	**Round Tunnel (diameter)**	**Other Structure Recommended**
15 m	1.8 m x 0.5 m	1.5 m x 0.75 m	0.6 m	
15-25 m	1.5 m x 1.0 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road

Additional Design Considerations

- Salamanders prefer tunnels with high moisture content and even small pools of standing water, but the tunnel should not be flooded with water.
- Open- or closed-top tunnels can be effective. Open-top tunnels allow more light into the tunnel and possibly greater moisture levels, the latter being important in longer tunnels. The use of open-top tunnels may allow the dimensions to be smaller than those listed above (see below).
- Open-top tunnels may result in higher levels of road salt and other pollutants in the tunnel. However, these may be washed away with storm events.
- Soils and leaf litter substrates should be used as opposed to larger gravel or stone substrates.
- Multiple tunnels should be used where migration paths cross roads towards aquatic breeding sites. Tunnels for salamanders should not be more than 30 m apart (e.g., Pagnucco et al. 2012).
- Fencing must be buried at least 10 cm into the ground to prevent salamanders from burrowing beneath it, and the height should be at least 30 cm (Table 3).
- Fencing should have an overhanging lip to prevent salamanders from climbing over (Figure 6).

Rationale

Northwestern Salamanders will swim through tunnels with slow-moving water (B. Beasley, unpubl. data).

Both closed-top (Patrick et al. 2010, Beasley 2013, Bain 2014) and open-top (Jackson and Tyning 1989, Allaback and Laabs 2002, Pagnucco et al. 2012) crossing structures have been used by *Ambystoma* spp. (mole salamanders).

Box culverts with local, damp soil conditions are recommended for amphibians (see Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013).

In general, tunnels for amphibians are recommended to be at least 1 m x 1 m in size (Schmidt and Zumbach 2008). Some salamanders may pass through smaller tunnels (e.g., Long-toed and Barred Tiger Salamanders moved through open-top tunnels manufactured by ACO Systems Ltd. that had interior dimensions of 0.50 m x 0.33 m (Pagnucco et al. 2011), and *Ambystoma* sp. salamanders have crossed through round tunnels as small as 0.25 m in diameter and 0.2 m wide (Bain 2014)); however, salamanders demonstrate hesitancy to enter small tunnels (Jackson 1996) and the percentage of salamanders that successfully cross through may be low (e.g., Allaback and Laabs 2002, Pagnucco et al. 2012). Larger tunnels are required to ensure sufficient space for natural substrate and cover

objects.

Salamanders will cross through tunnels with or without natural substrate, but Woltz et al. (2008) found that fewer individuals cross through bare concrete tunnels than tunnels with natural substrate. Furthermore, natural soil substrate will retain moisture longer, lessening the risk of salamanders dehydrating or not entering structures.

Photo x. Salamander in culvert.	Photo x. Salamander climbing fence.

SPECIFICATIONS FOR FROGS AND TOADS

Type of structure and minimum size based on tunnel length

Tunnel Length	Box Tunnel (w x h)	Arch Tunnel (w x h)	Round Tunnel (diameter)	Other Structure Recommended
15 m	1.8 m x 0.5 m	1.5 m x 0.75 m	0.6 m	
15-25 m	2.0 m x 0.5 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Frogs and toads prefer tunnels with high moisture content and even small pools of standing water, but the tunnel should not be flooded with water.
- Open- or closed-top tunnels may be used. Open-top tunnels will allow moisture and air flow in the tunnel, especially along long tunnels.
- Open-top tunnels may result in higher levels of road salt and other pollutants in the tunnel. However, these may be washed away with storm events.
- Soils and leaf litter substrates should be used as opposed to larger gravel or stone substrates.
- Fencing should be at least 50 cm high to prevent ranid frogs from jumping over it, and buried 10-20 cm below ground to prevent frogs and toads from burrowing underneath (Table 3).
- Fencing should not be made of ¼" plastic mesh because ranid frogs and toads will attempt to climb it rather than follow it to tunnel entranceways (B. Beasley, unpubl. data, P. Govindarajulu, pers. comm.).
- Fencing should have an overhanging lip to prevent frogs and toads from climbing over it (Figure 6).

Rationale

Frogs and toads have used a wide variety of crossing structures under roads (reviewed in Schmidt and Zumbach 2008, Puky et al. 2013).

Wide crossing surfaces with local, moist soil are recommended for amphibians (e.g., Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013).

Northern Red-legged Frogs were reluctant to enter tunnels with dry soil (Malt 2011) but readily enter tunnels with moist substrates (Beasley 2013).

Although toads have been documented using tunnels < 1.0 m wide (e.g., Lesbarrères et al. 2004, Pagnucco et al. 2012, Ottburg and van der Grift 2013, Puky et al. 2013, Wind 2014), larger tunnels tend to be more effective (e.g., Puky et al. 2013) and are easier to maintain. Very high toad crossing rates have been documented at tunnels 1.8 m wide (Biolinx Environmental Research & Nicola Naturalist Society 2013, 2014). Newly metamorphosed toadlets, which disperse en masse, move more readily through tunnels—even narrower ones—compared to adult toads (E. Wind, unpubl. data).

Guidelines for road crossing structures in England have been developed for the Common Toad (*Bufo bufo*). These guidelines recommend a rectangular crossing structure at least 1.0 m x 0.75 m (w x h) for tunnels up to 20 m long and 1.5 m x 1.0 m (w x h) for longer tunnels (Amphibian and Reptile Conservation 2009).

Both closed-top (Biolinx 2013, Puky et al. 2013, Wind 2014) and open-top (Pagnucco et al. 2012, Ottburg and van der Grift 2013) crossing structures have been used successfully by other toad species.

Photo x. Frog in culvert.	Photo x. Frog climbing fence.

4.3 Additional Planning and Design Mitigation Measures

Supplementary mitigation measures, such as installing signage or instituting reduced speed zones at fence ends, may be used with crossing structures and fencing to increase their effectiveness. In addition, supplementary measures may be used as temporary measures during construction, prior to road upgrade and rehabilitation projects, or on existing roads where there would otherwise be no mitigation. The effectiveness of some of these strategies at reducing road mortality and improving connectivity is difficult to measure and largely unknown. Therefore, implementation of these measures should proceed with caution using monitoring and an adaptive management approach.

This section classifies measures as either those that influence driver behaviour or those that influence wildlife movement, as defined by Huijser et al. (2007). The following list of measures is not exhaustive, but instead summarizes what has been used elsewhere, with specific consideration of how each strategy may be applied to amphibians and reptiles.

4.3.1 Influencing Driver Behaviour

Temporary road closures are an effective mitigation tool where there is local support. Other strategies that may influence driver behaviour are presented below. These techniques are attractive because they are often relatively inexpensive to implement. However, they rarely result in a significant reduction in road mortality. This is in part because many reptiles and amphibians are small and difficult to see or avoid. The success of these strategies is further limited by driver attitudes and behaviour; for example, Ashley et al. (2007) found that approximately 2.7% of drivers intentionally ran over reptiles.

The strategies outlined in this section have relatively low effectiveness when used in isolation, so several approaches should be used concurrently whenever possible. For example, a good strategy may include a reduced speed limit, traffic calming measures to reinforce the low speed limit, high quality signage to warn drivers, and a public education program to help drivers understand the measures that have been put in place.

Seasonal road closures offer an effective mechanism for reducing road mortality by eliminating vehicles from a road. Although this is a very effective solution, such closures are typically only feasible for a few days or weeks per year and they must be timed precisely to coincide with amphibian and reptile migrations. This method is particularly applicable at problem areas while more permanent measures are still under consideration or awaiting approval (see Case Study # 1 below). This method is most easily implemented in protected areas, on low volume roads where access to residences or businesses is minimal, or on roads where alternate access (i.e., a detour) exists. This type of strategy requires buy-in from both the road authority and the community using the roads. A public relations campaign is a useful tool to inform and gather support from local residents. This strategy has a relatively low cost.

CASE STUDY #1 – Road closure for the endangered Northern Leopard Frog

The Rocky Mountain population of Northern Leopard Frog (*Lithobates pipiens*) that occurs in BC and is considered endangered and is genetically distinct from leopard frog populations found elsewhere in Canada. Only one natural population of this species remains in BC, in the Creston Valley Wildlife Management Area (CVWMA). Monitoring since 2009 has shown that frogs are killed along the Duck Lake Dyke Road in the CVWMA during seasonal migrations. In fall of 2016 and 2017, a seasonal, voluntary road closure was put in place and patterns of vehicle use and frog migration and mortality were monitored nightly. Signage was used for the duration of the voluntary closures, and educational outreach (social media posts, newspaper articles, radio interviews, and an open house/information session) was provided. Researchers found that the voluntary road closure was ineffective because vehicles continued to use the road and frog mortality was observed both years. In October 2017, the species' Recovery Team submitted a regulation change proposal under the *Wildlife Act* to enact a legal seasonal closure to motorized vehicles, which was approved in 2018. The motorized vehicle closure is in now in effect annually during the spring (March 15 – April 30) and fall (August 15 – October 15) migrations.

INSERT PHOTOS – from Lindsay Anderson and Kat McGlynn

Reduced speed zones allow drivers more time to react to an animal on the road, making them more likely to safely avoid a collision. They have been implemented in Banff National Park to reduce collisions with larger wildlife, such as Grizzly bears (Banff National Park, unpublished data 2011-2014). This methodology is best suited for amphibians and reptiles on low-traffic volume roads or roads in protected areas and where more visible species, such as larger snakes and turtles, are the issue. Speed limits may be reduced seasonally and/or at specified times of day. A reduced speed zone is typically combined with a public awareness strategy and signage to educate motorists about the need to minimize road mortality for amphibians and reptiles. Enforcement or traffic calming mechanisms (see below) are usually necessary for the effective implementation of lower speed limits. This strategy can have a high cost due to the need for regular enforcement.

Traffic calming refers to the installation of road features designed to decrease vehicle speeds without interfering with the flow of traffic. As with reduced speed zones, this methodology is best suited for amphibians and reptiles on low-traffic volume roads and where more visible species are the concern. Some traffic-calming methods, such as speed bumps (Photo X), traffic circles, and raised medians, can only be implemented on low-speed roads. Other methods, such as narrow lane widths and rumble strip patches, may be used on moderate- or high-speed roads. In some cases, speed bumps may interfere with snow removal. However, installations can be used seasonally. This strategy has low to moderate costs depending on the measure used.

Photo X. The use of speed bumps as a traffic calming measure where amphibians and reptiles occur on roadways.

Signage is a low-cost, widespread method of roadside messaging that is relatively easy to implement but has low effectiveness (Photo x). The key objective for signs is to instill awareness so motorists can avoid hitting wildlife. Effectiveness may be improved with a well thought out strategy that discourages driver habituation and includes the following criteria (see Gunson and Schueler 2012, Kintsch et al. 2015):

- local education (e.g., public and school presentations, media articles, etc.);
- seasonal placement of signs with text indicating when target animals are likely crossing;
- enhancement of signs with flags, flashing lights, or unique art work (Pojar et al. 1975, Hardy et al. 2006);
- use of science and data to inform effective placement;
- limiting the use of signs to roads with moderate–high traffic volume to deter sign theft;
- strategic placement of signs, such as the ends of exclusion fencing; and
- use of signs as temporary measures and markers in advance of more permanent mitigation measures (Ontario Ministry of Transportation 2012).

As with all measures in this section, the effectiveness of signage can also be increased by combining it with other measures (e.g., reduced speeds, traffic calming). Benefits of signage for amphibians and reptiles include driver awareness of wildlife on the road and, when used with a public awareness and education campaign, greater understanding of the importance of conservation efforts (see example in Joyce and Mahoney 2001). In Ontario, signage has commonly been used on municipal and provincial park roads, and more recently on provincial roads (Ontario Ministry of Transportation 2012.

Photo x. Example of signage used to make drivers aware of amphibians and reptiles on roadways.

Public awareness and education campaigns are designed to inform drivers about wildlife and roads issues and how they can help minimize or avoid wildlife collisions. For amphibians and reptiles, public awareness campaigns typically target local communities near known high-risk road mortality locations (see Case Study #2 below).

While it is difficult to draw a direct correlation between heightened driver awareness and a decrease in road mortality, this strategy has the potential to improve effectiveness and public acceptance of other mitigation efforts, such as signage, reduced speed zones, or traffic calming measures. The cost of conducting a locally-based public awareness campaign is comparable to that of the other strategies discussed. However, a regional, coordinated, long-term strategy (i.e., similar to the well-known Drinking and Driving Campaign) would entail greater funding and a long-term commitment.

CASE STUDY #2 – Annual Toadfest generates awareness of road mortality

Toadfest is a free, family event held at Summit Lake Provincial Park each year. It is organized by the Fish & Wildlife Compensation Program (FWCP) to raise awareness about Western Toads (*Anaxyrus boreas*) and road mortality. An annual media release lets locals know when the event will take place based on the development rate and movement patterns of the toad tadpoles in Summit Lake. Participants learn about the toad's natural history, life cycle, and habitat needs. Toadlets migrate from Summit Lake to upland habitat in the summer, encountering roads along the way. Toadfest participants help carry toadlets across the road (see table below). The event draws hundreds of visitors each year and is used as a model for other eco-fests. It has also prompted the addition of a second toad crossing tunnel in the area. Toadfest is supported by the Fish and Wildlife Compensation Program, B.C. Parks, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, the Columbia Basin Trust, and the Ministry of Transportation and Infrastructure.

Summary of Toadfest results, 2010-2014 (taken from Dulisse 2015).

	2011	2012	2013	2014	2015
Estimated number of volunteer participants	400	500	500	400-500	300
Estimated total number of toadlets moved	5000*	14,753	13,253	6,853	391

* The number of toadlets moved each year does not reflect population numbers, but rather the relative number of toadlets that were moving at the time of the educational event, the date of which was scheduled early in the season. In some years, the event was held earlier or later than the peak in toadlet migration.

INSERT PHOTOS – asked Irene Manley

4.3.2 Influencing Wildlife Movement

Ramped curbs and escape gaps are used along roads (typically local, municipal roads) to replace vertical curbs that are too high for amphibians and reptiles to climb over. A good example is in Waterton Lakes National Park, where right-angle curbs were replaced with sloped curbs to allow Long-toed Salamanders to successfully escape the road (Photo x). Additionally, escape gaps can be used where the structures meet the road. Escape gaps work well along high-volume roads where continuous sections of precast concrete barriers divide opposing lanes of traffic and animals that enter the right-of-way cannot cross the road. For example, an unexpected mass migration of Western Toad metamorphs emerged onto Highway 19 on Vancouver Island in the summer of 2007 (Fyfe and Wind 2008). In addition to a bucket brigade salvage operation (see Assisted migration below), sections of precast concrete barriers were replaced with those with scuppers (i.e., gaps underneath) to allow toadlets that got onto the highway to get off the road (Photo X). This strategy has a relatively low cost.

Photo x. Right angle curbs used for Long-toed Salamanders in Waterton Lakes National Park, Alberta.

Photo x. Scuppers under precast concrete barriers for toadlets.

Assisted migration can be used where a concentrated amphibian migration crosses a defined stretch of road. Temporary traps (typically drift fencing and buckets) may be used to prevent animals from crossing the road. The captured animals are then collected and moved across the road by volunteers. Alternatively, volunteers can survey the road during peak times and move any animals that are encountered. This strategy requires a handling permit from the provincial government, is labour-intensive, relies on having local volunteers to monitor traps during a migration event, requires safety precautions for the volunteers, and poses some risks to the amphibians (e.g., disease transmission, stress, etc.). However, if timed and coordinated effectively, facilitated migrations can be an effective, temporary measure to help reduce road mortality for amphibians (Photo x; see Case Study #2 of how this technique can also be used for educational purposes).

Photo x. A volunteer assists amphibians across the road.

Habitat creation can be used to reduce the need for individuals to access habitat close to the road or cross the road to access habitat on the other side. Since reptiles and amphibians often show high fidelity to specific habitats and many individuals will continue using historical habitat features, a population-level transition to the new habitat can take decades. Consequently, roadside barrier fencing is still necessary alongside habitat creation to prevent dispersing animals from accessing the road. The costs, feasibility, and effectiveness of creating new habitat are variable and will be site- and species-specific (B.C. MFLNRO 2004).

New habitat creation may include wetlands as breeding sites for amphibians (e.g., Merrow 2007), artificial nesting sites for turtles (see Case Study #3 below; Clarke and Gruenig 2002, Paterson et al. 2013), or gestation/basking sites (Rouse 2005, Parent and Black 2006) and hibernacula (Willson 2005) for snakes. General recommendations for habitat creation, based on the Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014), are as follows:

- A thorough understanding of the habitat use and movements of the target species is necessary.
- New habitat should be in close proximity to, and on the same side of the road as, other habitat used by the target species.
- The created habitat should be suitable for the target populations.
- Other important habitats should not be manipulated, degraded, or destroyed to create new habitat, e.g., check whether other wildlife depend on the area to be altered.
- Ongoing monitoring and maintenance is required for artificial turtle nesting habitat to avoid high turtle egg/hatchling mortality from invasive plants and predators (wild and domestic), and for suitable hydroperiod at artificial aquatic breeding habitat for amphibians to avoid stranding and mass egg/larval mortality.

CASE STUDY #3 – Creating nesting habitat for the endangered Western Painted Turtle

On the Sunshine Coast, human development has reduced available nesting habitat for Western Painted Turtles. Each year, female turtles are killed on roads as they search for suitable nesting habitat or attempt to nest on road shoulders. Because the life history of this species relies on high adult survival and longevity, the loss of each reproductive female from the population can be devastating. To mitigate this threat, the Sunshine Coast Wildlife Project has built turtle nesting beaches at six sites where turtle road mortality was a concern. In general, this approach has been extremely effective, but results vary from population to population. At North Lake, Lily Lake, and Ruby Lake Lagoon, turtles immediately used the beaches, road mortality declined dramatically, hatchling success rate was high, and population monitoring through time showed an increase in juvenile age classes. At Sakinaw Lake, Trout Lake, and Garden Bay Lake, it took several years before turtles started using the new beaches.

INSERT PHOTOS – asked Michelle Evelyn

5.0 GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES

This section provides general considerations for mitigation during road construction work in areas with amphibians and reptiles. The following considerations address two components: 1) timing construction activities to avoid construction-related impacts, and 2) installing mitigation measures to minimize interactions with amphibians and reptiles and their habitats during construction.

Consultation with local species experts is strongly recommended because activity times for the target species vary annually with changing climatic conditions and can be site- and region-specific.

5.1 Timing of Construction Activities

When road construction occurs within or near amphibian and reptile habitat, some impacts can be minimized by carefully scheduling the timing of the work to avoid impacts to habitats when they are occupied or impacts to animals during sensitive periods. Construction during the overwintering period should avoid wetlands, underground burrows, large downed wood, potential snake hibernacula and other sites that are used for hibernation. This includes direct disturbance as well as indirect disturbance, such as decreasing water levels in overwintering wetlands and noise and vibration disturbance near potential hibernacula. Construction during the active season should avoid key habitat features or times when the species is most sensitive (see Appendix C and Table 1). The timing and duration of seasonal activities of amphibians and reptiles vary across the province. For example, amphibian and reptile populations are active from February to November along south-coastal BC, with the duration of activity decreasing as one moves northward. Also, the onset and end of the surface activity period can vary by almost two months depending on the weather. For example, the majority of Western Toads tracked on Vancouver Island using radio telemetry went into hibernation in November during each year of the three-year study but hibernation emergence timing varied from year to year, occurring in February in 2015, January in 2016, and March in 2017 (Wind 2018). Consultation with local QP species experts, provincial Ministry of Environment and Climate Change biologists, and the regional Ministry of Forests, Land, Natural Resource Operations and Rural Development office may provide information on annual variations in site-specific movements of the target species during construction activities.

5.2 Mitigation Measures for Construction Activities

Temporary mitigation measures can be implemented on-site at all road projects that occur within or adjacent to amphibian and reptile habitat to help avoid harming or killing individuals. The following are guidelines for temporary measures:

1) Consult Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014). This document discusses measures such as maintaining hydrological features; preventing the introduction of non-native species; reducing pollution in aquatic breeding habitats, such as erosion and sediment control plans and having an emergency response plan in place to contain and clean up oil and fuel spills safely and quickly; communicating measures with construction workers; avoiding compaction and/or disturbance of loose soils, the litter layer, coarse woody debris, and sensitive habitats, such as rocky slopes; and considerations for habitat enhancement and restoration (e.g., taking advantage of heavy equipment already onsite, as well as any surplus woody debris, rocks, gravel and soil, thus saving time and money compared to doing the work post-construction).
2) **Develop an amphibian and reptile salvage and relocation plan**. Assess and plan for the probability that amphibians and reptiles may be encountered during construction. Any animals within the construction area will need to be moved in order to avoid their injury or death and infractions under the *Wildlife Act*. Develop a salvage plan following the protocols outlined in the Best Management Practices for Amphibian and Reptile Salvages in British Columbia.

   Salvage and translocation should only be used when other measures fail; they should never be used as a primary mitigation measure.
3) **Submit an application to the province to obtain a wildlife handling permit at least six weeks (longer if possible) prior to the onset of construction work**.
   - Applicants must submit a General Permit Application, detailed project proposal, and complete BC Animal Care Form to Front Counter British Columbia via mail, in person, or online at http://www.frontcounterbc.gov.bc.ca/Start/fish-wildlife/.
   - Should an emergency salvage become necessary during construction because amphibians and reptiles are unexpectedly found on the project site, all construction that impacts the animals needs to be halted immediately and the regional Ministry of Forests, Lands, Natural Resource Operations and Rural Development office should be contacted for further direction. It is illegal, under the *Wildlife Act*, to knowingly harm or kill amphibians, reptiles, or other wildlife.
   - When amphibians and reptiles are found on a construction site, proper handling procedures should be followed. One of the permit requirements for salvage of amphibians is that all staff follow the Interim Hygiene Protocols for Amphibian Field Staff and Researchers (B.C. MOE 2008) to reduce risk of disease transmission between sites and among animals within a site.
4) **Consult with a QP**. A qualified species expert should be consulted to provide guidance around salvage needs and the permit application. The QP needs to be present or available at all times prior to and during construction to provide guidance around fencing design and installation, if needed (see below), to conduct searches, handle encounters, and to relocate animals.
   - Searches should be conducted daily prior to and during construction activities if work occurs in high-quality or designated amphibian habitat or during the activity period of the target species.

5) **Exclusion fencing**. Where needed, install exclusion fencing between the road construction zone and amphibian and reptile habitats.
    - Use fencing that will last the duration of the road construction project (e.g., a light duty geotextile fence for projects completed within one year or a heavy-duty geotextile fence for longer projects (see section 5.2, Province of British Columbia 2014)). If permanent fencing is going to be installed as part of the mitigation plan (i.e., along roads), the permanent fence can be installed instead of temporary construction fence to avoid extra costs (Photo 63).
    - Fencing should be inspected daily for animals trying to cross the landscape, especially during migratory periods, and for gaps or damage. Animals should be carried across and released on the opposite side of road if it is a known migratory route. Fences should be repaired daily to maintain effectiveness and avoid potential breaches.
    - Fencing should be installed so that construction sediment does not enter into wetlands or aquatic systems.
    - When possible, alternative measures (e.g., rock barriers) should be integrated to create a sufficient barrier between construction sites and adjacent amphibian and reptile habitat.
6) **Control blast size and vibrations** within or adjacent (up to 250 m) to snake habitat using blast mats and other approved measures (Ontario MNR 2011).
7) **Reporting**. Project-specific reporting and handling protocols should be developed in compliance with the requirements of the salvage permit. Observation records should include the observer's name, date and time, species, location (descriptive and georeferenced), photographs, and action(s) taken. Conditions of the Wildlife Act permit require that data and associated reports be submitted to the Wildlife Data & Information site.

6.0 GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES

Road maintenance activities are undertaken to maintain user safety or for engineering and infrastructure concerns. However, as described in Section 2.7, these activities can have ongoing impacts on nearby amphibian and reptile populations and habitat. This section provides information to develop guidance that can be provided to road maintenance contractors for safeguarding amphibians and reptiles and their habitats.

6.1 Assessing and Prioritizing Application of Mitigation Guidelines During Road Maintenance Activities

As with new road construction and expansion projects, road maintenance activities should be preceded by a screening exercise to assess maintenance activities that pose a risk to amphibians and reptiles (Section 2 of this document). The steps outlined in Section 3 (Screening Tool) may be applied to road maintenance activities to create a map of potentially vulnerable habitats (such as wetlands and ditches) and conservation areas (such as identified critical habitat). The maintenance activities should also be assessed for high risk activities (such as removal of a beaver dam that may dramatically change hydrology) and vulnerable time periods (such as during the breeding or migration season (Table 1)). This information can be provided to road maintenance contractors to apply the additional guidelines described below when implementing road maintenance activities.

6.2 Road Surface Maintenance Guidelines

Dust control and stabilization is used to minimize the impact of dust for road users, adjacent properties, and watercourses adjacent to dirt or gravel roads/highways and is usually applied early in the calendar year. De-icers, aggregate, and salt/brine are applied on roads to proactively monitor, anticipate, manage and minimize the development of slippery conditions and restore traction.

Guidelines for amphibians and reptiles:

- Consider alternative, non-chloride/"green" forms of dust control and de-icing agents, especially near sensitive habitats (e.g., adjacent to aquatic breeding sites and streams; see text box below).
- Minimize run-off of dust control agents into adjacent habitats, especially wetlands. Techniques might include pre-wetting surfaces to ensure proper adhesion, not applying dust control agents before, during or immediately after rain, and minimizing spraying on the shoulder.
- Install silt fencing adjacent to wetlands to prevent treated dust and sediment from washing into the wetlands.
- Store hazardous materials, such as de-icing compounds, on impermeable surfaces to prevent their release into soils and groundwater.
- Where possible, avoid depositing large snow and ice accumulations removed from roads into or immediately adjacent to roadside ponds, wetlands, and ditch habitats (where amphibians may breed).
- Reduce sediment runoff from aggregate storage piles to nearby watercourses (e.g., cover storage piles of materials containing de-icing compounds (road salt)).
- Consult the salt management plans outlined in Transportation Association of Canada's Syntheses of Best Practices - Road Salt Management (2013).

6.2 Drainage Maintenance Guidelines

The objective with ditch maintenance is to provide unobstructed drainage for roads.

Guidelines to mitigate potential impacts of drainage maintenance on amphibians and reptiles:

- Ditches in areas of known areas of concern, including critical habitat, should be surveyed for the presence of amphibians (all life stages) and reptiles before drainage maintenance activities are initiated.
- Culverts should be surveyed for the presence of amphibians (e.g., eggs and/or larvae in standing water) and reptiles prior to culvert maintenance activities.
- Ditches containing amphibians or reptiles need to be salvaged prior to the onset of maintenance work, especially where water drainage and/or culvert replacement is occurring. The salvage plan should include monitoring spoil piles for emerging amphibians and reptiles, and a protocol for relocating individuals exposed during excavation (e.g., reptile eggs and/or adults that were underground). An amphibian and reptile QP should assess the likelihood of amphibians and/or reptiles living in the soils within the ditches that require excavating and develop an environmental work window and salvage program, if necessary.
- Refer to the Government of B.C.'s *Best Practices for Drainage Maintenance Works in Oregon Spotted Frog Habitat* for details on BMPs for ditches containing water and aquatic-breeding amphibians.

- Prevent the collection of standing water in ditches, which act as "sink" habitats, by facilitating drainage (sink habitats are aquatic sites that attract amphibians for breeding but dry prematurely, resulting in high egg or larval mortality).
- Where maintenance activities occur within or adjacent to known, important amphibian or reptile habitats (e.g., snake egg-laying and gestating site, snake den, aquatic amphibian breeding site), remove spoil materials to predetermined dumping sites instead of spreading them on site where they may degrade important amphibian and reptile habitats.
- Avoid rip-rap materials where they might impede normal amphibian and reptile movements or impact habitats used by amphibians and reptiles seasonally as part of their life-cycle. Instead, re-seed affected areas with fast-growing, native vegetation to reinforce and maintain shoreline bank stability and provide habitat and cover for amphibians and reptiles.
- If maintenance activities require in-stream work, schedule activities during environmental timing windows (see definition and website links in the Glossary and Resources sections; Sections 5 & 6, respectively). Consult with a QP, as site, species and season specific plans may be required.
- Consult the BC Ministry of Environment's Beaver Dam Removal best management practices document.

6.3 Roadside Vegetation and Wildlife Fence Maintenance Guidelines

Roadside maintenance can include vegetation control and the maintenance of fences that prevent wildlife from entering the road surface. These activities are undertaken to increase visibility for drivers and to prevent mortality of wildlife on roads. Fences are often used to lead amphibians and reptiles to safe crossing structures and in most cases these fences require ongoing maintenance.

The following recommendations can be used to mitigate potential impacts of vegetation, fence and roadside maintenance on amphibians and reptiles:

- Do not mow in sites that have been chemically treated with herbicides within 14 days of treatment. These areas are marked with white treatment signs.
- Specialty wildlife fences along highways, such as the elk fencing along Highway 19 near Courtenay on Vancouver Island, have ¼" galvanized hardware cloth attached to the bottom to direct amphibians (Western Toads) and other smaller wildlife towards wildlife underpasses. The location of these specialty fences needs to be clearly identified for maintenance workers, and guidelines on specific maintenance requirements should be provided.
- Contractors need to be trained in vegetation maintenance along fences to avoid damaging the fence with mowing and trimming equipment (see Photo. X).
- Specialty fences leading amphibians and reptiles towards wildlife underpasses require annual maintenance by trained staff to repair holes and gaps (e.g., from removal of snow and debris off roads, tunnels created by mammals), and to clear away vegetation that can enable animals to climb over the fence (see Section 4.3.4.3). Vegetation within 0.25 m of an amphibian/reptile fence needs to be cut at least annually, timed in advance of seasonal movements of animals.
- Consult with a QP to design a vegetation management plan for use where specialty wildlife fences are installed.
- Research on wildlife fencing materials is rapidly evolving as many materials are tested and modified. At this time, an adaptive management approach is needed regarding allowable material use.

- Limit the use of herbicides for vegetation management where possible—especially in and around aquatic habitats and during the egg and larval development period for amphibians (see Table 1).

In addition to the above guidelines specific to amphibians and reptiles, some road authorities have developed documents that provide general environmental considerations and safety specifications, such as B.C. Ministry of Transport's Environmental Best Practices for Highway Maintenance Activities (2018).

7.0 MONITORING

BC is in the early stages of developing ways to mitigate the impacts of roads on amphibians and reptiles. There is uncertainty about how well best management practices developed in other areas will work for BC's unique set of species and physical landscapes. Adaptive management, or "learning by doing," uses monitoring to reduce uncertainty. **Monitoring is a systematic and long-term process** that gathers information about an implemented project and evaluates whether it has reached its goals and delivered what was expected. Monitoring is essential for improving our knowledge base and ensuring that we are using the most effective techniques.

There are various phases of road projects, including construction, retrofitting, and maintenance activities, that require different types of monitoring:

- **Compliance monitoring** – Did the contractor do as required as laid out in the service contract and the BMPs/guidelines?
- **Maintenance monitoring** – Are the mitigation features (e.g., tunnels and fencing) being maintained so that they function as intended?
- **Effectiveness monitoring** – Are the mitigation features working effectively, keeping amphibians and reptiles off roads and/or allowing animals to pass safely, and are they helping to maintain viable populations of amphibians and reptiles at the site?

Currently, only compliance monitoring may be required as part of a development permit condition, whereas post-construction maintenance and effectiveness monitoring are not often stipulated under permits or regulation. Further, ongoing routine monitoring and maintenance of mitigation structures are not usually factored into annual budgets or contractor or staff scheduling. In a few cases, effectiveness assessments have been conducted when there is collaboration between the road construction proponents and either university or independent researchers. These research projects contribute to improving effectiveness of mitigation measures and also contribute to making implementation more cost-effective. To effectively mitigate the impacts of road management activities on amphibians and reptiles, all three monitoring programs need to be adopted by the road construction and management authorities.

7.1 Compliance Monitoring

Compliance monitoring focuses on **quality assurance and adherence to the mitigation specifications** for each project. For example, routine quality checks are needed during the installation of directive and exclusion fencing to avoid small gaps or folds, which render the fences ineffective.

7.2 Maintenance Monitoring

Maintenance monitoring should be done at critical times throughout the year. Fences should be monitored at the end of the winter/storm season, prior to the active season for amphibians and reptiles (see Table 1): winter weather and snow removal can damage fencing; flooding can erode soil at the base

of fences, especially where they attach to crossing structures, and can also carry cover objects (e.g., logs) out of passageways. Over the spring and early summer, vegetative growth creates "ramps" that allow amphibians and reptiles to climb over fences. Fences should be inspected during the summer to ensure that this overgrown vegetation is cleared away before the late summer and fall migration season. Because vegetation removal techniques can sometimes damage fencing, after roadside work any fences in the area should be inspected for gaps and fixed.

A monitoring checklist should be followed to efficiently reveal when key design features become degraded and need repair. These data can be easily recorded and maintained digitally via a tablet or smart phone:

Example checklist for routine maintenance monitoring of crossing structures with fencing:

Date checked	Maintenance Issue	Y/N	Location (coordinate; UTM or Lat./Long.)	Description of repairs needed, and other comments	Photo #	Date Fixed
	Fence collapse (partial or complete)					
	Holes or gaps through/under fence					
	Bottom of fence still buried					
	Vegetation growing along fence					
	Fence abuts crossing structure					
	Cover objects remain in crossing structure					
	Opening blocked by vegetation or debris					
	Carcasses along fence					
	Carcasses along roadway					

7.3 Effectiveness Monitoring

Effectiveness monitoring focuses on answering the question: how well do the mitigation measures and/or structures reduce the impacts of the road on amphibians and reptiles? Where fences and crossing structures have been constructed, effectiveness monitoring should include, at minimum, data on whether these structures are keeping amphibians and reptiles off roadways and providing safe passage for habitat connectivity. More intensive effectiveness monitoring involves assessing whether the target populations of amphibians and reptiles that were impacted by the road remain stable after mitigation measures are implemented.

A recent review of 50 studies that quantified the relationship between road mortality and mitigation measures designed to reduce road mortality showed that there are insufficient data to answer many of the most pressing questions that road planners ask (Rytwinski et al. 2016). There were two main reasons. First, there was not enough variation in the attributes of the applied mitigation to test for effectiveness, e.g., fence heights were too similar across studies to see an effect on road mortality. Second, key information was unreported, e.g., length of crossing structures and distance between crossing structures was not reported in over 65% of the studies. This highlights the importance of developing a rigorous effectiveness monitoring plan with better research and data reporting for mitigation projects.

7.3.1 Developing an Effectiveness Monitoring Plan & Study Design

An effectiveness monitoring plan includes clear goals, objectives, and questions, and involves a team of experts and collaborators during the early stages of the project to develop a statistically well supported monitoring plan to quantify effectiveness (Rytwinski et al. 2015; Fig. 10). Effectiveness monitoring requires a plan for collecting data in a way that will allow for a comparison of conditions (1) before and after mitigation and (2) along sections of road with and without mitigation. This is referred to as a **Before-After-Control-Impact (BACI)** study design, which is the most reliable way to detect a change in the variable(s) of interest (i.e., rate of road mortality, movements through crossing structures, population size; see Case Study #4 below).

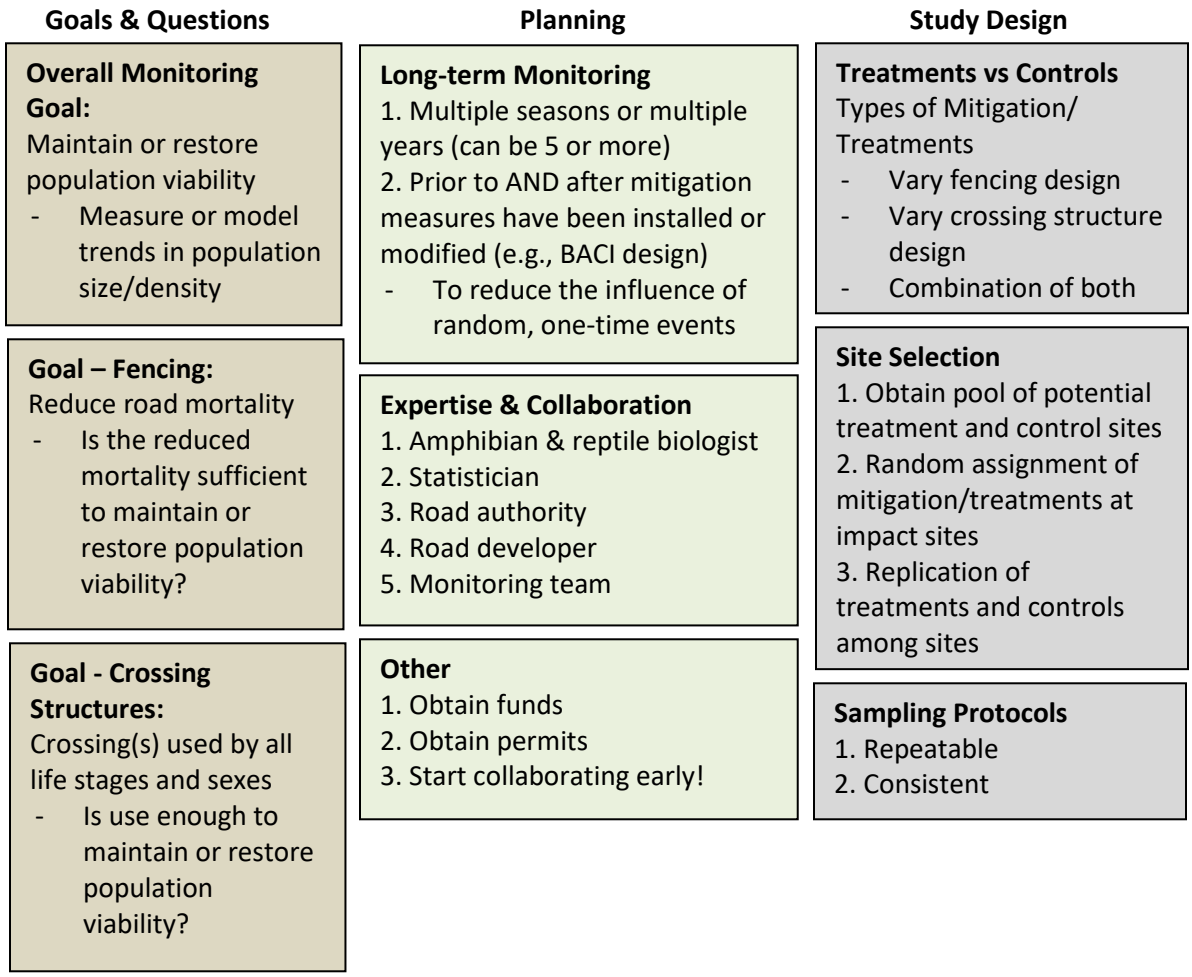


Figure 10. Overview and key elements for planning a rigorous study design that will assess the effectiveness of road mitigation for amphibians and reptiles.

Several seasons of monitoring data from both before and after a road mitigation project are recommended to measure changes. A minimum of four years or four sites in a BACI study design has been recommended by Rytwinski et al. (2016), although the appropriate time frame and number of sites

to monitor should be determined by consulting with experts, including a statistician and a biologist with knowledge of the species' movement patterns at the site(s) of interest. Building a collaborative partnership that includes the road developer, road authority, monitoring group, and experts should be done early. This team needs to work together to obtain funding and permits to carry out multi-season sampling and, ultimately, integrate the results of monitoring into improving mitigation in the future.

Case Stud Study #4 – Before-After-Control-Impact Study on Effectiveness of Fencing Material

The Association of Wetland Stewards for Clayoquot and Barkley Sounds wanted to install barrier fences to reduce amphibian road mortality at a known hotspot along Highway 4 near Ucluelet, B.C. They created a fence using plastic materials (UV-treated HDPE "puckboard") that had the top edge bent to create a rigid overhanging lip (6 cm across and 4 cm down). The purpose of the lip was to make it difficult for amphibians, especially Pacific Treefrogs (*Pseudacris regilla*) to climb over the fence onto the highway. Before installing the fence, they set up a simple BACI study to test the effectiveness of the new fence design in reducing road mortality. They surveyed for dead amphibians on the surface of the road in the morning after rainy nights in the autumn of 2012 (N=11 surveys before installation) and 2013 (N=16 surveys after installation). They compared the amount of road mortality before and after the fence was installed at both fenced (150 m) and unfenced sections (200 m) of the highway. The number of amphibians killed in the fenced section was reduced to 19% of what was found before the installation. Mortality in unfenced areas changed by less than 1%. Mapping of carcasses before and after the fence installation showed that there was no major increase in the numbers killed at each end of the fencing. Thus, the BACI comparison revealed that the new fencing was 80% effective at reducing amphibian road mortality.

Insert images - Barb

7.3.2 Sampling Protocols and Techniques for Effectiveness Monitoring

A variety of sampling protocols and techniques can be used to monitor the effectiveness of mitigation structures, which will depend on the questions being asked:

- *Road Surveys* – Counting the number of dead and alive amphibians and reptiles on the road surface to assess **reductions in road mortality**
- *Fence and Crossing Structure Surveys* – Following the movements of individuals to see if they travel along guiding fences and through crossing structures to **assess habitat connectivity**
- *Population Surveys* – Repeatedly counting the number of individuals in a population over the long term to **assess population viability**

It is very important that protocols and techniques are repeatable and consistent over time and across sites (Fig. 10). Less time, effort and technical skill are generally required for protocols that sample road mortality than protocols that sample habitat connectivity or population viability (Fig. 11). For example, measuring population viability requires a much greater time investment—at least 5 years before and 5 years after mitigation.

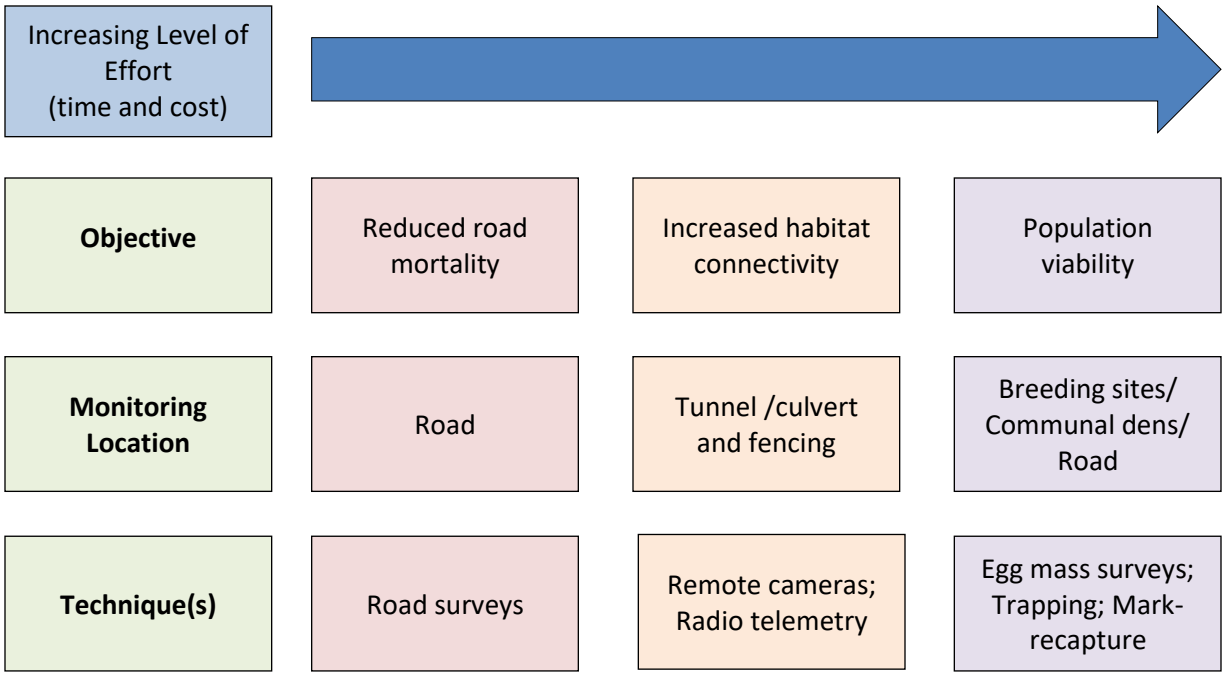


Figure 11. Relative level of effort required to collect data to meet different monitoring objectives, including where the monitoring takes place and example sampling techniques used for each.

7.3.2.1 Road Surveys

Methodical road surveys have been shown to more accurately quantify road mortality rates compared to opportunistic/incidental monitoring of roadkill (Winton 2018). Road surveys gather baseline data on the number and location of amphibians and reptiles crossing and getting killed on the road. Data gathered before mitigation help inform where to position mitigation structures and provide comparisons for after mitigation to see if mortality has been reduced.

Data are collected by driving, cycling, or walking along a selected length of road while looking for alive or dead individuals. Driving surveys allow surveyors to cover a greater distance of road over a sampling period; however, the detectability of small amphibians and reptiles is much lower from vehicles compared with surveying on foot (Langen et al. 2007). Surveys should be conducted with consistent and repeatable methods so that the road can be surveyed the same way before and after mitigation.

Important considerations:

- When a species is common, road surveys may generate adequate data in one or two seasons; however, for rare species, more time may be required.
- Surveys should take place during the active season or movement period for the target species (Table 1).
- Weather conditions, time of day, presence of scavengers, and traffic volumes will all impact detectability of carcasses. Data for these factors need to be recorded, at least during the duration of the road survey. Traffic counters should be installed to count the number of vehicles on an hourly basis daily throughout the active migration season (though traffic counters may not be necessary where road authorities are already collecting and reporting traffic volume data:

http://www.th.gov.bc.ca/trafficData/). Data on the amount of rainfall and temperature throughout the day and night can be obtained from local weather stations.

- For animals that move on rainy nights (e.g., the majority of amphibian species), surveys should be conducted at night, before rain, runoff and morning traffic obliterate carcass remains (Hels and Buchwald 2001, Langen et al. 2007). Bright lights positioned low to the pavement will detect individuals more effectively at night, as will lowering light levels inside the vehicle (i.e., turning headlamps down/off).
- Once mortality occurs and time elapses since mortality, carcasses can disappear or not be detected for a variety of reasons such as predation. Detectability measures (text box) should be obtained by marking and resurveying to assess the number of carcasses that remain or, at minimum, use known detectability multipliers to estimate undetected animals.
    - Amphibians are the most difficult to detect over time because of their small and soft bodies are easily obliterated by traffic, and these mortality surveys are best conducted at night time during the movement period.
    - More than 50% of snake carcasses will disappear in 24 hours, so surveys should be conducted daily during peak movements in spring and fall.
    - Dead turtles persist on roads the longest, so a survey frequency of two to three times per week during nesting season is recommended.
- Note that road surveys may not detect depleted populations (e.g., where road mortality has already depleted the number of individuals adjacent to the road), or species that avoid crossing roads all together.
    - If a population has declined due to road mortality in the past, then the density of amphibians and reptiles killed on the road may be low. Focusing mitigation efforts only on roadkill hotspots may ignore sites with the greatest historical road impact on population size (Eberhardt et al. 2013). Check sites with high traffic where good habitat is near the road, especially where it straddles the road. These may be particularly important locations for mitigation to restore populations.
    - Other survey techniques may be required to detect depleted, rare, or elusive amphibians and reptiles in habitats surrounding roads. Examples of survey techniques include coverboards for snakes, pitfall traps for amphibians, and hoop-net traps for turtles.
    - When information is lacking for rare species, data from a similar but more common species may indicate where road mortality of the rare species occurred.
- Each individual found on the road should be carefully examined and photographed to determine the species, sex, and age class. If possible, the length of the animal should be recorded (e.g., plastron of a turtle, total length of snakes, snout-vent length of frogs and salamanders; Photos x and x).
- Record direction of travel, with the understanding that this information is not always reliable because the individual may have been redirected by traffic.
- Depending on the project, it may also be important to collect a DNA sample or to mark individuals or their locations to avoid double-counting when surveys are repeated.
- Estimates of road mortality rates should account for the factors that might influence the accuracy of the estimate. For example, the equation developed in Winton (2018) for road mortality rate can be applied to surveys of any frequency, as long as survey effort, time between surveys, carcass persistence time/scavenger removal rates, and observer detection probability all are taken into account.

WHY SHOULD WE CONSIDER "DETECTABILITY"?

Numerous factors affect our ability to detect dead amphibians and reptiles on roadways, including observer characteristics (e.g., skill level, mode of travel, fatigue), scavengers, traffic volumes, and variability in carcass deterioration rates. Species that are more vulnerable to scavengers and/or that have carcasses that degrade rapidly may be detected less often by surveyors, making their population numbers or their likelihood of being hit by vehicles appear lower compared to other species. For example, after marking amphibian carcasses and then having different observers survey for them afterwards, < 7% of known salamander carcasses and 32-67% of frog carcasses were refound (detected) by surveyors during walking road surveys (Hels and Buchwald 2001). Using planted snake carcasses, Winton (2018) investigated the rate of carcass removal by scavengers and observer detection probability during road surveys. Fifty-two percent of carcasses were removed from the road by scavengers in two days, while 11% remained for >14 days. The mean observer detection probability was 0.76 for a team of two observers conducting surveys by walking.

CORRECTING FOR DETECTABILITY during road surveys:

To account for missed detections, the number of road-killed amphibians and reptiles found on the roadway can be multiplied by a compensation factor. In the case of the study by Hels and Buchwald (2001), their detections required multiplication of 1.5 and 15 for frogs and salamanders, respectively, for walking surveys. Corrections for driving surveys would have increased the compensation factor to 30 and 300, respectively, because the probability of detection is much lower from a vehicle than on foot (Beebee 2013). Winton (2018) estimated the true number of rattlesnake deaths as 2.7 times the number of dead rattlesnakes detected through all road surveys and incidental observations combined. Note that compensation factors are specific to the species, traffic levels, scavengers, etc. at each site and should not be applied across studies.

There is a great deal of uncertainty in these detectability factors which makes it challenging to accurately relate road kill numbers to actual deaths, but it is possible to calculate relative changes over time at the same place with repeated use of standard methods (Beebee 2013).

Photo x. Length of XX is recorded by...

Photo x. Length of XX is recorded by...

7.3.2.2 Monitoring Crossing Structures and Fencing

Amphibians and reptiles observed along fences and not on the road are evidence that the fences are helping to reduce road mortality; likewise, animals observed moving through tunnels serve as evidence and that crossing structures are providing safe passage and habitat connectivity. Assessments of the **proportion of animals that encounter the fence AND enter into the crossing structure**, and the **proportion of animals that enter crossing structures AND go through them**, are needed to best inform mitigation designs.

A variety of monitoring techniques are used for following the movements of amphibians and reptiles along fences and through crossing structures (see Appendix E for examples of crossing structures that are and have been monitored in BC):

Camera traps: Remote digital cameras are a non-intrusive sampling technique that does not require a wildlife sampling permit. The time lapse setting is used to take pictures of ectothermic (cold-blooded) animals, such as amphibians and reptiles, at regularly spaced intervals (e.g., every minute). In this scenario, approximately 20,000 images are taken over a two-week period. In some cases, camera detection software can help to find wildlife in images (Dillon Consulting Limited 2011). Setting the camera to take photos over shorter intervals (e.g., every 10 seconds) will improve the quality of the data but would require the batteries and SD cards to be replaced more regularly. Some researchers have experimented with using a standard digital camera and a light beam aimed across the bottom of an underpass, which triggers the shutter when the beam is broken by a passing animal (Dulisse 2017). Cameras should be placed at both ends of the underpass, securely fastened, and locked to the underpass structure (photo x). At larger underpasses, cameras should be mounted closer to the ground.

Photo X. Digital camera mounted and locked to crossing structure.

Sand pits, ink pads, and fluorescent powder: Surfaces at the entrance or inside crossing structures can be set up to receive tracks. Sand, cleaned and free of plant seeds, can be laid down on top of existing soil and litter and raked smooth after each inspection. Sticky ink or fluorescent powder can be placed in a shallow well or on a card adjacent to blank cardboard where animals will leave prints after they have moved across the ink/powder. These techniques rely on being able to identify the tracks of species. It may be challenging to distinguish tracks if there are a number of animals moving across the track pad.

Pitfall traps with fencing: Pitfall traps are buckets, cans, or other containers buried flush with the ground along a fence. The fence directs moving animals towards the traps. The use of pitfall traps requires a wildlife sampling permit from the provincial government. Pitfall traps need to be large enough that the target species cannot climb or jump out of the containers. In addition, once traps are set they need to be checked regularly (at least twice per day, and as frequently as every 6 hours in some areas) to avoid drowning, desiccation, or predation of individuals. Traps can be set at the entranceway and exit of a crossing structure to assess how many animals are moving to and through the crossing

structure. Traps can also be set in arrays within nearby habitats to assess the number of animals in the vicinity of the road. This technique provides a useful opportunity to capture, mark, and recapture individuals (see next technique).

Capture-mark-recapture: Capturing, marking, and recapturing animals can be used to determine if individuals are crossing a road, and as a method of assessing population levels. Several methods exist for marking amphibians and reptiles, including inserting Passive Integrated Transponders (PIT), notching scutes on turtles, marking salamanders and frogs with visible implant elastomer dye (e.g., MacNeil et al. 2011), and using image recognition software. Some of these techniques are discussed in more detail in the Canadian Council on Animal Care (2004) manual. Mark-recapture methods for turtles are discussed in detail in Robertson et al. (2013) and for all reptiles in McDiarmid et al. (2012).

Radio telemetry and passive data loggers/PIT tag readers: Radio-telemetry can be used to monitor amphibian and reptile movements using a handheld receiver (photos x and x), while passive data loggers (photo x) or PIT tag readers can be mounted near crossing structure entrances (James et al. 2011, Caverhill et al. 2011) to record the movement of marked individuals.

Table 5 provides a comparison of the advantages and disadvantages of these methodologies. A combination of several methods will provide the most robust data set and eliminate most of the disadvantages of any one method. For example, using both hand-held radio telemetry and passive receivers mounted in the crossing structures will provide high-quality data on crossing events as well as the detailed movements of individuals in relation to the crossing structures and the road.

Table 5. Advantages and disadvantages of techniques used to monitor road crossing structures.

Technique	Advantages	Disadvantages
Mounted digital cameras	• Provides information on the time and date of the crossing event • Should detect most individuals using the crossing structure if cameras are set to take photos regularly (e.g., every minute)	• Does not provide detailed information on the individuals using the structure (e.g., sex) • Effective cameras are expensive, and there is a risk of theft • It can be very time-consuming to review photographs and maintain cameras (downloading pictures, adjustments, batteries, water levels, etc.) • Cameras typically do not work under aquatic conditions
Pitfall and Funnel Traps	• Traps within a crossing structure provide information on the individuals using the structure (e.g., sex) and the date of the crossing event • Trapped animals can be used for genetic sampling to assess genetic mixing across roads	• Labour-intensive and costly for set up and sampling, as the traps should be checked at least twice per day • Risk of animals dying in traps • Risk of attracting predators to crossing structures
Capture-Mark-	• May be possible to capture and	• Does not provide direct evidence that

Technique	Advantages	Disadvantages
Recapture	recapture marked individuals from one side of the road to the other • The best way to obtain estimates of absolute population abundance using a crossing structure (with enough sampling)	animals used the crossing structure (e.g., cannot rule out crossing through holes in fence or at fence ends) • May not provide information on the time and date of crossings • Detection of individuals crossing the road is limited to the number of animals captured and subsequently recaptured • Labour- and time-intensive
Radio-telemetry and passive data loggers	• Provides information on the individuals using the structure (e.g., sex) and the time and date of crossing (PIT tags only) • Passive data loggers and PIT tag readers in the structure provide direct evidence that the structures are used (if placed at each end of the tunnel) • Radio-telemetry can track movements in relation to the road (e.g., home range size) • Will work under aquatic conditions	• Considerable field time, effort, and cost may be required to capture, handle, and monitor animals • Detection of individuals crossing the road is limited to the type and number of animals that are captured and tagged or tracked (e.g., only larger adults of some species are large enough to be tagged) • Radio-telemetry is unlikely to provide direct evidence that the structure is used, so it is ideal to combine this with passive readers mounted inside the structure

7.3.2.3 Monitoring Population Trends

The best sampling protocol for monitoring population sizes over the long term depends on the species' life cycle. Communal breeding sites or hibernacula may be the most efficient places to do annual surveys. Road survey data for species that move in large numbers all at once can also be used to estimate population trends; however, possible changes in traffic volume or changes in movement patterns due to habitat loss over time need to be considered. For a few species of amphibians in BC, it is possible to measure relative abundance by counting the number of egg masses laid in ponds near roads or by doing auditory surveys of the breeding calls. For many species, however, more time-intensive sampling or capture-mark-recapture projects are needed to monitor changes in relative abundance and population size. To prevent disease transmission among amphibians and between habitats, it is important for all field workers to follow the hygiene protocols developed by the B.C. Ministry of Environment (B.C. MOE 2008) and the decontamination protocols developed by the Canadian Herpetofauna Health Working Group (HHWG 2017).

A variety of sampling protocols can be used to monitor population trends for amphibians and reptiles:

Capture-mark-recapture techniques may be used to estimate population size, but a large number of individuals need to be marked and recaptured to produce statistically significant estimates. Population

trends (decreasing, increasing, or stable) can be observed if capture-mark-recapture sampling is repeated over time.

Relative abundance surveys (counts of animals per area and standardized by search effort) require a systematic study design with regular surveys by trained individuals to reduce observer bias. Surveys are carried out using standardized methods, such as timed searches, grids, or transects, that allow for comparisons over time or between sites. Visual searches, coverboards, and/or pitfall traps may be employed. Two effective measures of relative abundance for certain species of amphibians are counts of egg masses and call surveys.

Counts of egg masses provide efficient and non-invasive measures of the relative abundance of breeding amphibians. This technique can only be used for species in which individual breeding females lay single egg masses that are easy to distinguish and detect. Protocols should follow those outlined by provincial standards (RISC 1998a). Egg mass identification guides are available (Thoms et al. 2006, http://saltspringconservancy.ca/wp-content/uploads/2016/04/Pictorial-aquatic-egg-key6-logos.pdf). In BC, counts are possible for egg masses of Northern Red-legged Frogs (*Rana aurora*), Oregon Spotted Frogs (*Rana pretiosa*), Columbia Spotted Frogs (*Rana luteiventris*), Wood Frog (*Lithobates sylvaticus*), Northern Leopard frog (*Lithobates pipiens*), and Northwestern Salamanders (*Ambystoma gracile*).

Call surveys may be used to collect relative abundance data for toads and frogs at breeding ponds near roads, and do not require direct observation of the animals. Data logger monitoring devices can also be employed. However, in BC this monitoring technique is limited because few frog and toad species produce audible (surface detectable) calls. This technique is applicable to the Great Basin Spadefoot Toad (*Spea intermontana*), Wood Frog (*Lithobates sylvaticus*), Boreal Chorus Frog (*Pseudacris maculata*), and Northern Pacific Treefrog (*Pseudacris regilla*). Northern red-legged frogs (*Rana aurora*) produce calls underwater, which can be detected with the aid of a handheld hydrophone.

Genetic sampling involves taking blood or tissue samples from live or dead individuals to compare genetic relatedness and structuring (e.g., sex and age ratios) across the landscape bisected by the road before and after a road mitigation project (e.g., James et al. 2011).

Further information regarding methods for surveying amphibians and reptiles can be found in Heyer et al. (1994), Konze et al. (1997), and McDiarmid et al. (2012). RISC (1998b) and the Canadian Council on Animal Care (CCAC 2004) provide excellent manuals for handling and capturing amphibians and reptiles.

7.3.2.4. Population Viability Modelling

If it is not feasible to measure population size or relative abundance, then population viability modelling can be used to analyze the effect of mitigation on population levels (Section 2.4). **This approach integrates data on the changes in road mortality and movements across roads with life-history traits**.

Life-history traits are quantified as "vital rates" and include:

- average female fecundity (number of eggs laid per year per female),
- hatching success (number of eggs that hatch),
- juvenile survival (number of juveniles that grow from hatchling to sub-adult),
- sub-adult survival (number of sub-adults that reach adulthood), and
- adult survival (annual survival rates of adults from one breeding season to the next).

Vital rates for the female component of the population are necessary, and models improve with information about males. It can take years of effort to measure vital rates for local populations. Therefore, estimates from the literature are often used. Overall, this approach is a useful way of predicting relative, long-term changes in populations with and without mitigation. The accuracy of the model depends on the accuracy of the data input.

Data that need to be monitored for modeling purposes include:

- sex and age classes of individuals killed on the road
- sex and age classes of individuals moving through crossing structures in each direction
- proportion of individuals, by sex and age class, killed on the road

If particular individuals, such as breeding females, do not use a crossing structure to access breeding sites, this will lead to reduced breeding success and population declines. This would be true even if traffic mortality overall for the species has been reduced because some individuals, such as juveniles, use the crossing structure.

HOW DIFFERENCES IN LIFE-HISTORY TRAITS INFLUENCE POPULATIONS AFFECTED BY ROADS

The results from population viability models show that differences in life history traits across species are important when considering population responses to road mortality. Finding many dead animals of a specific species on a road does not necessarily reflect greater population impacts for that species. Species with lower reproductive output (e.g., some snake species) suffer more by the loss of only a few individuals than species with high reproductive output (e.g., some frog and toad species). In addition, the loss of only a few reproductively mature individuals has a greater impact on the population than the mortality of hundreds of subadults attempting to cross a road. For more information, see Section 2.4.

7.4 Communication Needs for Adaptive Management

Adaptive management consists of using the results from monitoring to inform decision-making. Monitoring, research, and open communication among project partners (e.g., people conducting the monitoring, the road authority, contractors, experts, etc.) and across projects facilitate this process. The B.C. Herpetofauna and Roads conferences and working group provide an opportunity to share information and build a pool of experts working in this field. Ongoing communication through annual conference calls of the B.C. Herpetofauna and Roads working group and face-to-face workshops once every five years will ensure that these guidelines are kept up-to-date and that road impacts on amphibians and reptiles are prevented and mitigated using the most current science and adaptive management techniques available.

8 REFERENCES

Alberta Northern Leopard Frog Recovery Team. 2005. Alberta Northern Leopard Frog Recovery Plan, 2005-2010. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No.7. Edmonton, AB. 26 pp.

Allaback, M. L., and D. M. Laabs. 2002. Effectiveness of road tunnels for the Santa Cruz Long-toed Salamander. Transactions of the Western Section of the Wildlife Society 38:5–8.

Amphibian and Reptile Conservation. 2009. Common toads and roads: Guidance for planners and highways engineers (England). Booklet, published by Amphibian and Reptile Conservation.

Andrews, K. M., and J. W. Gibbons. 2005. How do highways influence snake movement? Behavioral responses to roads and vehicles. Copeia 2005:772–782.

Andrews, K. M., J. W. Gibbons, and D. M. Jochimsen. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. Pages 121–143 in R. E. Mitchell, J. Brown, and B. Bartholomew, editors. Urban Herpetology, Society for the Study of Amphibians and Reptiles.

Antworth, R. L., D.A. Pike, and E.E. Stevens. 2005. Hit and Run: Effects of scavenging on estimates of roadkilled vertebrates. Southeastern Naturalist 4:647-656

Ardea Biological Consulting Ltd. 1999

Aresco, M. J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69:549–560.

Arizona Game and Fish. 2010. Safe roads for people and wildlife: culverts and fencing to reduce wildlife-vehicle collisions and maintain permeability. Available from http://www.rtamobility.com/images/stories/pdfs/RTAWLL/2010/RTAWLL-2010-05-14-Presentation%20Safe%20Roads%20for%20%20People%20and%20Wildlife.pdf.

Ascensão, F., and A. Mira. 2007. Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. Ecological Research 22:57–66.

Ashley, E. P., and J. T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110:403–412.

Ashley, E. P., A. Kosloski, and S. A. Petrie. 2007. Incidence of intentional vehicle-reptile collisions. Human Dimensions of Wildlife 12:137–143.

Ashpole, S.L., J. Crosby and B. Persello. 2018. Evaluating roadkill mitigation structure cost and longevity. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Austin, M.A., D.A. Buffett, D.J. Nicolson, G.G.E. Scudder and V. Stevens (eds.). 2008. Taking nature's pulse: the status of biodiversity in British Columbia. Biodiversity BC, Victoria, B.C. 268 pp. Accessed at www.biodiversitybc.org 19 March 2018.

Babbitt, K. J. 2005. The relative importance of wetland size and hydroperiod for amphibians in southern New Hampshire, USA. Wetlands Ecology and Management 13:269–279.

Bain, T.K. 2014.Evaluating the effect of moisture in wildlife crossing tunnels on the migration of the California tiger salamander, *Ambystoma californiense.* Master of Science thesis. Sonoma State University, Rohnert Park, California.

Barthelmess, E. L., and M. S. Brooks. 2010. The influence of body-size and diet on road-kill trends in mammals. Biodiversity and Conservation 19:1611–1629.

Baxter-Gilbert, J. H. 2014. The long road ahead: understanding road-related threats to reptiles and testing if current mitigation measures are effective at minimizing impacts. Master of Science thesis. Laurentian University.

Baxter-Gillbert, J.H., J.L. Riley, D. Lesbarreres and J.D. Litzgus. 2015. Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness. PLoS ONE 10(3): e0120537.

Beasley, B. 2006. A study of the incidence of amphibian road mortality between Ucluelet and Tofino, British Columbia. Wildlife Afield, 3:1 Supplement: 23-28.

Beasley, B.A. 2012. Amphibian rite of passage: designing and testing the effectiveness of culverts for connecting habitats in coastal British Columbia, Canada. Abstract. World Congress of Herpetology, Vancouver, 2012.

Beasley, B. A. 2013. The SPLAT project: Mitigating amphibian road mortality in the Clayoquot Sound UNESCO Biosphere Reserve. FrogLog 21:20–22.

Beasley, B. 2018a. Designing effective barriers to reduce road mortality and guide amphibians to crossing structures on Highway 4 on the west coast of Vancouver Island. Part 2: BACI design to test roadside HDPE fencing. Abstract and poster at the Herpetofauna and Roads Workshop II, B.C. Ministry of Environment, Kamloops, September 21, 2018.

Beasley, B. 2018b. SPLAT Project update: mitigation and monitoring of road effects on amphibians crossing Highway 4 on the west coast of Vancouver Island. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141:2550–2563.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2009. Seasonally dynamic habitat use by Spotted (*Clemmys guttata*) and Blanding's turtles (*Emydoidea blandingii*) in Maine. Journal of Herpetology 43:636–645.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2010. Nesting movements and the use of anthropogenic nesting sites by Spotted Turtles (*Clemmys guttata*) and Blanding's Turtles (*Emydoidea blandingii*). Herpetological Conservation and Biology 5:1–8.

Beben, D. 2016. Crossings construction as a method of animal conservation. Transportation Research Procedia 14:474-483.

Beebee, T.J.C. 2013. Effects of road mortality and mitigation measures on amphibian populations. Conservation Biology **27**:657-668.

Beckmann, C. and R. Shine. 2012. Do drivers intentionally target wildlife on roads? Austral Ecology 37:629-632.

Bellis, M., S. Jackson, C. Griffin, P. Warren, and A. Thompson. 2007. Utilizing a multi-technique, multi-taxa approach to monitoring wildlife passageways on the Bennington Bypass in Southern Vermont. Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Beresford, H. 2018. Western Toad Tunnel. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Bertram, N., K. Larsen, and J. Surgenor. 2001. Identification of critical habitats and conservation issues for the Western Rattlesnake and Great Basin Gopher Snake within the Thompson-Nicola region of British Columbia. BC Ministry of Water, Land and Air Protection and the Habitat Conservation Trust Fund of BC, Kamloops, British Columbia. 55 pp.

Biolinx Environmental Research and Nicola Naturalist Society. 2013. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July - August 2013. Unpublished report to BC Parks. 26 pp.

Biolinx Environmental Research and Nicola Naturalist Society. 2014. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July - August 2014. 36 pp. Unpublished report to BC Parks. 26 pp. Website: http://www.nicolanaturalists.ca/files/KA-Toad-Report-15-Dec-2014-sm.pdf (accessed June 2018)

Bings, B. and J. Steciw. 2018. Western Pond Turtle Highway Crossing. Abstract Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment. March 9, 2018.

Bissonette, J., C. A. Kassar, and L. J. Cook. 2008. Assessment of costs associated with deer–vehicle collisions: human death and injury, vehicle damage, and deer loss. Human-Wildlife Conflicts 2:122-130.

Bissonette, J. A., and W. Adair. 2008. Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. Biological Conservation 141: 482-488.

Blood and Henderson 2000

Bouchard, J., A. T. Ford, F. E. Eigenbrod, and L. Fahrig. 2009. Behavioral responses of Northern Leopard Frogs (*Rana pipiens*) to roads and traffic: Implications for population persistence. Ecology and Society 14. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art23/.

B.C. Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). 2004. Guidelines for Amphibians and Reptiles conservation during urban and rural land development in British Columbia. Victoria, British Columbia. 156 pp. http://www.env.gov.bc.ca/wld/BMP/bmpintro.html#second

B.C. Ministry of Environment (MOE). 2008. Interim Hygiene Protocols for Amphibian field staff and

researchers. Ecosystems Branch, Ministry of Environment, Victoria, B.C. [online] URL: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/bc_protocol-amphibian_field_researchers.pdf

B.C. Ministry of Environment (MOE). 2014. Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures). Version 1.0. B.C. Ministry of Environment, Victoria, BC. 70 pp.

B.C. Ministry of Environment (MOE). 2015. Management plan for the Coeur d'Alene Salamander (*Plethodon idahoensis*) in British Columbia. B.C. Ministry of Environment, Victoria, BC. 23 pp.

B.C. Ministry of Transportation and Infrastructure (MOTI). 2019. Recognized Products List January 1st 2019 Edition. New Products Evaluation Standing Committee, B.C. Ministry of Transportation and Infrastructure, Victoria, BC. 99 pp.

B.C. Ministry of Water, Land and Air Protection 2004

B.C. Species and Ecosystem Explorer. 2018. BC Ministry of Environment. Victoria, BC Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Feb 21, 2018).

Brooks, R. J., G. P. Brown, and D. A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the Common Snapping Turtle (*Chelydra serpentina*). Canadian Journal of Zoology 69:1314–1320.

Brown, J. 2006. The movement patterns, activity range size, and habitat preference of the Great Basin Gopher Snake (Pituophis melanoleucus) at Vaseux Lake: 2005 preliminary results. Unpubl. report prepared for Environment Canada.

Brown, W.S., and W.S. Parker. 1976. Movement ecology of Coluber constrictor near communal hibernacula. Copeia 1976:225-242.

Browne, C. 2010. Habitat use of the Western Toad in north-central Alberta and the influence of scale. Ph.D. dissertation, Department of Biological Sciences, University of Alberta, Edmonton, Alberta.

Browne, C. L., and C. A. Paszkowski. 2010. Factors affecting the timing of movements to hibernation sites by western toads (*Anaxyrus boreas*). Herpetologica 66: 250-258.

Buchanan, I. D., and D. Basso. 2007. Under the boardwalk – case history – St. John's sideroad at the Mckenzie wetland, Aurora, Ontario, Canada. Pages 100–113 in C. L. Irwin, D. A. Nelson, and K. P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. Available from http://escholarship.org/uc/item/6vr0n5bq (accessed February 25, 2014).

Bull, E. L. 2006. Sexual differences in the ecology and habitat selection of western toads (Bufo boreas) in northeastern Oregon. Herpetological Conservation and Biology 1: 27-38.

Canadian Council on Animal Care. 2004. CCAC species-specific recommendations on: AMPHIBIANS AND

REPTILES. Canadian Council on Animal Care, Ottawa, Ontario. Available from http://www.ccac.ca/Documents/Standards/Guidelines/Add_PDFs/Wildlife_Amphibians_Reptiles.pdf.

Canadian Environmental Assessment Agency. 2006. Glossary –Terms Commonly Used in Federal Environmental Assessments. Canadian Environmental Assessment Agency Training and Guidance. Ottawa, ON. Obtained from the World Wide Web March 23, 2018: http://publications.gc.ca/collections/collection_2008/ec/En106-58-2006E.pdf.

Canadian Herpetofauna Health Working Group (HHWG). 2017. Decontamination Protocol for Field Work with Amphibians and Reptiles in Canada. Obtained from the World Wide Web January 11, 2019: http://www.cwhc-rcsf.ca/docs/HHWG%20Decontamination%20Protocol%202017-05-30.pdf

Carr, L. W., and L. Fahrig, 2001. Effect of road traffic on two amphibian species of differing vagility. Conservation Biology 15: 1071–1078.

Carsignol. J. 2005 (translated to English 2007). Facilities and measures for small fauna: technical guide. Ministry of Transportation and Infrastructure, Technical Department for Transport, Road and Bridges Engineering and Road Safety. Bagneux Cedex, France.

Caverhill, B., B. Johnson, J. Phillips, E. Nadeau, M. Kula, and R. Holmes. 2011. Blanding's tTurtle (*Emydoidea blandingii*) and Snapping tTurtle (*Chelydra serpentina*) habitat use and movements in the Oakland Swamp wetland complex, Ontario, Canada, and their response to the Provincial Highway 24 exclusion fence and aquatic culvert ecopassage from 2010-2011. Report prepared by the Toronto Zoo, Adopt-A-Pond Programme, Toronto, ON.

Central Lake Ontario Conservation Authority March 2015. Watershed Wildlife and Corridors Protection and Enhancement Plan - Action Plan #5. Oshawa, ON.

Chan-McLeod, A.A. 2003. Factors affecting the permeability of clearcuts to red-legged frogs. Journal of Wildlife Management 67:663–671.

Charry B., and J. Jones. 2009. Traffic volume as a primary road characteristic impacting wildlife: a tool for land use and transportation planning. Session 142. Technical Tools for Integrating Ecological Considerations in Planning and Construction. ICOET Proceedings 2009. Pp. 159-172. https://escholarship.org/uc/item/4fx6c79t.

Church, D., L. Bailey, H. Wilbur, W. Kendall, and J. Hines. 2007. Iteroparity in the variable environment of the salamander Ambystoma tigrinum. Ecology 88(4):891- 903.

Clark, R. W., W.S. Brown, R. Stechert, and K.R. Zamudio. 2010. Roads, interrupted dispersal, and genetic diversity in timber rattlesnakes. Conservation Biology 24:1059-1069.

Clark, R.W., M.N. Marchand, B.J. Clifford, R. Sechert and S. Stephens. 2011. Decline of an isolated timber rattlesnake (*Crotalus horridus*) population: interacions between climate change, disease, and loss of genetic diversity. Biological Conservation 144:886-891.

Clarke, R. and A. Gruenig 2002. Summary Report: Painted Turtle (*Chrysemys picta belli*) nest site enhancement and monitoring Elizabeth Lake, Cranbrook, B.C. Unpublished report for Columbia Basin Fish and Wildlife Compensation Program Rocky Mountain Naturalists, Nelson, B.C.

Clayton, G. and D. Bywater. 2012. BMPs for Public Works Department working within the Georgian Bay Biosphere Reserve. Georgian Bay Biosphere Reserve. Parry Sound, Ontario. 16 pp. http://www.gbbr.ca/download/Species%20at%20Risk/BMPs%20Working%20in%20SAR%20Habitat.pdf

Clegg, S. 2011. Assessing the impacts of vehicular mortality of migrating amphibians near Ryder Lake, B.C. Report for the Fraser Valley Conservancy. http://fraservalleyconservancy.ca/wp-content/uploads/2011/11/RLAPP-Data-Report-24-02-2011-updated-01-11-11.pdf

Clevenger, A. P. 2012. Mitigating continental-scale bottlenecks: How small-scale highway mitigation has large-scale impacts. Ecological Restoration **30**:300–307.

Clevenger, A. P., and M. Huijser. 2011. Wildlife crossing structures handbook: Design and evaluation in North America. Report # FHWA-CFL/TD-11-003. Federal Highway Administration, Washington, D.C. 223 pp.

Clevenger, A. P., B. Churszcz, K. Gunson, and J. Wierzchowski. 2002. Roads and wildlife in the Canadian Rocky Mountain Parks – movement, mortality, and mitigation. Final Report to Parks Canada. Banff, AB.

Clevenger, A. P., M. McIvor, D. McIvor, B. Chruszcz, and K. Gunson. 2001. Tiger salamander, *Ambystoma tigrinum*, movements and mortality on the Trans-Canada Highway in southwestern Alberta. Canadian Field-Naturalist **115**:199–204.

Coffin, A. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15(5):396-406.

Colley, M., Lougheed, S.C., Otterbein, K. and J.D. Litzgus 2017. Mitigation reduces road mortality in a threatened rattlesnake. Wildlife Research 44:48-59.

Collins, S.J., and R.W. Russell. 2009. Toxicity of road salt to Nova Scotia amphibians. Environmental Pollution. Volume 157 (1): 320-324.

Collinson, W. J., D.M. Parker, R.T. Bernard, B.K. Reilly, and H.T. Davies-Mostert. 2014. Wildlife road traffic accidents: a standardized protocol for counting flattened fauna. Ecology and Evolution, 4:3060-3071.

Compton, B. W., and P. R. Sievert. 2002. An evaluation of turtle tunnels and curbs at Towermarc Office Park. Unpublished report. University of Massachusetts, Amherst, MA, USA.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology **7**:826–833.

COSEWIC. 2002a. COSEWIC assessment and update status report on the Spiny Softshell Turtle *Apalone spinifera* in Canada. Page vii + 17. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2002b. COSEWIC assessment and status report on the Milksnake *Lampropeltis triangulum* in Canada. Page vi + 29. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2004. COSEWIC assessment and update status report on the Spotted Turtle *Clemmys guttata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2005. COSEWIC assessment and update status report on the Blanding's Turtle *Emydoidea blandingii* in Canada. Page viii + 40. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2006. COSEWIC assessment and update status report on the Lake Erie watersnake *Nerodia sipedon insularum* Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007a. COSEWIC assessment and update status report on the Eastern Hog-nosed Snake *Heterodon platirhinos* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007b. COSEWIC assessment and update status report on the Wood Turtle *Glyptemys insculpta* in Canada. Page vii + 42. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007c. COSEWIC assessment and update status report on the Gray Ratsnake *Elaphe spiloides* (Great Lakes/St. Lawrence population and Carolinian population) in Canada. Page vii + 33. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007d. COSEWIC assessment and update status report on the Five-lined Skink *Eumeces fasciatus* (Carolinian population and Great Lakes/St. Lawrence population) in Canada. Page vii + 50. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC 2007. COSEWIC assessment and update status report on the Great Basin Spadefoot Spea intermontana in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 34 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2008a. COSEWIC assessment and status report on the Snapping Turtle *Chelydra serpentina* in Canada. Page vii + 47. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2008b. COSEWIC assessment and update status report on the Eastern Foxsnake *Elaphe gloydi*, Carolinian population and Great Lakes/St. Lawrence population, in Canada. Page vii + 45. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010a. COSEWIC assessment and status report on the Jefferson Salamander *Ambystoma jeffersonianum* in Canada. Page xi + 38. Committee on the Status of Endangered Wildlife in Canadaa. Ottawa.

COSEWIC. 2010b. COSEWIC assessment and status report on the Fowler's Toad *Anaxyrus fowleri* in

Canada. Page vii + 58. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010c. COSEWIC assessment and status report on the Butler's Gartersnake *Thamnophis butleri* in Canada. Page xi + 51. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010d. COSEWIC assessment and status report on the Queensnake *Regina septemvittata* in Canada. Page vii + 34. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012a. COSEWIC assessment and status report on the Eastern Musk Turtle *Sternotherus odoratus* in Canada. Page xiii + 68. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012b. COSEWIC assessment and status report on the Eastern Ribbonsnake *Thamnophis sauritus* Atlantic population, Great Lakes population in Canada. Page xii + 39. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012c. COSEWIC assessment and status report on the Massasauga *Sistrurus catenatus* in Canada. Page xiii + 84. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012d. COSEWIC assessment and status report on the Western Toad *Anaxyrus boreas* in Canada. Page 21. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 71 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the Great Basin Gophersnake *Pituophis catenifer deserticola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 53 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the Northern Map Turtle *Graptemys geographica* in Canada. Page xi + 63. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2014a. COSEWIC status appraisal summary on the Western Skink *Plestiodon skiltonianus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xvi + pp.

COSEWIC. 2014b. COSEWIC assessment and status report on the Wandering Salamander Aneides vagrans in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 44 pp

COSEWIC 2014 – Coastal Giant Salamander

COSEWIC. 2015a. COSEWIC assessment and status report on the Western Rattlesnake Crotalus oreganus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 44 pp.

COSEWIC. 2015. COSEWIC assessment and status report on the Eastern Yellow-bellied Racer Coluber constrictor flaviventris and Western Yellow-bellied Racer Coluber constrictor mormon in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xvii + 64 pp.

COSEWIC. 2016. COSEWIC assessment and status report on the Northern Rubber Boa Charina bottae in

Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 38 pp. (http://www.registrelep-sararegistry.gc.ca/default_e.cfm)..

Cosgrove, A.J., T.J. McWhorter and M. Maron. 2018. Consequences of impediments to animal movements at different scales: a conceptual framework and review. Diversity and Distributions 24:448-459. https://doi.org/10.111/ddi/12699

Crisafulli C.M., Trippe L.S., Hawkins C.P., MacMahon J.A. (2005) Amphibian Responses to the 1980 Eruption of Mount St. Helens. In: Dale V.H., Swanson F.J., Crisafulli C.M. (eds) Ecological Responses to the 1980 Eruption of Mount St. Helens. Springer, New York, NY

Crosby, J. 2014. Amphibian occurrence on South Okanagan roadways: investigating movement patterns, crossing hotspots, and roadkill mitigation structure use at the landscape scale. MSc Thesis, University of Waterloo, Ontario. 95 pp.

Crowley, J. F. 2006. Are Ontario reptiles on the road to extinction? Anthropogenic disturbance and reptile distributions within Ontario. Master's thesis. University of Guelph, Guelph, Ontario.

Cushman, K.A., and C. Pearl. 2007. A conservation assessment for the Oregon spotted frog (Rana pretiosa). USDA Forest Service Region 6. USDI Bureau of Land Management, Oregon and Washington. 47 pp.

Cunnington, G.M., E. Garrah, E. Eberhardt and L. Fahrig. 2014. Culverts alone do not reduce road mortality in anurans, Écoscience, 21:1, 69-78, DOI: 10.2980/21-1-3673

Daugherty C.H. and A.L. Sheldon 1982. Age-specific movement patterns of the frog Ascaphus truei. Herpetologica 38:468-474.

Davis, T.M. 1991. Natural history and behavior of the salamander, Aneides ferreus Cope. M.Sc. thesis. University of Victoria, Victoria, B.C. 149 pp

Davis, T. M. 2000. Ecology of the western toad (Bufo boreas) in forested areas on Vancouver Island. Final Report; unpublished report for Forest Renewal B.C., Ministry of Forestry, Victoria, British Columbia.

Davies, T.W., J. Bennie and K.J. Gaston. 2012. Street lighting changes the composition of invertebrate communities. Biology Letters 8:764-767.

Deguise, I., and J.S. Richardson. 2009a. Movement behaviour of adult western toads in a fragmented, forest landscape. Canadian Journal of Zoology 87:1184-1194.

deMaynadier, P. G., and M. L. Hunter Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Review 3:230–261.

deMaynadier, P. G., and M. L. Hunter Jr., 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal 20: 56–65.

De Rivera, C. E., and L. L. Bliss-Ketchum. 2010. The effectiveness of vertebrate passage and prevention

structures: a study of Boeckman Road in Wilsonville. Final report for Oregon Transportation Research and Education Consortium.

Dillon Consulting Limited. 2011. Terry Fox Drive extension project wildlife guide system monitoring report, Year 1 of 3. 10-3663. City of Ottawa, Ottawa, Ontario.

Dillon Consulting Limited. 2013. Terry Fox Drive extension project wildlife guide system monitoring report, Year 3 of 3; and, three year summary. 12-6019. City of Ottawa, Ottawa, Ontario.

Dodd, N. L., J. W. Gagnon, A.L. Manzo, and R. E. Schweinsburg. 2007. Video surveillance to assess highway underpass use by elk in Arizona. The Journal of Wildlife Management 71: 637-645.

Dodd, K. J., W. J. Barichivich, and L. L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118:619–631.

Dole, J.W. 1965. Summer movements of adult leopard frogs, Rana pipiens Schreber, in northern Michigan. Ecology 46:236–255.

Dougherty C.K., and G.R. Smith. 2006. Acute effects of road de-icers on the tadpoles of three anurans. Applied Herpetology. Volume 3 (2): 87 – 93.

Dulisse 2006b

Dulisse, J. 2014. Western Toad Migration at Summit Lake 2014 Field Season. Unpublished report prepared for Ministry of Forests, Lands and Natural Resource Operations Fish & Wildlife Compensation Program-Section. Nelson, BC.

Dulisse, J. 2015. Amphibian Underpass Design Considerations for Highway 3A at Grohman Narrows Provincial Park. Report prepared for the B.C. Ministry of Water, Land and Air Protection. Nelson, BC.

Dulisse J. and R. Clarke. 2018. Swansea Bridge replacement turtle nesting site enhancement and exclusion fencing. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Dulisse, J. J. Boulanger and I. Manley. 2017. Summit Lake Western Toad Project 2016 Field Season. Report prepared for the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Nelson, BC.

Dupuis and Friele 2002

Dupuis and Friele 2003

Dupuis and Friele 2004

Dyer, O. 2018. Tiger Salamander structured decision making process example. Abstract presented at Online Herpetofauna and Roads Meeting, 9 March 2018.

Eads, B. 2013. Behavioral responses of two syntopic snakes (genus *Thamnophis*) to roads and culverts. Master of Science thesis. Purdue University, Fort Wayne, Indiana.

Eads, B., L. Hayter, and B. Kingsbury. 2012. Road responses and culverts as a tool for increasing habitat connectivity for the federally threatened Copper-bellied Watersnake (*Nerodia erythrogaster neglecta*) and other wetland snakes. Conference abstract, World Congress of Herpetology. Victoria, BC.

Eastern Foxsnake Recovery Team. 2010. Recovery strategy for the Eastern Foxsnake (*Pantherophis gloydi*) – Carolinian and Georgian Bay populations in Ontario. Page vi + 39. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Eberhardt, E., S. Mitchell, and L. Fahrig. 2013. Road kill hotspots do not effectively indicate mitigation locations when past road kill has depressed populations. The Journal of Wildlife Management **77**:1353–1359.

EcoPlans. 2006. Environmental guide for wildlife in the Oak Ridges Moraine. Environmental Standards and Practices. Ontario Ministry of Transportation.

Eigenbrod, F., S. J. Hecnar, and L. Fahrig. 2008a. Accessible habitat: an improved measure of the effects of habitat loss and roads on wildlife populations. Landscape Ecology 23:159–168.

Eigenbrod, F., S. J. Hecnar, and L. Fahrig. 2008b. The relative effects of road traffic and forest cover on anuran populations. Biological conservation 141:35–46.

Engelstoft, C. and K. Ovaska. 1999. Sharp-tailed Snake study on the Gulf Islands and southeastern Vancouver Island, March-November 1998. Unpublished report prepared by Alula Biological Consulting for the BC Ministry of Environment, Lands and Parks (now Ministry of Environment), Vancouver Island Regional Office, Nanaimo, B.C. Project # PA-96-242-IN. 53pp.

Engelstoft, C., K. Ovaska, and N. Honkanen. 1999. The harmonic direction finder: a new method for tracking movements of small snakes. Herpetological Review 30:84–87.

Engelstoft, C., K. Ovaska, A. Taylor, and D. Copley. 2011. Mitigating road mortality of the Western Painted Turtle in the municipality of Saanich: road sign installation in 2010. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Environmental Reporting BC. 2018. Roads & Roadless Areas in British Columbia. State of Environment Reporting, Ministry of Environment and Climate Change Strategy, British Columbia, Canada. http://www.env.gov.bc.ca/soe/indicators/land/roads.html (accessed on <Aug 2018>).

Ernst, C.H., and J.E. Lovich. 2009. Turtles of the United States and Canada. Second edition. Johns Hopkins University Press.

Ernst et al. 1994

Ervin, E.L., R.N. Fisher, and K.R. Crooks. 2001. Factors influencing road-related amphibian mortality in Southern California. In G.L. Evink, P. Garrett, and K.P. McDermott, eds. Proceedings of the 2001 International Conference on Ecology and Transportation. P. 43. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Evelyn, M. 2018. Mitigating turtle road mortality by building nesting beaches. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Eye, D., J. Maida, O. McKibbin, K. Larsen and C. Bishop. 2018. Oosoyoos snake fence Outline. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Faggyas, S., and M. Puky. 2012. Construction and preliminary monitoring results of the first ACO Wildlife Pro amphibian mitigation system on roads in Hungary. Állattani Közlemények 97: 85–93.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177–182.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14:21-40. http://www.ecologyandsociety.org/vol14/iss1/art21/

Farmer, R. G., and R.J. Brooks. 2012. Integrated risk factors for vertebrate roadkill in southern Ontario. The Journal of Wildlife Management 76:1215-1224.

Fenech, A., B. Taylor, R. Hansell, and G. Whitelaw. 2001. Major road changes in southern Ontario 1935–1995: Implications for protected areas. Available from http://www.utoronto.ca/imap/papers/road_changes.htm (accessed April 10, 2014).

Findlay, C. S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000–1009.

Ford, A. T., A. P. Clevenger, and K. Rettie. 2010. The Banff Wildlife Crossings Project: an international public-private partnership. Pages 157–173 in J.P. Beckmann, A.P. Clevenger, M.P. Huijser, J.A. Hilty, editors. Safe passages—highways, wildlife and habitat connectivity. Island Press, Washington, DC. Island Press, Washington, DC.

Forman, R. and L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Forman, R., D. Sperling, J. A. Bissonette and A. Clevenger. 2003. Road ecology: science and solutions. Island Press, Washington D.C.

Fortney, A. N., R. G. Poulin, J.A. Martino, D.L. Parker, and C.M. Somers. 2013. Proximity to hibernacula and road type influence potential road mortality of snakes in southwestern Saskatchewan. Canadian Field-Naturalist 126:194-203.

Fraser Valley Conservancy 2018. Ryder Lake amphibian protection project. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Frey and Conover 2006

Fyfe, L. and E. Wind. 2008. Emergency Response and Mitigation Measures for Two Western Toad Migrations Along Highway 19 near Courtenay, British Columbia. Unpublished report. BC Ministry of Transportation.

Gallagher, M.T., J.W. Snodgrass, A.B. Brand, R.E. Casey, S.M. Lev and R.J. Van Meter. 2014. The role of pollutant accumulation in determining the use of stormwater ponds by amphibians. Wetlands Ecol. Manage. 22:551-564.

Garrah, E. 2012. Wildlife road mortality on the 1000 islands parkway in southeastern Ontario: peak times, hot spots, and mitigation using drainage culverts. Master of Environmental Studies thesis. Queen's University, Kingston, Ontario.

Gartner Lee and EcoPlans. 2009. 407 East individual Environmental Assessment and preliminary design study: Natural environmental (terrestrial) impact assessment of the recommended design. Report to the Ministry of Transportation.

Gartshore, R. G., M. Purchase, R. I. Rook, and L. Scott. 2005. Bayview Avenue extension, Richmond Hill, Ontario, Canada habitat creation and wildlife crossings in a contentious environmental setting: a case study. Pages 55-76 in C.L. Irwin, P. Garrett, and K.P. McDermott, editors. Proceedings of the 2005 International Conference on Ecology and Transportation, Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Gates, J. E., and J. L. J. Sparks. 2012. An investigation into the use of road drainage structures by wildlife in Maryland, USA. Human-Wildlife Interactions 6:311–326.

Gibbs, J. P., and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647–1652.

Gibbs, J. P., and W. G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13:281–289.

Gillies and St. Clair 1997

Gillingwater, S. D. 2011. Recovery strategy for the Queensnake (*Regina septemvittata*) in Ontario. Page vi + 34. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Glenside Ecological Services. 2011. Community mobilization and habitat modelling. Pages 24 – 109. Species at Risk. Ontario Ministry of Natural Resources, Haliburton Highlands Land Trust.

Glista, D.J., T.L. DeVault and J.A. DeWoody. 2009. A review of mitigation measures for reducing wildlife mortality on roadways. Landscape and Urban Planning 91:1-7.

Gomez, L.M. 2007. Habitat use and movement patterns of the Northern Pacific Rattlesnake (Crotalus o.

oreganus) in British Columbia. M. Sc. Thesis, University of Victoria, Victoria, British Columbia. 81 pp.

Gomez, L., K. Larsen and P.T. Gregory. 2015. Contrasting Patterns of Migration and Habitat Use in Neighboring Rattlesnake Populations. Journal of Herpetology 49 (3): 371–376.

Government of British Columbia. 2014. Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures). Version 1.0. Victoria. BC. Accessed via the internet Aug. 30, 2018. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/environmental-mitigation-policy/em_procedures_may27_2014.pdf.

Govindarajulu, P. 2011. Do roads affect herpetofauna in B.C.? Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Govindarajulu, P., E. Wind and B. Beasley. 2012. British Columbia's response to herpetofauna and road issues. Abstract presented at 2012 Annual Meeting of the Society for Northwestern Vertebrate Biology, Hood River, Oregon. Northwestern Naturalist 93:170.

Graham, K.G. 1997. Habitat use of Long-toed Salamanders (Ambystoma macrodactylum) at three different scales. M.Sc. thesis, University of Guelph, Guelph, ON. 71 pp.

Grift et al. 2009 - https://library.wur.nl/WebQuery/wurpubs/fulltext/185626

Gravel, M., M.J. Mazerolle and M. Villard. 2012. Interactive effects of roads and weather on juvenile amphibian movements. Amphibia-Reptilia 33:113-127.

Gregory and Campbell 1987

Grods, J. and J. Garner. 2018. Using telemetry as a pre-development tool to inform planning and mitigation measures that decrease the impacts of development. Abstract submitted to the Online Herpetofauna and Roads Meeting. B.C. Ministry of Environment. 9 March 2019.

Griffin, K. 2005. Use of low fencing with aluminum flashing as a barrier for turtles. Pages 366-368 in C.L. Irwin, P. Garrett, and K.P. McDermott, eds. Proceedings of the 2005 International Conference on Ecology and Transportation, Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Gunson, K. E., G. Mountrakis, and L. J. Quackenbush. 2011. Spatial wildlife-vehicle collision models: A review of current work and its application to transportation mitigation projects. Journal of Environmental Management 92:1074–1082.

Gunson, K. E., and F. W. Schueler. 2012. Effective placement of road mitigation using lessons learned from turtle crossing signs in Ontario. Ecological Restoration 30:329–334.

Gunson, K.E., Ireland, D., Schueler, F.W. 2012. A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in southern Ontario, Canada. NorthWestern Journal of Zoology

8:409-413.

Gunson, K. E., D. Lesbarrères, and D. C. Seburn. 2013. Monitoring turtle movements across highways 7 and 41: Final report. Unpublished report to Highway Infrastructure Innovation Funding Program. Ontario Ministry of Transportation.

Gunson, K.E., and F.Z. Teixeira. 2015. Road-wildlife mitigation planning can be improved by identifying the patterns and processes associated with wildlife-vehicle collisions. Pages 101-019 in R. van der Ree, D. Smith, C. Grilo, editors. Handbook of Road Ecology. Wiley-Blackwell Publications.

Hagood, S., and M. J. Bartels. 2008. Use of existing culverts by eastern box turtles (*Terrapene c. carolina*) to safely navigate roads. Pages 169–170 in J. C. Mitchell, R. E. J. Brown, and B. Bartholomew, editors. Urban Herpetology, Society for the Study of Amphibians and Reptiles.

Hammerson 2005

Hardy, A., S. Lee, and A.F. Al-Kaisy. 2006. Effectiveness of animal advisory messages on dynamic message signs as a speed reduction tool: case study in Rural Montana. Transportation Research Record: Journal of the Transportation Research Board 1973:64-72.

Harless, M.L., Huckins, C.J., Grant, J.B., and T.G. Pypker. 2011. Effects of six chemical deicers on larval wood frogs (*Rana sylvatica*). Environmental Toxicology and Chemistry. Volume 30 (7): 1637-1641.

HAT (Habitat Acquisition Trust). 2015a. Website: http://www.hat.bc.ca/i-want-to/report-a-turtle-slug-or-snake/amphibian-roads for maps (accessed June 2018).

HAT (Habitat Acquisition Trust). 2015b. Website http://www.hat.bc.ca/data for 2015 data (accessed June 2018).

Haxton, T. 2000. Road mortality of Snapping Turtles, *Chelydra serpentina*, in central Ontario during their nesting period. Canadian Field-Naturalist 114:106–110.

Hayes, M.P., C.A. Pearl, and C.J. Rombough. 2001. Rana aurora aurora. Movement. Herpetological Review 32:35-36.

Hayes, M.P., C.J. Rombough, and C.B. Hayes. 2007. Rana aurora aurora (Northern Red-legged Frog), movement. Herpetological Review 38:192-193

Helferty, N. J. 2002. Natural Heritage Planning for amphibians and their habitats with reference to populations on the south slope of the Oak Ridges Moraine. Page 71. Supplementary Report for Oak Ridges Moraine Richmond Hill, Ontario Municipal Board Hearing. Save the Rouge Valley System Inc. and the City of Toronto.

Hels, T., and E. Buchwald, 2001. The effect of road kills on amphibian populations. Biological Conservation 99: 331–340.

Heyer, W. R., M. A., Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds). 1994. Measuring and monitoring biological diversity. Standard methods for amphibians. Smithsonian Institution Press, Washington, D. C. 364 pp.

Hine et al. 1981

Hobbs, J. 2013. Den survey and population assessment of the Northern Pacific Rattlesnake in BC: Final Report. Unpubl. report prep. for BC Ministry of Forests, Lands and Natural Resource Operations, Victoria, British Columbia. 85 pp.

Hocking, D.J. and K.J. Babbitt. 2014. Amphibian contributions to ecosystem services. Herpetological Conservation and Biology 9:1-17.

Holling, C. S. 1978. Adaptive environmental assessment and management. Adaptive environmental assessment and management. Available from http://www.cabdirect.org/abstracts/19800666996.html (accessed April 10, 2014).

Houston 2010

Huijser, M. P., P. T. McGowen, J. Fuller, A. Hardy, and A. Kociolek. 2007. Wildlife-vehicle collision reduction study: report to congress. U.S. Department of Transportation, Federal Highway Administration, Washington, DC, USA. Available from http://trid.trb.org/view.aspx?id=884083 (accessed April 10, 2014).

IUCN. 2010. IUCN Red list of threatened species 2010. International Union for the Conservation of Nature (IUCN), Gland, Switzerland. [online] URL: http://www.iucn.org

Iuell, B. 2003. COST 341: Wildlife and Traffic: A European handbook for identifying conflicts and designing solutions. Utrecht, The Netherlands: KNNV Publishers.

Jackson, S. D., and T. F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders *Ambystoma maculatum* under roads. Pages 93–99 in T. E. S. Langton, editor. Amphibians and Roads, Proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England. Available from http://works.bepress.com/cgi/viewcontent.cgi?article=1017andcontext=scott_jackson (accessed April 10, 2014).

Jackson, S. D. 1996. Underpass systems for amphibians. In G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in Addressing Transportation Related Wildlife Mortality: Proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.

Jackson, S. D., and M. N. Marchand. 1998. Use of a prototype tunnel by Painted Turtles, *Chrysemys picta*. Unpublished report.

Jackson, S. D. 2003. Ecological considerations in the design of river and stream crossings. Page 10 in C. L. Irwin, P. Garrett, and K. P. McDermott, editors. 2003 Proceedings of the International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina. Available from

http://works.bepress.com/scott_jackson/11/ (accessed April 10, 2014).

Jackson, S.D., and Griffin, C.R., 2000. A strategy for mitigating highway impacts on wildlife. In: Messmer, T.A., West, B. (Eds.), Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society, Bethesda, MD, pp. 143–159

Jackson, S. D., D. J. Smith, and K. E. Gunson. 2015. Sharing the road: Mitigating road impacts on small vertebrates. Pages 177-208 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

James, P.W., R.S. Wagner, K.A. Ernest, D. Beck, and J. Irwin. 2011. Monitoring fish and low-mobility vertebrates along a major mountain highway: a snapshot before construction of I-90 wildlife crossing structures. Pages 527-533 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Jochimsen, D. M., C. R. Peterson, K. M. Andrews, and J. W. Gibbons. 2004. A literature review of the effects of roads on amphibians and reptiles and the measures used to minimize those effects. US Forest Service report. 79 pp.

Jacobson, S. L. 2007. An alternative to the openness "ratio" using underpass physical attributes and behavioral implications of deer vision and hearing capabilities. Page 605 in C.L. Irwin, D. Nelson, and K.P. McDermott, editors.Proceedings of the 2007 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Johnston, B. 1998. Terrestrial Pacific Giant Salamanders (Dicamptodon tenebrosus Good): natural history and their response to forest practices. M.Sc. thesis. Univ. of British Columbia, Vancouver, BC. 98 pp.

Johnston, B. and L. Frid. 2002. Clearcut logging restricts the movements of terrestrial Pacific Giant Salamanders (Dicamptodon tenebrosus Good). Can. J. Zool. 80:2170–2177.

Joyce, T. L., and S. P. Mahoney. 2001. Spatial and temporal distributions of moose-vehicle collisions in Newfoundland. Wildlife Society Bulletin 29:281–291.

Karlson, M. A. Seiler, U. Mortberg. 2017. The effect of faunal passages and landscape characteristics on barrier mitigation success. Ecological Engineering 105:211-220.

Karraker, N. E. 2008. Impacts of road deicing salts on amphibians and their habitats. Pages 211–223 in Urban herpetology. R. E. Jung, and J. C. Mitchell, editors. Herpetological conservation Vol. 3. Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah, USA.

Karraker, N. E., and J. P. Gibbs. 2011. Contrasting road effect signals in reproduction of long-versus short-lived amphibians. Hydrobiologia 664:213–218.

Kaye, D. R., K. M. Walsh, E. L. Rulison, and C. C. Ross. 2005. Spotted Turtle use of a culvert under relocated Route 44 in Carver, Massachusetts. Pages 426-432 in C.L. Irwin, P. Garrett, and K.P.

McDermott, editors. Proceedings of the 2005 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Kilburn, V. and A. Mitchell. 2011. Western Painted Turtle Monitoring at Alaksen National Wildlife Area (NWA). March 2011. Prepared for Canadian Wildlife Service, Delta, BC.

Kilburn, V.L., A.M. Mitchell, M.J. Evelyn and D.A. Stiles. 2011. Creation of Western Painted Turtle nesting habitat reduces road mortality on the South Coast of B.C. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Kingsbury, B.A. 2011. The benefits and limitations of telemetry data and modeling to explore road permeability for snakes. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Kintsch, J., and P. C. Cramer. 2011. Permeability of existing structures for terrestrial wildlife: A passage assessment system. WA-RD 777.1. Washington State Department of Transportation, Olympia, WA.

Kintsch, J., K. E. Gunson, and T. A. Langen. 2015. Engaging the public through public education and citizen science. Pages 94-110 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Konze, K. and McLaren, M. 1997. Wildlife monitoring programs and inventory techniques for Ontario. Ontario Ministry of Natural Resources. Northeast Science and Technology. Technical Manual TM-009. 139 pp.

Kraus, T., B. Hutchinson, S. Thompson, and K. Prior. 2010. Recovery strategy for the Gray Ratsnake (*Pantherophis spiloides*) – Carolinian and Frontenac Axis populations in Ontario. Page vi + 23. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Laidig, K. J., and D. M. Golden. 2004. Assessing Timber Rattlesnake movements near a residential development and locating new hibernacula in the New Jersey Pinelands. Unpublished report to the Pinelands Commission, New Lisbon, NJ. Available from http://199.20.64.195/pinelands/images/pdf%20files/final%20Sanctuary%20report.pdf (accessed April 10, 2014).

Lang, J. W. 2000. Blanding's turtles, roads and culverts at Weaver Dunes. File report on culvert utilization, The Nature Conservancy and Minnesota Department of Natural Resources, Contract# CFMS AO 9492.

Langen, T. A., A. Machniak, E. K. Crowe, C. Mangan, D. F. Marker, N. Liddle, and B. Roden. 2007. Methodologies for surveying herpetofauna mortality on rural highways. The Journal of Wildlife

Management 71:1361–1368.

Langen, T.A., K.M. Andrews, S.P. Brady, N.E. Karraker and D.J. Smith. 2015. Road effects on habitat quality for small animals. Chapter 4 In K.M. Andrews, P. Nanjappa, S.P.D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Langen, T. A. 2011. Design considerations and effectiveness of fencing for turtles: three case studies along northeastern New York State highways. Pages 521-532 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Langton, T. 2014. Safe passage for all: A review of the adoption of surface tunnels and stop channels on roadways for wildlife/road impact mitigation worldwide. Report prepard for ACO Tunnel Safety Review July 2014.

Lawrence, D.P. 2003. Environmental Impact Assessment: Practical solutions to recurrent problems. John Wiley and Sons, Hoboken, New Jersey.

Lesbarrères, D., T. Lodé, and J. Merilä. 2004. What type of amphibian tunnel could reduce road kills? Oryx 38:220–223.

Lesbarrères, D., and L. Fahrig. 2012. Measures to reduce population fragmentation by roads: what has worked and how do we know? Trends in Ecology and Evolution 27:374–380.

Le Viol I., F. Chiron, R. Julliard, and C. Kerbiriou. 2012. More amphibians than expected in highway stormwater ponds. Ecological Engineering 47:146–154.

Lininger, M., and M. Perlik. 2014. Effectiveness of the TRU-88 wildlife roadway crossing culverts and exclusion fencing. Unpublished report to the Ohio Department of Transportation.

Little, S.J., R.G. Harcourt, A.P. Clevenger. 2002. Do wildlife passages act as prey traps? Biological Conservation 107:135-145.

Lomas, E. 2013. Effects of disturbance on the Northern Pacific Rattlesnake (Crotalus oreganus oreganus) in British Columbia. M.Sc. Thesis. Thompson Rivers University, Kamloops, British Columbia. 107 pp.

Lowcock, L.A. and V. Woodruff. 2014. Observations on the distribution, ecology, movements and reproduction of Rubber Boas (*Charina bottae*) in the Pemberton Valley, British Columbia: implications for population studies and conservation. Canadian Herpetological Society, 12-15 Sept. 2014.

Macartney, J.M. 1985. The ecology of the Northern Pacific Rattlesnake, Crotalus viridis oreganus, in British Columbia. M.Sc. Thesis, University of Victoria, Victoria, British Columbia. 289 pp.

MacKinnon, C. A., L. A. Moore, R. J. Brooks, G. Nelson, T. Nudds, M. Beveridge, and B. Dempster. 2005. Why did the reptile cross the road? Landscape factors associated with road mortality of snakes

and turtles in the southeastern Georgian Bay area. Pages 18–25 Parks and Research Forum. Available from http://casiopa.mediamouse.ca/wp-content/uploads/2010/05/PRFO-2005-Proceedings-p153-166-MacKinnon-Moore-and-Brooks.pdf (accessed February 27, 2014).

Machmer, M.M. 2015. 2014 terrestrial surveys and monitoring for the Waneta Expansion Project. Report prepared by Pandion Ecological Research Ltd. for Columbia Power Corporation, Castlegar, BC. 40pp. (annual reports available for 2009, 2011, 2012, 2013).

Machmer, M.M. 2012. Impacts of increased road use associated with major project development on listed and other wildlife species in southern BC. Pp.19-24 In Proceedings of Resource Roads in BC: Environmental Challenges at the Site Level. Columbia Mountains Institute of Applied Ecology, November 7-8, 2012, Cranbrook, BC.

MacNeil, J. E., G. Dharmarajan, and R.N. Williams. 2011. Salamarker: A code generator and standardized marking system for use with visible implant elastomers. Herpetological Conservation and Biology 6:260-265.

Malt, J. 2012. Assessing the effectiveness of amphibian mitigation on the Sea to Sky Highway: population-level effects and best management practices for minimizing highway impacts. Final Report Oct 1, 2012. Ministry of Forests, Lands and Natural Resource Operations, South Coast Region. Surrey.

Maltby 2000

Marchand, M. N., and J. A. Litvaitis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758–767.

Marsh, D.M. and J.A.G. Jaeger. 2015. Direct effects of roads on small animal populations. Chapter 3 In K.M. Andrews, P. Nanjappa, S.P.D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Marsh, D., R. Page, T. Hanlon, R. Corritone, E. Little, D. Seifert, and P. Cabe, 2008. Effects of roads on patterns of genetic differentiation in red-backed salamanders, *Plethodon cinereus*. Conservation Genetics 9: 603–613.

Materi 2008

Mazzerolle, M.J., M. Huot, and M. Gravel. 2005. Behavior of amphibians on the road in response to car traffic. Herpetologica 61:380-381.

McCarthy K., R.G. Lathrop. 2011. Stormwater basins of the New Jersey coastal plain: subsidies or sinks for frogs and toads? Urban Ecosystems 14:395–413.

McCrory, W. and M. Mahr. 2018. Fish/Bear Lakes Western Toad (Anaxyrus boreas) ecology and Highway 31A mortality mitigation study. Abstract and presentation at the Herpetofauna and Roads Workshop II, B.C. Ministry of Environment, Kamloops, September 21, 2018.

McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). 2012. Reptile Biodiversity: Standard Methods for Inventory and Monitoring. Berkeley: University of California Press.

Meese, R.G., F.M. Shilling, and J.F. Quinn. 2009. Wildlife crossings guidance manual. Report to the California Department of Transportation. Sacramento, CA. 111 pp.

Merrow, J. 2007. Effectiveness of amphibian mitigation measures along a new highway. Pages 370-376 n C.L. Irwin, D. Nelson, and K.P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Ministry of Forests, Lands, and Natural Resource Operations. 2016. Best Management Practices for Amphibian and Reptile Salvages in British Columbia. Version 1.0., June 2, 2016. Victoria, BC.

Meyer, A.H., B.R. Schmidt and K. Grossenbacher. 1998. Analysis of three amphibian populations with quarter-century long time-series. Proc. R. Soc. Lond. B. 265:523-528.

Nelson, D.V., H. Klinck, A. Carbaugh-Rutland, C.L. Mathis, A.T. Morzillo and T.S. Garcia. 2017. Calling at the highway: the spatiotemporal constraint of road noise on Pacific chorus frog communication. Ecology and Evolution 7:429-440. https://doi.org/10.1002/ece32622

Neilson, J. 2018. Ryder Lake Amphibian Protection Project. Abstract presented at the Online Herpetofauna and Roads Meeting. B.C. Ministry of Environment, March 9, 2018.

Ohanjanian, I.A. 2000. The Coeur d'Alene Salamander (P. idahoensis) in the Kootenay Lake and Arrow Forest Districts. Report to B.C. Ministry of Environment, Lands and Parks and the Habitat Conservation Trust Fund. 43 pp.

Ohanjanian, I.A. 2003. The Coeur d'Alene Salamander (Plethodon idahoensis) in southeastern British Columbia – final report. Report for B.C. Ministry of Water, Land and Air Protection and the Habitat Conservation Trust Fund. 44 pp.

Ohanjanian, I.A., and M.- A. Beaucher. 2002. Coeur d'Alene Salamander inventory results, Year 5. Report to Wynndel Box and Lumber Co. Ltd., and Min. of Water, Land and Air Protection. Nelson, B.C. 19 pp

Olson, D. 2018. White Lake area road crossing culverts. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh Jr., and D.F. Bradford. 2007. Biodiversity management approaches for stream riparian areas: perspectives for Pacific Northwest headwater forests, microclimate and amphibians. For. Ecol. Manag. 246:81–107.

Ontario Ministry of Natural Resources (MNR). 2011. Massasauga search protocol where site alteration will occur in gestation habitat for Highway 69/400 ESA authorization requirements. Ontario Ministry of Natural Resources, Parry Sound Sudbury District. 5pp.

Ontario Ministry of Natural Resources (MNR). 2013. Reptile and Amphibian Exclusion Fencing: Best Practices, Version 1.0. Species at Risk Branch technical note. Prepared for the Ontario Ministry

of Natural Resources, Peterborough, Ontario. 11 pp. Available from http://files.ontario.ca/environment-and-energy/species-at-risk/mnr_sar_tx_rptl_amp_fnc_en.pdf (accessed February 26, 2014).

Ontario Ministry of Natural Resources and Forestry (MNRF). 2016. Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario. Queen's Printer for Ontario. 112 pp.

Ontario Ministry of Transportation (MT). 2012. Wildlife Habitat Awareness Signs. Policy Number 2012-03. Traffic Office, St. Catharines, Ontario.

Ontario Wood Turtle Recovery Team. 2010. Recovery strategy for the Wood Turtle (*Glyptemys insculpta*) in Ontario. Page vi + 25. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Ostergaard, E.C., K.O. Richter and S.D. West. Amphibian use of stormwater ponds in the Puget Lowlands of Washington, USA. In Urban Herpetology. J.C. Mitchell, R.E. Jung Brown, and B. Bartholomew, eds., Herpetological Conservation 3:259-270.

Ottburg, F. G. W. A., and E. A. van der Grift. 2013. Effectiveness of road mitigation for preserving a common toad population. Proceedings of the 2013 International Conference on Ecology and Transportation. Poster. Retrieved from http://www.icoet.net/ICOET_2013/proceedings.asp.

Ovaska, K. 1988. Spacing and movements of the salamander *Plethodon vehiculum*. Herpetologica 44:377 – 386.

Ovaska, K. and C. Engelstoft. 2005. Identification of critical habitat components for Sharp-tailed Snake. Unpublished report prepared for Endangered Species Recovery Fund (Environment Canada), Hull, Quebec. Project # 2005-ESR1116

Ovaska and Engelstoft 2011

Ovaska, K., C. Engelstoft, and L. Sopuck. 2016. Community-based amphibian monitoring program in multi-use landscapes in south-central British Columbia, 2011 -2015. Unpubl. report prepared for Habitat Conservation Trust Fund. 57 pp. Website: http://www.nicolanaturalists.ca/files/Nicola-Amphibian-Report-2011-2015-copy.pdf (accessed June 2018).

Ovaska, K, L. Sopuck, C. Engelstoft, A. Burger, and A. Lawrence. 2018. Western Toad roadkill mitigation in Kentucky-Alleyne Provincial Park. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Pagnucco, K. S., C. A. Paszkowski, and G. J. Scrimgeour. 2011. Using cameras to monitor tunnel use by Long-toed Salamanders (*Ambystoma macrodactylum*): an informative, cost-efficient technique. Herpetological Conservation and Biology 6:277–286.

Pagnucco, K. S., C. A. Paszkowski, and G. J. Scrimgeour. 2012. Characterizing movement patterns and spatio-temporal use of under-road tunnels by long-toed salamanders in Waterton Lakes National Park, Canada. Copeia 2012:331–340.

Painter, M. L., and M. F. Ingraldi. 2007. Use of simulated highway underpass crossing structures by flat-tailed horned lizards (*Phrynosoma mcallii*). Final Report 594. Arizona Department of Transportation, Phoenix, AZ.

Parent, C and R. Black. 2006. Construction of artificial gestation sites for the Massasauga, Eastern Georgina Bay Population. Unpublished report submitted to the Ministry of Natural Resources.

Parren, S. G. 2013. A twenty-five year study of the Wood Turtle (*Glyptemys insculpta*) in Vermont: Movements, behavior, injuries, and death. Herpetological Conservation and Biology 8:176–190.

Paterson, J. E., B.D. Steinberg, and J.D. Litzgus. 2013. Not just any old pile of dirt: evaluating the use of artificial nesting mounds as conservation tools for freshwater turtles. Oryx 47:607-615.

Patrick, D.A., and Gibbs, J.P. 2009. Snake occurrences in grassland associated with road versus forest edges. Journal of Herpetology 43:716-720.

Patrick, D. A., C. M. Schalk, J. P. Gibbs, and H. W. Woltz. 2010. Effective culvert placement and design to facilitate passage of amphibians across roads. Journal of Herpetology 44:618–626.

Patrick, D. A., J. P. Gibbs, V. D. Popescu, and D. A. Nelson. 2012. Multi-scale habitat-resistance models for predicting road mortality "hotspots" for turtles and amphibians. Herpetological Conservation and Biology 7:407–426.

Paulson, D. J. 2010. Evaluating the effectiveness of road passage structures for freshwater turtles in Massachusetts. Master of Science thesis. University of Massachusetts, Amherst, Amherst, MA.

Peaden, J.M., Nowakowski, A.J., Tuberville, T.D., Buhlmann, K.A., and B.D. Todd. 2017. Effects of roads and roadside fencing on movements, space use, and carapace temperatures of a threatened tortoise. Biological Conservation, 2017; 214: 13 DOI: 10.1016/j.biocon.2017.07.022.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-893.

Perry, G., B.W. Buchanan, R.N. Fisher, M. Salmon and S.E. Wise. 2008. Effects of artificial night lighting on urban reptiles and amphibians. Pages 239-246 in Urban Herpetology, R.E. Jung and J.C. Mitchell, eds. Herpetological Conservation Vol. 3. Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah, USA.

Persello, B., J.E. Crosby, S.L. Ashpole and S. Murphy. 2011. Amphibian occurrence on South Okanagan roadways, B.C.: realising movement corridors and improving connectivity. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011.

Pickard, D. 2009. Snakes on a lane: Analysis of snake observations on a rural road in southern British Columbia. Unpubl. report prepared for Ecosystems Branch, BC Ministry of Environment, Victoria, British Columbia.

Pickard, D., M.J. Sarell, and A. Haney. 2009. Snakes on a Lane. Presented at the Annual Meeting of the

Society for Northwestern Vertebrate Biology, Feb 18-21, 2009. Stevenson, Washington.

Pike, D.A., L. Pizzatto, B.A. Pike and R. Shine. 2008. Estimating survival rates of uncatchable animals: the myth of high juvenile mortality in reptiles. Ecology 89:607-611.

Pojar, T.M., D. F. Reed, and T.C. Reseigh. 1975. Effectiveness of a lighted, animated deer crossing sign. Journal of Wildlife Management 39:87-91.

Province of British Columbia. 2014. Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014). A companion document to Develop with Care. Victoria, BC.Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-895.

Puky, M., J. Farkas, and M. T. Ronkay. 2007. Use of existing mitigation measures by amphibians, reptiles, and small to medium-size mammals in Hungary: crossing structures can function as multiple species-oriented measures. Pages 521-530 in C.L. Irwin, D. Nelson, and K.P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation, . Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Puky, M., B. Mester, and T. Mechura. 2013. How much does size matter? Tunnel size significantly influence amphibian crossings at Parassapuszta, Hungary according to mid-term monitoring used to delineate mitigation measure improvement plans. Proceedings of the 2013 International Conference on Ecology and Transportation. Available from http://www.icoet.net/ICOET_2013/proceedings-poster-sessions.asp.

Reconyx. 2010. HyperFireTM instruction manual. Holman, Wisconsin.

Reed, D. F., T. D. I. Beck, and T. N. Woodward. 1979. Regional deer-vehicle accident research. FHWA-RD-79-11. US Department of Transportation, Federal Highway Administration, Washington, DC.

Regester, K.J., K.R. Lips and M.R. Whiles. 2006. Energy flow and subsidies associated with the complex life cycle of ambystomatid salamanders in ponds and adjacent forest in southern Illinois. Oecologia 147:303-314.

Reid and Dunne 1984

Richardson, J.S., W. Klenner, and J. Shatford. 2000. The tiger salamander in British Columbia: an amphibian in an endangered desert environment. In Proc. Biology and management of species and habitats at risk. L.M. Darling (ed.). Kamloops, BC. pp. 407–412.

Riley, J. L., J. H. Baxter-Gilbert, and J. D. Litzgus. 2013. A trifecta of insight: merging field biology, infrastructure planning and aboriginal community knowledge to design successful highway mitigation for at-risk reptiles. Proceedings of the 2013 International Conference on Ecology and Transportation. Available from http://www.icoet.net/ICOET_2013/proceedings.asp (accessed February 27, 2014).

RISC 1998a. Inventory methods for pond-breeding amphibians and painted turtle. Standards for components of British Columbia's Biodiversity No. 37. Prepared by Ministry of Environment,

Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee. March 13, 1998. Version 2.0. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/pond.pdf

RISC 1998b. Live animal capture and handling guidelines for wild mammals, birds, amphibians and reptiles. Standards for components of British Columbia's Biodiversity No. 3. Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee. December 4, 1998. Version 2.0. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/capt.pdf

Roberts, D. 2010. Mitigation of Red-sided Garter Snake mortality on provincial trunk Highway #17 at the Narcisse snake dens: A progress report. Unpublished report to Manitoba Conservation.

Robertson, C., N. Richards and M. Karch. 2013. Standard turtle handling and research practices and protocols. Prepared for the Ontario Turtle Conservation Group.

Robson, L. E., and G. Blouin-Demers. 2013. Eastern Hognose Snakes (*Heterodon platirhinos*) avoid crossing paved roads, but not unpaved roads. Copeia 2013:507–577.

Roedenbeck, I. A., L. Fahrig, C. S. Findlay, J.E. Houlahan, J. A. G. Jaeger, N. Klar, S. Kramer- Schadt and E. A. van der Grift. 2007. The Rauischholzhausen agenda for road ecology. Ecology and Society 12: 11. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art11/

Rogers, L., D. Stimson, K. Holden, D. Kay, D. Kaye, R. McAdow, B. Metcalfe, B. Windmiller, and N. Charney. 2009. Wildlife tunnels under a busy, suburban Boston roadway. Pages 102-115 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2009 International Conference on Ecology and Transportation. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Rosen, P. C., and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68:143–148.

Rouse, J. 2005. Monitoring the Eastern Massasauga and Eastern Hog-nosed Snake along the Highway 69 Extension. Ontario Ministry of Natural Resources, Parry Sound, ON.

Rouse, J. D., R. J. Willson, R. Black, and R. J. Brooks. 2011. Movement and spatial dispersion of *Sistrurus catenatus* and *Heterodon platirhinos*: implications for interactions with roads. Copeia 2011:443–456.

Row, J. R., G. Blouin-Demers, and P. J. Weatherhead. 2007. Demographic effects of road mortality in Black Ratsnakes (*Elaphe obsoleta*). Biological Conservation 137:117–124.

Rowe 2003

Rutherford, P.L., and P.T. Gregory. 2001. Habitat Use and Movement Patterns of Northern Alligator Lizards and Western Skinks in Southeastern British Columbia. Columbia Basin Fish and Wildlife Compensation Program, BC Hydro, B.C. Minist. Environ, Lands and Parks, B.C. Fish. in

partnership with Creston Valley Wildl. Manage. Area, Columbia Basin Trust and Univ. Victoria. 52pp.

Rutherford, P.L. and P.T. Gregory. 2003. Habitat use and movement patterns of Northern Alligator Lizards (*Elgaria coerulea*) and Western Skinks (*Eumeces skiltonianus*) in southern British Columbia. Journal of Herpetology 37:98-106.

Rytwinski, T., and L. Fahrig. 2012. Do species life-history traits explain population responses to roads? A meta-analysis. Biological Conservation 147:87–98.

Rytwinski, T., R. van der Ree, G.M. Cunnington, L. Fahrig, C.S. Findlay, J. Houlahan, J.A.G. Jaeger, K. Soanes, E.A. van der Grift. 2015. Experimental study designs to improve the evaluation of road mitigation measures for wildlife. Journal of Environmental Management 154:48-64.

Rytwinski, T., K. Soanes, J.A.G. Jaeger, L. Fahrig, C.S. Findlay, J. Houlahan, R. van der Ree, E.A. van der Grift. 2016. How effective is road mitigation at reducing road-kill? A meta-analysis. PLoS ONE 11(11): e0166941. Doi:10.137/journal.pone.0166941.

Santos, S. M., F. Carvalho, and A. Mira. 2011. How long do the dead survive on the road? Carcass persistence probability and implications for road-kill monitoring surveys. PloS one [electronic resource] 6:e25383–e25383.

Sanzo, D. and S.J. Hecnar. 2006. Effects of road de-icing salt (NaCl) on larval wood frogs (Rana sylvatica). Environmental Pollution 140:247-256.

Sarell, M. Undated. Snake Barrier Fencing. Part of the Living in Nature Series. Prepared for the South Okanagan Similkameen Stewardship Program, Penticton, BC.

Sarell 1993

Sarell, M.J. 2004. Racer. Pp 1 – 7 in Accounts and Measures for Managing Identified Wildlife. BC Ministry of Environment, Victoria, British Columbia. Web site: http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Reptiles/r_racer.pdf [accessed Feb 2019]

Sarell, M.J., and S. Robertson. 1994. Survey of tiger salamanders (Ambystoma tigrinum) in the Okanagan Sub-region (1994). B.C. Environment, Victoria, British Columbia. 5 p.

Schmetterling, D. A., and M. K. Young. 2008. Summer movements of boreal toads (Bufo boreas boreas) in two western Montana basins. Journal of Herpetology 42:111-123.

Schmidt, B. R., and S. Zumbach. 2008. Amphibian road mortality and how to prevent it: A review. Pages 157–167 in J. C. Mitchell, R. E. Jung Brown, and B. Bartolomew, editors. Urban Herpetology. Society for the Study of Amphibians and Reptiles.

Seburn, D. C. 2007. Recovery strategy for species at risk turtles in Ontario. Draft Report for the Ontario Multi-species Turtles at Risk Recovery Team, Ontario, Canada.

Semlitsch, R. D. 2008. Differentiating migration and dispersal processes for pond-breeding amphibians. Journal of Wildlife Management 72:260-267.

Serra Shean, J.T.S. 2002. Post-breeding movements and habitat use by the Northern Red-legged Frog, Rana aurora aurora, at Dempsey Creek, Thurston County, Washington. M.Sc. dissertation. Evergreen State College, Olympia, Washington. 89 pp.

Sheppard, R. F. 1977. The ecology and home range movements of Ambystoma macrodactylum krausei (Amphibia: Urodela). M. Sc. thesis, University of Calgary, Calgary, AB. 138 pp.

Shewchuk, C.H. 1996. The natural history of reproduction and movement patterns in the gopher snake (Pituophis melanoleucus) in Southern British Columbia. MSc thesis, Dept. of Biology, University of Victoria, Victoria, British Columbia.

Shewchuk, C.H., and H.L. Waye 1995. Status of the Western Yellow-bellied Racer in British Columbia. Unpubl. report prepared for Ministry of Water, Land and Air Protection, Lands and Parks. Victoria, British Columbia. 16 pp.

Shine, R., M. Lemaster, M. Wall, T. Langkilde, and R. Mason. 2004. Why did the snake cross the road? Effects of roads on movement and location of mates by garter snakes (*Thamnophis sirtalis parietalis*). Ecology and Society 9:9.

Slater, F. M. 2002. An assessment of wildlife road casualties–the potential discrepancy between numbers counted and numbers killed. Web Ecology 3:33–42.

Smith, D. J. 2003. Monitoring wildlife use and determining standards for culvert design. Unpublished report to Florida Department of Transportation.

Smith, D. J., D. Marsh, K. E. Gunson, and S. Tonjes. 2015. Monitoring and adaptive management of road impacts and mitigation. Pages 240-261 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Snook and Blaine 2012

Smith, D. J., and R. F. Noss. 2011. A reconnaissance study of actual and potential wildlife crossing structures in Central Florida, final report. UCF-FDOT Contract No. BDB-10. Florida Department of Transportation.

Souder 2000

Southern Interior Reptile and Amphibian Working Group. 2016. Recovery plan for the Blotched Tiger Salamander (*Ambystoma mavortium*) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, BC. 39 pp.

Spalding 1995

Steen, D. A., and J. P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.

Steen, D., L. Smith, G. Miller, and S. Sterrett. 2006. Post-breeding terrestrial movements of Ambystoma tigrinum (Eastern Tiger Salamanders). Southeastern Naturalist 5(2):285-288.

Steen, D.A., J.P. Gibbs, K.A. Buhlmann, J.L. Carr, B.W. Compton, J.D. Congdon, J.S. Doody, J.C. Godwin, K.L. Holcomb, D.R. Jackson, F.J. Janzen, G. Johnson, M.T. Jones, J.T. Lamer, T. Langen, M.V. Plummer, J.W. Rowe, R.A. Saumure, J.K. Tucker, and D.S. Wilson. 2012. Terrestrial habitat requirements of nesting freshwater turtles. Biological Conservation 150:121–128.

Steciw, J. 2018. Snake den construction 2016. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Stevens et al. 2006

Stevens et al. 2007

Sullivan, B.K. 1981. Observed differences in body temperature and associated behaviour of four snake species. Journal of Herpetology 15:245-246.

Summit Environmental Consultants 2010

Taylor, B. D., and R. L. Goldingay. 2003. Cutting the carnage: wildlife usage of road culverts in north-eastern New South Wales. Wildlife Research 30:529–537.

Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos 68:571–573.

Thoms, C., C.C. Corkran and D.H. Olsen. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. In D.H. Olsen, W.P. Leonard and R.B. Bury (eds.) Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Society for Northwestern Vertebrate Biology, Olympia, Washington.

Torres, A., C. Palacín, J. Seoane, and J.C. Alonso. 2011. Assessing the effects of a highway on a threatened species using Before–During–After and Before–During–After-Control–Impact designs. Biological conservation 144, 2223–2232.

TRCA. 2013. Heart Lake Road Ecology Volunteer Monitoring Project, Phase II. Toronto and Region Conservation Authority (TRCA), Toronto, Ontario. Available from http://www.trca.on.ca/dotAsset/187823.pdf

Tuttle and Hawkes 2011

United States Department of Agriculture (USDA). n.d. Dust Palliative Selection and Application Guide. Technology & Development Program, Forest Services, United States Department of Agriculture. Retrieved from https://www.fs.fed.us/eng/pubs/html/99771207/99771207.html#Pall (Accessed 14 December 2018).

van der Grift, E., F. Ottburg, and R. Snep. 2009. Monitoring wildlife overpass use by amphibians: Do artificially maintained humid conditions enhance crossing rates? Pages 341-347 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2009 International Conference on Ecology and Transportation. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

van der Grift, E. A., S. Findlay, R. van der Ree, L. Fahrig, J. Houlahan, L. F. Madriñan, J.A.G. Jaeger, Nina Klar, and L. Olson. 2013. Evaluating the effectiveness of road mitigation measures. Biodiversity Conservation DOI 10.1007/s10531-012-0421-0.

van der Ree R., J.A.G. Jaeger, T. Rytwinski, and E. van der Grift. 2015. Good science and experimentation are needed in road ecology. Pages 71-81 in: R. van der Ree, C. Grilo, and D. Smith, editors. Handbook of Road Ecology. Wiley Publications.

van Gelder, J.J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo bufo L.* Oecologia 13: 93-95.

Vos, C. C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology 35:44–56.

Wahbe, T. R., F.L. Bunnell, and R.B. Bury. 2004. Terrestrial movements of juvenile and adult tailed frogs in relation to timber harvest in coastal British Columbia. Canadian Journal of Forest Research 34: 2455-2466.

Watson, J.W., K.R. McAllister, and D.J. Pierce. 2003. Home ranges, movements, and habitat selection of Oregon spotted frogs (Rana pretiosa). Journal of Herpetology 37:292–300.

Waye, H.L. and J.M. Cooper. 2000. Status of the Northern Leopard Frog (Rana pipiens) in the Creston Valley Wildlife Management Area 1999. Columbia Basin Fish and Wildlife Compensation Program.

Waye, H., and C.H. Shewchuk. 2002. COSEWIC status report on the Gophersnake Pituophis catenifer in Canada, in COSEWIC assessment and status report on the Gophersnake Pituophis catenifer in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. 33 pp.

Wershler, C.L. 1991. Status of the Northern Leopard Frog in Alberta - 1990. Alberta Forestry Lands & Wildlife, Edmonton, Alberta.

White, K. 2008. Spatial ecology and life history of the Great Basin Gopher Snake (Pituophis catenifer deserticola) in British Columbia's Okanagan Valley. M.Sc. Thesis, University of British Columbia, Department of Biology, Vancouver, British Columbia.

Whitelock, C. 2014. 2013 Long Point causeway monitoring and adaptive management report. Unpublished report.

White, K. 2008. Spatial ecology and life history of the Great Basin Gopher Snake (Pituophis catenifer deserticola) in British Columbia's Okanagan Valley. M.Sc. Thesis, University of British Columbia, Department of Biology, Vancouver, British Columbia.

Williams, K.E., K.E. Hodges, and C.A. Bishop. 2012. Small reserves around hibernation sites may not adequately protect mobile snakes: the example of Great Basin Gopher Snakes in British Columbia. Canadian Journal of Zoology 90(3):304-312.

Willson, R. J., and G. M. Cunnington. 2014. DRAFT Recovery strategy for the Blue Racer (*Coluber constrictor foxii*) in Ontario. Page vi + 35. Ontario Recovery Strategy Series. Prepared for the

Ontario Ministry of Natural Resources, Peterborough, Ontario.

Willson, R.J. 2005. Artificial hibernation site construction for Eastern Massasaugas in Georgian Bay. Report submitted to the Ontario Ministry of Natural Resources.

Wilson, J.S. and S. Topham. 2009. The negative effects of barrier fencing on the Desert Tortoise (*Gopherus agassizii*) and non-target species: is there room for improvement? Contemporary Herpetology 2009:1-4.

Wind, E. 2012. Amphibian road surveys and mitigation assessments at three sites on Vancouver Island. Unpublished report produced for Environmental Management Section, Ministry of Transportation and Infrastructure, Victoria, B.C. E. Wind Consulting, Nanaimo. B.C.

Wind and Willmott 2012

Wind, E. 2014. Amphibian road surveys and mitigation assessments at Wake Lake on Vancouver Island in 2012. Unpublished report to the BC Ministry of Transportation and Infrastructure.

Wind, E. 2018. Western Toad Winter Habitat Requirements in Modified Landscapes on Vancouver Island Year 3. Unpublished report prepared for the MFLNRO, Nanaimo, BC and the Habitat Conservation Trust Foundation, Victoria, BC.

Wind, E. 2018. Amphibian road surveys and mitigation assessments at two sites on Vancouver Island for MoTI. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Winton, S. 2017. Road mortality hot spots and movement corridors of at-risk snake species in the White Lake Basin of British Columbia. Unpublished report prepared for Orville Dyer, Ecosystems Branch, BC Ministry of Environment, Penticton, BC.

Winton, S. 2018. Impacts of Road Mortality on the Western Rattlesnake (Crotalus oreganus) in British Columbia. Master of Science thesis, Thompson Rivers University, Kamloops, BC.

Woltz, H. W., J. P. Gibbs, and P. K. Ducey. 2008. Road crossing structures for amphibians and reptiles: informing design through behavioral analysis. Biological Conservation 141:2745–2750.

Yannis, I. 2011. Effectiveness of road barriers and underpasses for reptiles: The case of Milos viper (*Macrovipera schweizeri*). Proceedings of the 2011 IENE conference.

Yorks, D. T., P. R. Sievert, and D. J. Paulson. 2011. Experimental tests of tunnel and barrier options for reducing road mortalities of freshwater turtles. Page 1034 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, Raleigh, NC.

9.0 APPENDICES

Appendix A – Amphibian and Reptile Species, their status (federally SARA listed species are highlighted in bold), and the TRANS region(s) where they occur. (current to June 2018; please check SARA registry and BC Species and Ecosystem Explorer for updates)

Scientific Name	English Name	COSEWIC*	BC List	Identified Wildlife	SARA*	MOE Region(s)**	TRAN Region(s)
TERRESTRIAL-BREEDING SALAMANDERS							
Aneides vagrans	**Wandering Salamander**	**SC (2014)**	**Blue**		**1-SC (2018)**	**1**	**1,2,3 (some Georgia Strait islands - 3 or 5?)**
Ensatina eschscholtzii	Ensatina	NAR (1999)	Yellow			1,2,5,6	1,2,3,4,5,6
Plethodon idahoensis	**Coeur d'Alene Salamander**	**SC (2007)**	**Yellow**	**Yes (2004)**	**1-SC (2003)**	**4**	**9,10**
Plethodon vehiculum	Western Red-backed Salamander	NAR (2001)	Yellow			1,2	1,2,3,4,6, south end of 5
STREAM-BREEDING AMPHIBIANS							
Ascaphus montanus	**Rocky Mountain Tailed Frog**	**T (2013)**	**Blue**	**Yes (2004)**	**1-T (2018)**	**4**	**11**
Ascaphus truei	**Coastal Tailed Frog**	**SC (2011)**	**Yellow**	**Yes (2004)**	**1-SC (2003)**	**1,2,3,5,6,8**	**4,5,6,7,17,26**
Dicamptodon tenebrosus	**Coastal Giant Salamander**	**T (2014)**	**Blue**	**Yes (2004)**	**1-T (2003)**	**2**	**7**
POND-BREEDING AMPHIBIANS							
Ambystoma gracile	Northwestern Salamander	NAR (1999)	Yellow			1,2,5,6	1,2,3,4,5,6,7,17,26
Ambystoma macrodactylum	Long-toed Salamander	NAR (2006)	Yellow			1,2,3,4,5,6,7,8,9	1-21, 23-28
Ambystoma mavortium	**Blotched Tiger Salamander**	**E (2012)**	**Red**	**Yes (2004)**	**1-E (2018)**	**8**	**8,9**
Anaxyrus boreas	**Western Toad**	**SC (2012)**	**Yellow**		**1-SC (2005)**	**1,2,3,4,5,6,7,8,9**	**1-28**
Lithobates pipiens	**Northern Leopard Frog**	**E (2009)**	**Red**	**Yes (2004)**	**1-E (2003)**	**1,4,8**	**10,11**
Lithobates sylvaticus	Wood Frog		Yellow			3,4,5,6,7,9	11,12,15-26, 28
Pseudacris maculata	Boreal Chorus Frog		Yellow			7,9	21,22
Pseudacris regilla	Northern Pacific Treefrog		Yellow			1,2,3,4,5,6,7,8,	1-18,20,27
Rana aurora	**Northern Red-legged Frog**	**SC (2015)**	**Blue**	**Yes (2004)**	**1-SC (2005)**	**1;2;5;6**	**1-7,17**
Rana luteiventris	Columbia Spotted Frog	NAR (2000)	Yellow			2,3,4,5,6,7,8,9	4-27,28
Rana pretiosa	**Oregon Spotted Frog**	**E (2011)**	**Red**		**1-E (2003)**	**2**	**6,7**
Spea intermontana	**Great Basin Spadefoot**	**T (2007)**	**Blue**	**Yes (2004)**	**1-T (2003)**	**3,5,8**	**8,9,13-15**
Taricha granulosa	Roughskin Newt		Yellow			1,2,3,5,6	1,2,3,4,5,6,7,17,26
Lithobates catesbeianus	American Bullfrog		Exotic				1,2,6,7
Lithobates clamitans	Green Frog		Exotic				1,2,3,4,5,6,7,8

* SC - Special Concern; NAR - Not at Risk; T - Threatened; E - Endangered

*** MOE Region: 1 - Vancouver Island; 2 - Lower Mainland; 3 = Thompson-Nicola; 4 - Kootenays; 5 - Cariboo; 6 - Skeena-Bulkley Valley; 7 - Omineca; 8 - Okanagan; 9 - Peace*

Scientific Name	English Name	COSEWIC*	BC List	Identified Wildlife	SARA*	MOE Region**	TRAN Region(s)
TURTLES							
Chrysemys picta pop. 1	**Painted Turtle - Pacific Coastal Population**	**T (2016)**	**Red**		**1-E (2007)**	**1,2**	**1,2**
Chrysemys picta pop. 2	**Painted Turtle - Intermountain-Rocky Mountain Pop.**	**SC (2016)**	**Blue**		**1-SC (2007)**	**3,4,5,8**	**south part of 5, 8-11, 13**
Trachemys scripta	Pond Slider		Exotic				1,2,4,6,8,9 (in lakes & ponds in many cities and towns)
LIZARDS							
Elgaria coerulea	Northern Alligator Lizard	NAR (2002)	Yellow			1,2,3,4,5,8	**1-11,13,14**
Plestiodon skiltonianus	**Western Skink**	**SC (2014)**	**Blue**		**1-SC (2005)**	**3,4,8**	**8-10**
Podarcis muralis	Common Wall Lizard		Exotic				1
SNAKES							
Charina bottae	**Northern Rubber Boa**	**SC (Apr 2016)**	**Yellow**		**1-SC (2005)**	**2,3,4,5,8**	**4-11,13-16**
Coluber constrictor	**North American Racer**	**T (2015)**	**Blue**	**Yes (2006)**	**1-SC (2006)**	**2,3,4,5,8**	**8,9, 13-16**
Contia tenuis	**Sharp-tailed Snake**	**E (2009)**	**Red**		**1-E (2003)**	**1,2,3**	**1,4**
Crotalus oreganus	**Western Rattlesnake**	**T (2015)**	**Blue**	**Yes (2006)**	**1-T (2005)**	**3,8**	**8,9,13-15**
Hypsiglena chlorophaea	**Desert Nightsnake**	**E (2011)**	**Red**		**1-E (2003)**	**8**	**8**
Pituophis catenifer	**Gopher Snake - *deserticola* subspecies**	**T (2013)**	**Blue**		**1-T (2005)**	**1,2,3,4,5,8**	**8,9, 13-16**
Thamnophis elegans	Terrestrial Gartersnake		Yellow			1,2,3,4,5,6,7,8,9	1-17
Thamnophis ordinoides	Northwestern Gartersnake	NAR (2003)	Yellow			1,2,3,5	1-7
Thamnophis sirtalis	Common Gartersnake		Yellow			1,2,3,4,5,7,8,9	all

* SC - Special Concern; NAR - Not at Risk; T - Threatened; E - Endangered

*** MOE Region: 1 - Vancouver Island; 2 - Lower Mainland; 3 = Thompson-Nicola; 4 - Kootenays; 5 - Cariboo; 6 - Skeena-Bulkley Valley; 7 - Omineca; 8 - Okanagan; 9 - Peace*

APPENDIX B – Impacts of Roads on Amphibians and Reptiles (federally listed species are highlighted in bold)

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
TERRESTRIAL-BREEDING SALAMANDERS		
Wandering Salamander	Few reported at any site. Highway 4 Ucluelet-Tofino: 21 dead over 6 years, < 1% of the population adjacent to the highway killed each year (Beasley unpubl. data); Lazo Rd, Comox: 1 live, 2 dead in 2011; Nanaimo Lakes Rd: 1 dead from 2007-2011 (Wind 2012). Ross-Durrance Rd, Highlands (CRD): 1 dead adult in 2015 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015b).	Genetic divergence found in several populations of terrestrial-breeding salamanders bisected by large highways (Marsh *et al.* 2008).
Ensatina	Lazo Rd, Comox: 1 live, 1 dead in 2011; Nanaimo Lakes Rd: 97 dead, 33 live from 2007-2011; Riverbottom Rd at Wake Lake near Duncan (Wind 2012). Highlands & Saanich (CRD): 33 live, 8 dead from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b and Ovaska and Engelstoft, unpubl. data).	
Coeur d'Alene Salamander	Mt Revelstoke National Park road: numerous adults and juveniles on wet paved road surface, Sept. 2010 (Ovaska and Sopuck, unpubl. data). Rangewide: Found clinging to rock walls and venturing onto the gravel shoulder of highways on rainy nights (Ohanjanian 2003).	A threat to at least 20 of the 56 known species sites is highway widening and maintenance (COSEWIC 2007). Planned widening of the Trans-Canada Highway near Revelstoke would cause direct mortality and habitat disruption (B.C. MOE 2015). Rock-scaling, ditch-cleaning, culvert repair and replacement, blasting, vegetation clearing, dumping of spoil, and salt application will cause mortality/harm.
Western Red-backed Salamander	Highway 4 Ucluelet-Tofino: 26 dead, 25 live from 2001-2006 (Beasley 2006); Nanaimo Lakes Rd: 57 dead, 13 live from 2007-2011; Riverbottom Rd at Wake Lake near Duncan; Lazo Rd, Comox: 1 live, 1 dead in 2011 (Wind 2012); Highlands, Saanich, and East Sooke (CRD): 9 live, 4 dead from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	
STREAM-BREEDING AMPHIBIANS		
Rocky Mountain Tailed Frog	Not reported. Risk of road mortality may be low because of nocturnal habits and low traffic volumes at night.	Extensive road networks in Yahk and Flathead areas are sources of chronic sedimentation that lower tadpole abundance (Dupuis and Friele 2002, 2004). Full-round culverts are barriers to upstream movements; General Wildlife Measures within Tailed Frog Wildlife Habitat Areas specify the use of bridges or open-bottom (half-round) culverts for road crossings (B.C. Ministry of

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
		Water, Land and Air Protection 2004).
Coastal Tailed Frog	Not reported.	Sedimentation from constructed channel crossings (Ardea Biological Consulting Ltd. 1999, Dupuis and Friele 2003). Road use is chronic source of sedimentation (Reid and Dunne 1984).
Coastal Giant Salamander	Not reported. The majority of roads in the region where this species occurs are in upslope habitats that are less occupied (i.e., not near and parallel to watercourses) (COSEWIC 2014).	Sediments and chemical pollutants to reduce road dust and to de-ice roads; fragmented forest habitats interfere with movement and dispersal of adults and juveniles (COSEWIC 2014).
POND-BREEDING AMPHIBIANS		
Northwestern Salamander	Highway 4 Ucluelet-Tofino: 258 dead, 139 live (Beasley 2006); Lazo Rd, Comox: 6 dead, 3 live in 2011; Nanaimo Lakes Rd: 14 dead, 5 live from 2007-2011 (Wind 2012).	
Long-toed Salamander	Lazo Rd, Comox: 5 dead, 5 live in 2011; Nanaimo Lakes Rd: 25 dead, 6 live from 2007-2011 (Wind 2012); Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 3A at Grohman Narrows Provincial Park: 16 dead, 10 live in Mar/Apr 2015 (Dulisse 2015); White Lake: 23 dead from 2015-2016, though this is an underestimate, as car-based surveys ceased to prevent additional road mortality (Winton 2017); Highlands & Saanich (CRD): 9 dead, 13 live from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	
Blotched Tiger Salamander	Highway 97 Oosoyoos: 13 dead, 2 live from 2010-2012 (Crosby 2014); White Lake, Penticton: 240 dead juveniles from 4 surveys, 2-23 Aug 2013 (Dyer 2018); White Lake: 13 dead from 2015-2016 (Winton 2017).	
Western Toad	Vancouver Island sites: Sooke Mainline at Sooke Lake, Riverbottom Rd in Duncan, Spruston Rd in Nanaimo, Katherine Dr in Port Alberni, Highway 19 near Courtenay, Railway Ave in Merville, MU-55 near Gold River—all report high mortality of juveniles and some adults (Wind and Willmott 2012). Also at Nanaimo Lakes Rd in lower numbers (Wind 2012). Mainland/Interior sites: Ryder Lake Rd in Chilliwack (Clegg 2011), Allard Crescent in Langley, Lost Lake in Whistler (Wind and Willmott 2012), Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011), Prince George (Thompson, pers. comm. 2011 in COSEWIC 2012), Dawson Creek (Kinsey pers. comm. 2011 in COSEWIC 2012), Chilliwack, and Summit Lake (Dulisse et al. 2017), Kentucky-Alleyne Provincial Park 2011 - 2014 (Biolinx Environmental Research & Nicola Naturalist Society 2013, 2014), Highway 31A at Fish/Bear Lakes (McCrory and Mahr 2018),	Irrigation ponds/borrow pits created during road construction provide poor larval habitat (Stevens et al. 2006). Beaver control, used to prevent road flooding, can result in loss and deterioration of breeding habitat (Stevens et al. 2007). Roadside culverts and verges of logging roads used as movement corridors (Deguisse and Richardson 2009).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	Highway 22A near Waneta Dam. Most report both juvenile and adult mortality (Machmer 2012, 2015).	
Northern Leopard Frog	Dyke road at Creston Valley Wildlife Management Area: 1 adult and 1 young-of-the-year killed with only 2 cars using the road (Houston 2010a). Remain immobile at the approach of a vehicle (Mazerolle et al. 2005). Very small amount of road mortality impacts the very small population of Northern Leopard Frogs at Creston.	
Wood Frog	No data	
Boreal Chorus Frog	No data	
Northern Pacific Treefrog (a.k.a. Pacific Chorus Frog)	Highway 4 Ucluelet-Tofino: 315 dead, 69 live from 2001-2006 (Beasley 2006); Lazo Rd, Comox: 299 dead, 32 live in 2011; Nanaimo Lakes Rd, Nanaimo, and Riverbottom Rd at Wake Lake near Duncan (Wind 2012); Highway 97 near Oosoyoos: 279 dead, 148 live from 2010-2012 (Crosby 2014); Ryder Lake Rd in Chilliwack (Clegg 2011); Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 3A at Grohman Narrows Provincial Park: 81 dead, 13 live in Mar/Apr 2015 (Dulisse 2015); Highlands, Saanich, Metchosin, East Sooke (CRD): 1099 dead, 256 live from 2015-2018 surveys (74% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data); White Lake: 114 dead from 2015-2016 (Winton 2017); Highway 22A near Waneta Dam: 13 dead during the Waneta Expansion Project 2011-2014 (Machmer 2012, 2015).	
Northern Red-legged Frog	Highway 4 Ucluelet-Tofino: 330 dead, 37 live, 2001-2006, (Beasley 2006); Coombs (Blood and Henderson 2000); Nanaimo Lakes Rd (Wind 2012); Highway 4 within Pacific Rim National Park Reserve; Ryder Lake Rd in the Fraser Valley (Clegg 2011); Laburnum Rd, Qualicum (Materi 2008); Lazo Rd, Comox: 78 dead, 2 live in 2011 (Wind 2012); Wake Lake near Duncan (Wind 2012); Sea-to-Sky Highway at Pinecrest (Malt 2012); Highlands, Saanich, Metchosin (CRD): 30 dead, 10 live (2% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	Road construction along Sea-to-Sky Highway 99 resulted in removal of 4160 m^2 of wetland habitat and salvage of 1,037 amphibians (including 683 Northern Red-legged Frogs). Roads are barriers to movement in dry conditions (B. Beasley, unpubl. data). Road de-icing salts and other pollutants from roads drain into ditches and wetlands where the species spends time, and sometimes breeds (B. Beasley, unpubl. data).
Columbia Spotted Frog	Highway 22A near Waneta Dam: 3 dead during the Waneta Expansion Project 2011-2014 (Machmer 2012, 2015).	
Oregon Spotted Frog	Not reported. Populations at Maintenance Detachment Aldergrove, Maria Slough, and Mountain Slough are close to roads but road mortality is a knowledge gap. Road mortality is not anticipated for this species as it does not spend substantial time out of water. Western Toads and Northern Red-legged Frogs have been found dead on the roads adjacent to the Maria Slough site. Oregon Spotted Frogs	At Maria Slough, improper timing of culvert maintenance and watercourse clearing resulted in water level dropping and stranding eggs out of water. Ditch clearing and deepening alters availability and suitability of habitat, causes direct

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	are thought to move through wetted culverts with low water flow (K. Morgan, pers. comm.).	mortality, and enables American Bullfrog (an invasive competitor/predator) occupation and breeding. Roads isolate populations and prevent new colonization.
Great Basin Spadefoot	Inkaneep Rd near Oliver, July 1990 (R. Cannings, pers. obs.); Highway 97 near Osoyoos: 1,648 dead, 1,894 live from 2010-2012 (Crosby 2014); White Lake: 44 dead from 2015-2016 (Winton 2017); Douglas Lake Rd, Upper Nicola: 21 live adults and juveniles on road from 2011-2015 (Ovaska et al. 2016 and Ovaska unpubl. data).	Effects of magnesium chloride for dust abatement during road maintenance need study (Packham, pers. comm., 2014).
Rough-skinned Newt	Highway 4 near Coombs (Blood and Henderson 2000); Nanaimo Lakes Road: 1,781 dead, 81 live from 2007-2011 (Wind 2012); Highway 4 Ucluelet-Tofino: 65 dead, 6 live from 2001-2006 (Beasley 2006); Ryder Lake Rd in the Fraser Valley (Clegg 2011); Lazo Rd, Comox: 313 dead, 14 live in 2011; Wake Lake, Duncan: 11 dead, 2 live in 2011 (Wind 2012); Highlands, Saanich, Metchosin (CRD): 334 (14% of amphibians) dead, 28 live (22.5% of roadkill of amphibians that could be identified to species) (HAT 2015, Ovaska and Engelstoft, unpubl. data). Gulf Islands - numerous roads (Penn, pers. comm. 2018).	

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
TURTLE		
Painted Turtle	Beaver Lake Rd in Saanich (Ovaska and Engelstoft 2011); Sunshine Coast Highway (Kilburn et al. 2011); Arrow Lakes Reservoir (Tuttle and Hawkes 2011); White Lake: 2 dead from 2015-2016 (Winton 2017); Highway 6 at Summit Lake (Dulisse 2018); Highway 3 in Cranbrook (Gillies and St. Clair 1997). Nesting females are killed when crossing these roads to nest in the fill material or exposed cutbanks along roadsides, or to nest at sites on the opposite side of the road.	Road construction immediately adjacent to wetlands destroys nests (Maltby 2000). Roadways increase predaton by raccoons, skunks, coyotes, and foxes (Frey and Conover 2006).
LIZARDS		
Northern Alligator Lizard	Creston: Not commonly found on roads even though six of ten sites within a study were bordered on one side by a road (Rutherford and Gregory 2001).	Not attracted to roads as heat sources but it is possible that roads serve as barriers between populations (Rutherford and Gregory 2001).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
Western Skink	Creston: Not commonly found on roads even though six of ten sites within a study were bordered on one side by a road (Rutherford and Gregory 2001).	Rock blasting may cause direct mortality and destruction of important basking sites, nesting sites, or hibernacula. Conversely, road and other corridor construction may enhance skink habitat through the creation and maintenance of open areas. Also, blast rock pieces that are created from the construction of roads, power lines, or pipelines may also increase available cover for skinks (Dulisse 2006b).
SNAKES		
Northern Rubber Boa	Okanagan, Creston, Pemberton—Lillooet Highway (P. Gregory, pers. comm. 2014 cited by COSEWIC).White Lake: 19 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 18 dead during the Waneta Expansion Project 2011-2014 and 1 dead prior to the Project 2009 (Machmer 2012, 2015)	Bentley Rd to Okanagan Lake Parkway Highway construction destroyed den and snakes (Summit Environmental Consultants 2010).
Western Yellow-bellied Racer	Okanagan Connector: almost all suitable habitats are intersected by road. White Lake: 128 dead from 2015-2016 (Winton 2017); Highway 22A near Waneta Dam: 29 dead, 3 alive during the Waneta Expansion Project 2011-2014 and 2 dead prior to the Project in 2009 (Machmer 2012, 2015)	Habitat loss and fragmentation.
Sharp-tailed Snake	North Pender and South Pender Islands: 6 dead (Spalding 1995; Engelstoft and Ovaska 1999; C. Engelstoft, pers. comm., 2008). Ferry terminal on Saltspring Island: 45% annual increase in vehicle traffic (from 147,830 vehicle trips in 1992-1993 to 214,787 trips in 2001-2002) within the past decade increases risk to snakes nearby (B. Bourquin, pers. comm., 2002). Another site on Vancouver Island is bisected by a popular recreational trail, and mortality from collisions with bicycles is a possibility although undocumented.	Localities on Gulf Islands: habitat fragmentation hinders dispersal movements.
Western Rattlesnake (a.k.a. North Pacific Rattlesnake)	Osoyoos Indian Reserve: roadkills were 72-100% of known mortalities over the 3-year period reported (Snook and Blaine 2012); White Lake: 92 dead from 2015-2016 (Winton 2017) with 6.6% of rattlesnake population killed on road annually and projected population decline (Winton 2018); Highway 97 between US border and Okanagan Falls: none detected from 2010-2013, though heavy traffic incompatible with species (S. Ashpole, pers. comm., 2014).	Both snakes and hibernacula destroyed by earth-moving equipment during road construction (M. Sarell, pers. obs.).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	Across BC range: 50% of 106 dens were subject to regular road mortality or to damage from road construction (Sarell 1993); 86% of 368 confirmed dens located within 2 km of a road (Hobbs 2013).	
Desert Nightsnake	South-central British Columbia: Only about 20 Desert Nightsnakes have been reported in Canada, all from a small region that is under intense development pressure.	Habitat loss and population isolation.
Great Basin Gopher Snake	Highway 1 from Chase to Ashcroft and Highway 97 from Summerland to Peachland: local extirpations/precipitous declines (J. Hobbs, pers. comm., 2013). White Lake: 84 dead from 2015-2016 (Winton 2017).	Highways 3 and 8 bisect prime habitat.
Terrestrial Gartersnake	Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011). White Lake: 9 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 8 dead, 2 alive during the Waneta Expansion Project 2011-2014 and 1 dead, 1 alive prior to the Project 2009 (Machmer 2012, 2015)	
Northwestern Gartersnake		
Common Gartersnake	Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 4 Ucluelet—Tofino (B. Beasley, unpubl. data); White Lake: 20 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 5 dead, 1 alive during the Waneta Expansion Project 2011-2014 and 3 dead, 1 alive prior to the Project 2009 (Machmer 2012, 2015)	

APPENDIX C – General Habitat Associations of Amphibians and Reptiles in BC

Scientific Name	English Name	**Forest** (moist/wet, mesic, dry, mixed, deciduous, Garry Oak coastal bluffs)	**Shrub** (natural, logged, sagebrush steppe, Antelopebrush steppe, hedgerow)	**Meadow / Grassland**	**Rock** (cliff, sparsely vegetated rock, talus)	**Subterreanean** (subsoil, caves)	**Riparian** (forest, shrub, herbaceous)	**Seeps / streams** (stream, river. Splash zone, gravel bar)	**Wetland / Lake** (bog, fen, swamp, marsh, lake, pond / open water, vernal pool)	**Built / Industrial** (urban, suburban)	**Agricultural** (pasture, old field, cultivated field)
TERRESTRIAL-BREEDING SALAMANDERS											
Aneides vagrans	**Wandering Salamander**	**X**	**X**		**X**		**X**				
Ensatina eschscholtzii	Ensatina	X				X	X				
Plethodon idahoensis	**Coeur d'Alene Salamander**	**X**			**X**	**X**	**X**	**X**			
Plethodon vehiculum	Western Red-backed Salamander	X			X	X	X				
STREAM-BREEDING AMPHIBIANS											
Ascaphus montanus	**Rocky Mountain Tailed Frog**	**X**					**X**	**X**			
Ascaphus truei	**Coastal Tailed Frog**			**X**			**X**	**X**			
Dicamptodon tenebrosus	**Coastal Giant Salamander**	**X**					**X**	**X**			
POND-BREEDING AMPHIBIANS											
Ambystoma gracile	Northwestern Salamander	X					X	X	X		
Ambystoma macrodactylum	Long-toed Salamander										
Ambystoma mavortium	**Blotched Tiger Salamander**										
Anaxyrus boreas	**Western Toad**	**X**		**X**			**X**	**X**	**X**		
Lithobates pipiens	**Northern Leopard Frog**			**X**			**X**	**X**	**X**		
Lithobates sylvaticus	Wood Frog	X		X			X	X	X		
Pseudacris maculata	Boreal Chorus Frog						X		X		
Pseudacris regilla	Northern Pacific Treefrog										
Rana aurora	**Northern Red-legged Frog**	**X**		**X**			**X**	**X**	**X**		
Rana luteiventris	Columbia Spotted Frog						X	X	X		
Rana pretiosa	**Oregon Spotted Frog**						**X**	**X**	**X**		
Spea intermontana	**Great Basin Spadefoot**	**X**	**X**	**X**					**X**		
Taricha granulosa	Roughskin Newt										
Lithobates catesbeianus	American Bullfrog							X	X		
Lithobates clamitans	Green Frog										

Scientific Name	English Name	**Forest** (moist / wet, mesic, dry, mixed, deciduous, Garry Oak coastal bluffs)	**Shrub** (natural, logged, sagebrush steppe, Antelopebrush steppe, hedgerow)	**Meadow / Grassland**	**Rock** (cliff, sparsely vegetated rock, talus)	**Subterreanean** (subsoil, caves)	**Riparian** (forest, shrub, herbaceous)	**Seeps / streams** (stream, river. Splash zone, gravel bar)	**Wetland / Lake** (bog, fen, swamp, marsh, lake, pond / open water, vernal pool)	**Built / Industrial** (urban, suburban)	**Agricultural** (pasture, old field, cultivated field)
TURTLES											
Chrysemys picta	**Painted Turtle**						**X**	**X**	**X**	**X**	
Trachemys scripta	Pond Slider										
LIZARDS											
Elgaria coerulea	Northern Alligator Lizard	X		X	X		X	X			
Plestiodon skiltonianus	**Western Skink**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Podarcis muralis	Common Wall Lizard										
SNAKES											
Charina bottae	**Northern Rubber Boa**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Coluber constrictor	**North American Racer**	**X**	**X**	**X**	**X**						
Contia tenuis	**Sharp-tailed Snake**	**X**		**X**	**X**	**X**					
Crotalus oreganus	**Western Rattlesnake**	**X**	**X**	**X**	**X**	**X**	**X**				
Hypsiglena chlorophaea	**Desert Nightsnake**	**X**	**X**	**X**	**X**			**X**			
Pituophis catenifer	**Gopher Snake**										
Thamnophis elegans	Terrestrial Gartersnake										
Thamnophis ordinoides	Northwestern Gartersnake		X	X	X	X	X			X	X
Thamnophis sirtalis	Common Gartersnake										

APPENDIX D – Migration, Dispersal, and Movement Distances of Amphibians and Reptiles in BC (federally listed species are highlighted in bold)

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
TERRESTRIAL-BREEDING SALAMANDERS		
Wandering Salamander	No seasonal migrations, but occasionally found on roads.	94% of movements between recaptures of marked individuals at Rosewall Creek were < 10 m; average distance between captures was 2.8 m and longest distance was 38 m (N=176) (Davis 1991).
Ensatina	No seasonal migrations, but occasionally found on roads.	
Coeur d'Alene Salamander	Annual fall migration from interior of a cave to outside is ~25 m (Ohanjanian 2000).	Longest distance was 52.8 m (Ohanjanian and Beaucher 2002).
Western Red-backed Salamander	No seasonal migrations, but occasionally found on roads.	In Goldstream Provincial Park, Vancouver Island, individuals showed high fidelity to particular cover objects on the forest floor, and their movements over several years were very small: distance between 2 farthest captures was 2.5 m for adult males, 1.7 m for adult females, 2.0 m for juveniles, based on capture-mark-recapture study (Ovaska 1988).
STREAM-BREEDING AMPHIBIANS		
Rocky Mountain Tailed Frog	Seasonal migration mainly follows elevational gradient along streams but dispersal movements between streams are also likely.	Juvenile female moved 360 m over one year 50% of reproductively mature adults had maximum movement of 20 m/yr in Montana (Daugherty and Sheldon 1982).
Coastal Tailed Frog	No seasonal migration reported. Rapid recolonization of Mt. St. Helens following the 1980 eruption (Crisafulli et al. 2005) may indicate they are capable of occasional, long-range dispersal.	Average daily distances on land of 23.3 m ± 7.8 m for females and 16.8 m ± 3.9 m for males in the B.C.'s south coast region (Wahbe et al. 2004).
Coastal Giant Salamander	Johnston (1998) and Johnston and Frid (2002) found 67% of locations of 18 radio-tracked adults in old-growth and mature second-growth forest were within 5 m of the stream bank. Longest distance of an adult from the stream bank was 66 m. Several studies in Oregon have reported the Pacific Giant Salamander up to 400 m from stream edges (reviewed in Olson et al. 2007).	Average movement lengths for individual salamanders ranged from 3 to 21 m (Johnston and Frid 2002). Average adaptive kernel home-range size for individual salamanders ranged from 3 to 35,321 m^2 (Johnston and Frid 2002).
POND-BREEDING AMPHIBIANS		
Northwestern Salamander	Migrate toward breeding ponds in fall and away from ponds in spring, some individuals crossing road > 500 m from breeding pond (Beasley	

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	2006, 2013).	
Long-toed Salamander	Migrate from over-wintering sites to breeding ponds in early spring and away from ponds after egg-laying. Individual captured 750 m from breeding pond in Hinton, Alberta (Graham 1997).	Straight-line distances between capture sites ranged from 135 to 525 m in Hinton, Alberta (Graham 1997). Home range estimates per individual ranged from 115 to 282 m^2 in the Bow Corridor of Alberta (Sheppard 1977).
Blotched Tiger Salamander	Radio-tagged adults rarely moved more than 250 m from the wetland of capture (Richardson et al. 2000; Steen et al. 2006). Juveniles are more likely to disperse than are adults (up to 20% of juveniles versus 3-6% of adults moving between wetlands in any given year; Church and Wilbur, unpubl. data cited in Church et al. 2007). Anecdotal reports exist of salamanders found up to 3 km from the nearest wetland (Sarell and Robertson 1994).	Daily movements were generally constrained within a 5-m radius and were often centred on abandoned animal burrows (Richardson et al. 2000).
Western Toad	On Vancouver Island (Davis 2000) and in east-central Alberta (Browne 2010), most Western Toads used terrestrial habitats within 2 km of breeding sites, although much longer movements have occasionally been reported. Hibernation sites have been found 146-1,936 m (Browne and Paszkowski 2010) and 180-6,230 m (Bull 2006) from breeding sites in Alberta and Oregon, respectively. Average distance from breeding site was 2500 m in Oregon (max. 6,200 m; Bull 2006), 4,400m in Montana (max. 7400m; Schmetterling and Young 2008). From COSEWIC (2012d): "Western Toads are capable of directional long-distance dispersal movements (up to 7.2 km in <24 hours in spring on Vancouver Island; Davis pers. comm. 2004). Schmetterling and Young (2008) documented movements up to 13 km." "Toads moved extensive distances in the fall and spring, averaging 496 m between their point of capture and their hibernation site, and 474 m between their hibernation site and their breeding site. Average distance that 7 non-breeders hibernated from a potential breeding site was 1438 m. Maximum fall movement from point of capture to hibernaculum was 1979 m." (Wind 2018)	Longest straight-line movement of radio-tagged adult male toads released in an unfamiliar area was 1,482 m (Deguise and Richardson 2009).
Northern Leopard Frog	Recently metamorphosized Northern Leopard Frogs disperse in all directions and have been observed 1 km from natal ponds in Creston (Waye and Cooper 2001). In southern Alberta, adults may travel up to 1.6 km from hibernation sites to breeding habitats (Wershler 1991). Seasonal dispersal distances of 8-10 km have been documented in	Adults maintain small home ranges varying from 15 to 600 m^2 (Dole 1965). Adults may move up to 160 m on a single rainy night (Waye and Cooper 2001) but generally remain in the vicinity of breeding areas.

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	Alberta (Alberta Northern Leopard Frog Recovery Team 2005).	
Wood Frog		
Boreal Chorus Frog		
Northern Pacific Treefrog (a.k.a. Pacific Chorus Frog)		
Northern Red-legged Frog	Adults appear to leave breeding sites relatively soon after the breeding period and move substantial distances (commonly 1.5 km to up to 4.8 km from breeding pools) (Hayes et al. 2001, 2007); observed travelling 312 m away in straight-line distance from breeding sites (Serra Shean 2002); some juveniles disperse over 500 m from natal ponds (Beasley unpubl. data 2014).	> 190 m (straight-line distance) through clearcuts during 2-3 rainy days (Chan-McLeod 2003); in Washington, five adult females moved up to 80 m day during the spring migration period (Serra Shean 2002).
Columbia Spotted Frog		
Oregon Spotted Frog		In Washington, home ranges during the breeding and autumn seasons averaged 1.8–1.9 ha, whereas the dry-season home range averaged only 0.9 ha (Watson et al. 2003). The same study reported movements of 32-111 m/day for 2-18 days. The longest reported movement is of an adult female frog along Jack Creek in Oregon, which moved 2,799 m (stream distance) from her original capture location (Cushman and Pearl 2007). In the same study, two juvenile frogs were recorded moving 1,245 m and 1,375 m downstream from their initial capture location.
Great Basin Spadefoot	Little information on movement distances in BC or other areas. Based on anecdotal information on spadefoots in general, spadefoots will move several hundred meters or more from breeding sites and thus, in the absence of more specific information, it can be assumed that spadefoots use terrestrial habitat up to a minimum of 500 m around breeding sites and probably up to 1 km, depending upon the terrain (COSEWIC 2007).	
Rough-skinned Newt		
TURTLE		
Painted Turtle	Movements several hundred metres overland between ponds are not uncommon (Gregory and Campbell 1987). Females, in particular, make	Based on a study of Midland Painted Turtles in a small marsh system in southern Michigan, Rowe

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	extensive use of the terrestrial environment, laying their eggs up to 150 m or more away from the water's edge. In Nebraska, this species often migrates several kilometres from shallow or dry marshes and basins to permanent water bodies during dry summer months (Ernst et al. 1994).	(2003) documented an average home range size of 1.8 ha in 1999 and 0.7 ha in 2000 in his study, and average daily travel distances of 39 m/day in 2000 and 102 m/day in 1999.
LIZARDS		
Northern Alligator Lizard	Do not make large movements between hibernation or summer sites, as far as known.	Rutherford and Gregory (2001) found an average distance of 16 m between recapture locations in Creston. The maximum distance was 500 m.
Western Skink	Rutherford and Gregory (2003) found that Western Skinks had high site fidelity over 3 years.	Rutherford and Gregory (2003) found that 25 recaptures of tagged Western Skinks in the Creston Valley Wildlife Management Area in B.C. had a mean of 8 m distance from the previous capture in the same year, with a maximum movement of 61.4 m during a season. They estimated home range to be roughly 0.01 ha (a circle with a 10 m diameter is 78 m^2 or approximately 0.01 ha) but it may be higher.
SNAKES		
Northern Rubber Boa	One hibernaculum was about 450 m from the general area that the snake used in summer (St. Clair, unpubl. data cited in COSEWIC 2016). Lowcock and Woodruff (2014) noted that some travel short distances (<100 m) to the valley bottom.	Using telemetry data, St. Clair (unpubl. data) calculated home ranges of two Northern Rubber Boas, including the hibernaculum, as 0.298 and 1.203 ha (COSEWIC 2016).
Western Yellow-bellied Racer	Migration distances from dens are poorly known for the Western Yellow-bellied Racers in British Columbia. In British Columbia, gravid females may travel more than 500 m to suitable egg-laying sites (Sarell 2004).	In Utah, radio telemetry studies by Brown and Parker (1976) indicate maximum movement distances of 1.6 and 1.8 km from two den sites, respectively, with average straight-line distance of less than 1 km (781 m for males and 663 m for females). While on their summer ranges, Shewchuk and Waye (1995) found that daily movements were usually less than 200 m and

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
		sometimes followed a circuit returning to a regular overnight roost.
Sharp-tailed Snake	There is no evidence to suggest that individual snakes undertake migration movements between seasonal habitats, and hibernation and aestivation might take place within habitats occupied year-round but long movements are very difficult to document.	Within a rural residential area on North Pender Island, 16 recaptured adult snakes were found within areas of usually less than 55 m along the greatest dimension (average = 25 m; range: 16-93 m) over a year (Engelstoft and Ovaska 1999). The longest movement was by an adult male that moved a straight-line distance of 93 m within a 3-week period in March-April (Engelstoft et al. 1999). In relatively undisturbed habitat on Vancouver Island, 5 recaptured snakes moved straight-line distances of up to 32 m within one active season (Ovaska and Engelstoft 2005).
Western Rattlesnake (a.k.a. North Pacific Rattlesnake)	The migration distance between summer foraging areas and overwintering dens varies depending on habitat, and distances of 290 to 3,500 m have been reported in BC. Gravid females do not migrate but remain within 400 m of the hibernacula, frequently at group basking areas termed rookeries (Macartney 1985; Bertram et al. 2001). The maximum migration distance of a mature male was 3,568 m (Gomez 2007), but most males remained within 1,400 m of the den (Macartney 1985, Bertram et al. 2001, Gomez 2007, Lomas 2013). Migration from dens in the Okanagan occurs along specific corridors (Macartney 1985).	The linear distance moved by ten adults (non-gravid females and males) from five dens near Kamloops varied from 290 to 3000 m (Bertram et al. 2001). Bertram et al. (2001) reported home ranges of 0.12 to 103.5 ha based on radio-telemetry locations from 12 snakes near Kamloops, with the smallest range being that of a gravid female. Other BC estimates range from 1.2 to 171 ha (Macartney 1985) and average 23 ha (Lomas 2013).
Desert Nightsnake		
Great Basin Gopher Snake	Females may travel long distances (>2 km) to nest sites. The longest single-season movements made by gopher snakes (>2 km) are generally those by females travelling to oviposition sites in summer and fall (Shewchuk 1996, Bertram et al. 2001). Brown (2006) reported that 2 females near Vaseaux Lake oviposited 81.2 m and 40.2 m from their respective hibernacula. White (2008) observed that males in her study in the Okanagan Valley moved farther than females in spring (perhaps searching for mates), while females moved farther than males in summer and fall.	Average movement distances of 350 m – 500 m have been reported from B.C. (Kamloops: average maximum of 453 m Bertram et al. 2001; Osoyoos: 934 ± 185 m (Shewchuk 1996); South Okanagan: 357 m (Williams and Bishop 2011); 520 ± 25 m (Williams et al. 2012), but occasional longer distances up to 2,360 m have been documented (Williams et al. 2012). After reaching their summer ranges, movements of snakes in Osoyoos were relatively short (average 153 ± 96.2 m/day for females and 124.8 ± 23.7 m/day for males) and

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
		were centred on a particular retreat site (Shewchuk 1996). Home ranges of 1.14-33.47 ha have been documented in BC (Bertram et al. 2001, Brown 2006, White 2008).
Terrestrial Gartersnake		
Northwestern Gartersnake		
Common Gartersnake	Travel several kilometers between foraging sites and dens.	

APPENDIX E – Examples of mitigation projects to reduce road impacts on amphibians and reptiles in BC

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Crossing Structures with Fencing				
Western Toad	Park road at Lost Lake Municipal Park, Whistler	A single tunnel (corrugated metal 60 cm diameter culvert approximately 8 m long), and over 100 m of fencing (manufactured by ACO Systems Ltd.) installed in 2014 to keep juvenile toads away from recreational areas with high human use and guide them upslope into forest. Portable ramp installed across a trail allows toads to crawl beneath while people walk overtop.	ACO wildlife fencing works well to exclude juvenile toads from high human use areas as long as it is installed properly (dug in with substrate covering back side with no gaps between panels). Toadlets safely move under ramp and follow fencing into the forest but do not use tunnel despite installing LED lights; Not possible to seal the migration path and lead toadlets to enter tunnel; road closure was more effective in past; future efforts will install new ACO fencing to guide toads to a creek flowing out of park.	Beresford 2018; Williamson pers. comm. 2018
Western Toad	Highway 6 at Summit Lake, near Nakusp	One plastic tunnel (0.86 m diameter x 16.5 m long, 1.2 m depth of fill over culvert) installed in 2006, one concrete box tunnel (1.2 m x 1.5 m wide x 21 m long, 0.58 m depth of fill over culvert) installed in 2014, 1 existing corrugated metal culvert (0.6 m in diameter x 25 m long, 2 m depth of fill over culvert) and 1152 m of fencing (550 m ACO, 310 m mesh, 240 m polypropylene sheeting, and 60 m concrete wing walls);	High use of both tunnels by adults (533) and juveniles (10s of 1000s) caught by camera traps between 2015-2018 in the plastic and concrete tunnels; regular fence maintenance required; portions of the fence will be replaced with a product made by Animex in 2019.	Dulisse et al. 2018; Dulisse, pers. comm. 2019; McGlynn pers. comm. 2019
Western Toad	Highway 31A at Fish/Bear Lakes	In 2018, installed directional fencing made of split pvc pipe (25 cm diameter and 400 m long) to guide migrating toadlets from rest area to a raised wooden structure (dimensions?) crossing under an existing highway bridge. In 2015-17, directional fencing made of ___? guided toadlets to 3 existing culverts (corrugated metal, 60 cm in	In 2018, >100,000 toadlets successfully followed fencing to crawl over the raised wooden structure under the highway bridge and moved along creek bank. Raised structure must be re-constructed each year because of seasonal stream flow. From 2015-17 toadlets followed fencing but would not cross through existing culverts despite	McCrory and Mahr 2018

		diameter?) at highway.	installing LED lights. Toads may have been deterred because one of the culverts was too dry and in the wrong orientation, the others were too wet and possibly too small (verify dimensions of all 3).	
Western Toad	Park road at Kentucky-Alleyne Provincial Park, south of Merritt	Single semi-cylindrical "half culvert" with earthen floor (3.6 m long, 1.8 cm wide at ground level, 0.5 m high, 0.3 m from top to road surface) installed in May 2013. In 2014, a temporary fence was replaced with wooden fencing (~20 cm high with a 5 cm lip) that has a 20 cm strip of landscape cloth stapled to the base of each board and buried to prevent toads from burrowing under the fence. The fence extends 136 m on the pond side of the road and 34 m on the forest side. One-way ramps allow toads to move back towards the pond.	Reduction in road mortality at the crossing location; thousands of post-metamorphic juveniles moved alongside fence and through tunnel; some spillover at fence ends	Biolinx Environmental Research Ltd and Nicola Naturalist Society 2014; Ovaska et al. 2018
Western Toad	Wake Lake	Temporary directional fencing attached to existing drainage culverts	Post-metamorphic juveniles moved through drainage culverts. Housing development plans in hotspot location make it challenging to do permanent mitigation.	Wind 2018
Western Toad	Highway 19 Courtenay	Tunnels (of various sizes) and short sections of guiding fences and barrier fences (made of steel mesh hardware cloth) attached to elk barrier fences	Toads have breached the fencing when it has not been maintained (e.g., thick vegetative growth and holes and small mammal burrows allow toads to move over or through the fence).	Fyfe and Wind 2008
Western Toad and other coastal amphibians	Ryder Lake Rd, Chilliwack	Box culvert with natural substrate and 3 daylighting openings in road surface with temporary directional fencing made of landscape cloth fabric	Camera monitoring shows amphibians are using tunnel, still collecting data to examine changes in road mortality; directional fencing is temporary in some locations due to land use, fencing is most challenging aspect to the long-term sustainability of project	Fraser Valley Conservancy 2018
Northern Red-legged Frog and other coastal	Highway 99, Pinecrest	8 tunnels ranging in length from 21 to 37 m and made of various materials including 3	Frogs reluctant to move through culverts (culvert substrates are very dry because	Malt 2012

amphibians	south of Whistler	plastic polyvinyl chloride (PVC) culverts (1 m diameter), 3 concrete culverts (2 m diameter) and 1 corrugated steel culvert (3 m diameter); fencing is made of black plastic polyethylene mesh (1/4") mounted on rebar posts, and steel mesh hardware cloth (1/4" mesh) on plastic wood stakes.	water drains away from entrances), road kill persisted except where original steel mesh fencing was installed. More fencing has been added but not monitored. Key lesson was the importance of ensuring that an adequate environmental assessment is done at road planning stage.	
Northern Red-legged Frog and other coastal amphibians	Highway 4 at Lost Shoe Creek near Ucluelet	200 m of barrier roadside fencing attached to bridge installed next to constructed salmon off-channel	Reduced road mortality of amphibians by 80% but have not monitored frequency of movements under bridge. Appears that animals stay still at fences. We suspect that rip rap under bridge would be a deterrent to movement.	Beasley 2018a
Northern Red-legged Frog and other coastal amphibians	Highway 4, between Ucluelet and Tofino	1 concrete box tunnel (1.8 m x 0.9 m x 14.5 m) with directional fencing made of fabric/plastic wood/cedar for 150 m leading to box tunnel and existing drainage culvert	Reduced road mortality, Northern Red-legged Frogs and Northwestern Salamanders use passage through both the new tunnel and existing drainage culvert, some predation events in culverts have been observed and frequencies are being monitored. Fences require regular monitoring and maintenance but maintenance costs are inexpensive.	Beasley 2018b
Great Basin Spadefoot, Blotched Tiger Salamander, Western Rattlesnake, Great Basin Gophersnake, Western Yellow-bellied Racer	Highway 97 South Okanagan	Tunnels and ACO fencing installed in 2010	Fenced areas covering both sides of the highway resulted in a 94% reduction in amphibian road occurrence for 2 years post installation. Since 2003, data collected from adjacent wetlands on species detection and reproductive success demonstrate significant variability. Fence degradation by sun, expenditures for fencing upkeep and repair range from $2000 to $10,000 CDN annually since installation.	Ashpole et al. 2018
Western Rattlesnake, Great Basin Gophersnake, Western Yellow-bellied Racer, Great Basin Spadefoot, Blotched Tiger	White Lake	11 pipe arch and 3 round corrugated steel culverts installed in 2017 with directional fencing in development	No monitoring results available yet.	Olson 2018

Salamander				
Western Painted Turtle	Highway 97, south of 150 Mile House	Corrugated metal tunnel (1.6 m diameter) across 4-lane highway with 1-m high fencing made of hardware cloth extending parallel to road from entranceways on each side of tunnel for a total of 150 m. Culvert and fencing installed from 2012 to 2015. Tunnel had to be redone because of erosion (when?)	After 4 years of monitoring with wildlife cameras, turtles do not pass through culvert; some go around the extended fence and get killed on the highway. Rip rap and strong spring current may impede turtle movement through tunnel.	Bings and Steciw 2018; Steciw pers. comm. 2019

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Artificial Habitat and/or Exclusion Fencing				
Western Toad	Highway 23 Mica Dam	Artificial pond was constructed to compensate for road mortality; no barrier fencing was installed	Terrain constrained options for a crossing structure and road mortality was not high enough to warrant exclusion fencing along the road that would restrict migration movements. Toads breed in new artificial pond as well as continuing to breed in original pond.	Wind 2018
Western Rattlesnake	Osoyoos	Exclusion fencing (1/4“ galvanized wire hardware cloth) installed and extended at campground from 2006; cover boards placed as refuges along fence	Mortality due to heat stress along fence, cover boards did not help	Eye et al. 2018
Western Terrestrial and Common Gartersnakes	Highway 97, south of Williams Lake	Constructed artificial hibernaculum (4 m x 4 m x 1.5 m) 650 m west of original hibernaculum that was dug up during highway expansion in October 2016. Released 150 salvaged snakes into artificial hibernaculum in November with a fence around it. Removed a portion of the fence before spring of 2017 to direct snakes towards the lake, away from the highway. There is still fencing along the backside of the den and winged out to either side	A few snakes were observed emerging in the spring of 2017. During the 2017 summer season there was construction adjacent to the den and then wildfires dominated the landscape in the Williams Lake area. An approx. 600-m radius around the den did not burn. It is unsure whether the extreme smoke conditions and fire in the adjacent area affected snake movement and other life stages, or not. Ongoing highway construction has made it	Steciw 2018; Steciw pers. comm. 2019

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Artificial Habitat and/or Exclusion Fencing				
		encouraging the snakes to move in the opposite direction of the highway.	difficult to monitor. Highway construction is still a major disturbance adjacent to the den site. The highway completion is expected in summer of 2019.	
Western Painted Turtle	Swansea Bridge, Highway 3 west of Cranbrook	Artificial nest pad and 150-200 m of chain link fencing in 2017	No nesting in 2017 but it was under construction; no monitoring since	Dulisse and Clarke 2018
Western Painted Turtle	Lower Sunshine Coast	Nesting beaches installed at 6 sites on lake side to keep turtles from crossing road. Sizes vary and include 15 m x 5 m x 0.5 m deep; 5 m x 5 m	Extremely effective at 3 of the sites in terms of successful nesting and reduction in road mortality; slower progress at other 3 sites because it took several years for turtles to start using new nesting beaches. Lessons learned: good to use pure sand and orient beaches southward.	Evelyn 2018

Appendix F – Instructions for Navigating iMapBC

Visit: https://maps.gov.bc.ca/ess/hm/imap4m/

Critical Habitat for Federally-Listed Species at Risk – Posted:

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Fish Wildlife and Plant Species"
4) Select "Critical Habitat for Federally-Listed Species at Risk – Posted"

For the most up-to-date information, mapped **Critical Habitat** (proposed and approved) for federal species at risk that occur in B.C. can also be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en

Wildlife Habitat Areas – Approved, Proposed, and FRPA

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Fish Wildlife and Plant Species"
4) Select "Wildlife Habitat Areas" Approved and Proposed

Terrestrial Ecosystem Mapping (TEM)

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Forest Grasslands and Wetlands"
4) Select "Terrestrial Ecosystem Mapping"

Vegetation Resources Inventory (VRI)

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Forests Grasslands and Wetlands"
4) Select "Vegetated Land Cover"

BC Freshwater Atlas

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Base Maps"
4) Select all layers with Streams, Lakes, Rivers, Wetlands, and Manmade Waterbodies

ENVIRONMENTAL ASSESSMENT & MITIGATION PLAN
LAKESTONE MASTER PLAN

Prepared For:

Macdonald Lakeshore Properties LP
11th Floor, 938 Howe Street
Vancouver, BC V6Z 1N9

ATTENTION TO: Don Erdely

Prepared By:

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
102 - 450 Neave Court
Kelowna, BC
V1V 2M2

January 7, 2021

Ecoscape File No. 20-3272

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Project Area 2
1.2 Proposed Works 2
2.0 Environmental Assessment 4
2.1 Ecosystems and Vegetation Communities 4
2.2 Wetland and Riparian Habitats 6
2.3 Wildlife 8
2.4 Species And Ecosystems At Risk 12
2.5 Environmentally Sensitive Areas (ESAs) 15
3.0 Impact Assessment 17
4.0 Mitigation Measures and Recommendations 18
4.1 Clearing and Grubbing 19
4.2 Tree Protection 20
4.3 Erosion and Sediment Control 21
4.4 Emergency Spill/Response Plan 24
4.5 Stormwater Management and Wetland Protection 24
4.6 Air Quality & Greenhouse Gas Reduction 25
4.7 Habitat Remediation and Enhancement 28
4.8 Rockfall Mitigation 31
4.9 Invasive Species Management 31
4.10 Site Clean Up 32
4.11 Environmental Monitoring 32
4.12 Restoration, Performance and Maintenance Bonding 33
5.0 CONCLUSION 33
6.0 CLOSURE 34
7.0 REFERENCES 35

TABLES

Table 1. Summary of Completed and Proposed Development 2012 – 2020. 3
Table 2. Summary of Disturbance Limits and Green Spaces for the 2020 Master Plan. 3
Table 3. Ecosystem communities occurring within the Project Area. 5
Table 4. Summary of herptile species and habitat associations within the Project Area. 8
Table 5. Summary of mammal species and habitat associations within the Project Area. 9
Table 6. Summary of bird species and habitat associations within the Project Area. 10
Table 7. Summary of vertebrate species at risk with the potential to occur in the Project Area based on the suitability of habitats for each species. 13
Table 8. Summary of invertebrate species at risk with the potential to occur within the subject Project Area. 15
Table 9. Percent composition of ESAs within the Project Area. 17
Table 10. Impact assessment of proposed development on identified ESAs 17
Table 11. Restoration Grass Seed mix 20
Table 12. DLC GHG Reduction and Conservation Factors Checklist 27

FIGURES

Figure 1 .....Site Location
Figure 2 .....Ecosystem Polygons
Figure 3 ..... Environmental Sensitivity Analysis
Figure 4 ..... Impact Assessment
Figure 5 .....Wildlife Crossings

APPENDICES

Appendix 1 ..... Lakestone 2020 Master Plan Phasing
Appendix 2 .....Lakestone Summit Phase
Appendix 3 ..... Proposed Parks and Open Space Areas
Appendix 4 ..... Common native plant species occurring within the Project Area
Appendix 5 ..... Bird and Bat Box Designs
Appendix 6 .....Native Plant Salvage Plan
Appendix 7 .....Guidelines for Amphibian and Reptile Conservation

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) was retained by Macdonald Lakeshore Properties LP (the Proponent) to conduct an Environmental Assessment (EA) and Environmentally Sensitive Areas (ESA) analysis for the proposed 2020 Lakestone Master Plan residential and multi-family development project (the Project) in Lake Country, BC (the Project Area).

Previous development completed for the Lakestone residential and multi-family development has included Phases 1 – 5.1, as shown in the Lakestone 2020 Master Plan (**Appendix 1**). Ecoscape completed an EA for the Summit Phase (**Appendix 2**) in November 2020, however the remaining phases in the Master Plan are in the conceptual stages, therefore the designs provided by the Proponent present a preliminary overview ahead of detailed designs for each phase.

The Project Area and scope of this assessment is composed of the following phases (**Figure 1**):

- Glenmore Industrial
- Chase Residential
- Ok Centre Plateau
- Highlands South
- Highlands West
- Highlands Central
- Highlands East
- East Ridge
- Summit Phase

The purpose of this report is to provide an environmental assessment for the proposed phases of the 2020 Lakestone Master Plan (**Appendices 1 - 2**).

This report identifies existing terrestrial, riparian, and wetland resource values, assesses the potential for rare and/or endangered species and habitats, and provides recommendations to maintain the natural integrity of existing ecological communities through sensitive design.

The on-site environmental impact of the Project has been reviewed by Ecoscape. With the Project Area largely undeveloped, impacts to environmental values are reduced for the Project through retention of greenspace. The retention of significant features of the environment is recommended, such as steep slopes and cliffs, wetlands, wildlife trees, existing trails, and wildlife crossings.

According to Lakestone's 2020 Master Plan Environmental Impact Statement (Macdonald Lakeshore Properties LP, 2020), environmental retention is a primary objective of Lakestone's approach to development. The Master Plan places a premium on environmental co-existence through introduction of the following:

- Clustering of development to allow for retention of substantial areas of existing forest, wetlands, rock outcroppings, and other natural features;
- Extensive open space provision (54%) which depends on retention of the natural setting with the residential, amenity, and foreshore facilities;

- Significant trail system, which also provides wildlife movement and habitat opportunities;
- Limited development at the environmentally sensitive foreshore, consisting of a drop-off/pickup wharf encouraging the use of kayaks, canoes, and other non-motorized watercraft;
- Building Design Guideline process which maximizes retention of existing site conditions through to the end of construction; and
- Specific road and servicing standards designed for hillside conditions that minimize scarring and maximize retention of the natural surround.

Following Ecoscape's field survey and ESA analysis, the Proponent modified their designs to accommodate the very high value ESAs (wetland, riparian, gullies, and moisture receiving areas) to keep those areas intact and maintain connectivity.

1.1 Project Area

The Project Area encompasses approximately 329.79 acres bounded by Glenmore Rd and Okanagan Centre Rd W to the south, Tyndall Rd to the west, Camp Rd to the north, and Chase Rd to the east (**Figure 1**).

The Project Area consists of one large parcel (Block B) and three lots (136, 137, 138) zoned as DC3 (Direct Control), legally described as:

- Block B, Plan KAP521, Section 3&4&9, Township 20, Osoyoos Div of Yale Land District, Except Plan EPP86639
- Lot 136, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District, Except Plan H10875
- Lot 137, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District
- Lot 138, Plan KAP521, Section 3,4&9, Township 20, Osoyoos Div of Yale Land District

The Project Area occurs within District of Lake Country Natural Environment and Hillside Development Permit Areas (DPAs) and requires an environmental assessment to address the potential for adverse environmental effects resulting from the proposed development.

A mosaic of steep slopes and gullies, coniferous woodland, grassland, talus slope, cliff, wetlands, and riparian habitats encompass the Project Area. There are a number of wetlands and riparian communities that occupy the central region of the Project Area and the northern and southern extents of the Lakestone development. The Project Area contains a network of trails that are currently used recreationally. The surrounding areas have been previously disturbed, with extensive development to the north and west from Lakestone Phases 1 – 5.1, in addition to older residential and industrial developments to the north and east. Despite trail development and previous development disturbance and fragmentation, forest and wetland communities remain generally intact and in excellent condition.

1.2 Proposed Works

The proposed development includes the following:

- Clearing, grubbing, and earthworks for the development of single-family lots and multi-family townhomes, duplexes and apartments;
- Construction of roadways, including collector roads, local roads, strata roads, emergency access roads, and extensions of previously constructed roads from Phases 1 – 5.1;
- Retention of open green spaces;
- Retention/construction of urban recreational park areas;

Table 1 provides an overview of the number of lots, townhomes/duplexes, and apartments proposed for each phase of development, and **Table 2** provides the areas of disturbance, parks, and open spaces.

Table 1. Summary of Completed and Proposed Development 2012 – 2020.

Phase	Master Plan Reference	Lakestone Neighborhood	Single Family Lots	Townhome and Duplex	Apartment	Total	Density Transfer
Phase 1	2012	Waterside	20	0	0	20	N/A Completed
Phase 2	2012	Waterside	86	18	0	104	N/A Completed
Phase 3	2012	Benchlands	91	0	80	171	N/A Completed
Phase 4	2012	Highlands	52	28	0	80	N/A Completed
Phase 5.1	2012	Highlands	58	0	0	58	N/A Completed
Summit Phase	2020	Highlands	57	0	0	57	5.6
Highlands Central Phase	2020	Highlands	63	0	0	63	6.3
Highlands East Phase	2020	Highlands	34	33	0	67	6.7
East Ridge Phase	2020	Highlands	56	12	0	68	6.9
Highlands West Phase	2020	Highlands	73	0	0	70	7.3
Highlands South Phase	2020	Highlands	0	74	0	74	7.4
OK Center Plateau Phase	2020	Highlands	0	50	100	150	15
Glenmore Phase	2020	Glenmore	70	180	130	380	38
TOTALS			**660**	**395**	**310**	**1365**	

Table 2. Summary of Disturbance Limits and Green Spaces for the 2020 Master Plan.

Phase	Master Plan Reference	Neighborhood	Number of Lots	Limit of Disturbance (acres)	Park Area (acres)	Open Spaces (acres)
Summit Phase	2020	Highlands	57	22.0	7.85	26.65
Highlands Central Phase	2020	Highlands	63	21.6	1.74	12.21
Highlands East Phase	2020	Highlands	67	16.9		10.09
East Ridge Phase	2020	Highlands	68	16.5	0.96	15.49
Highlands West Phase	2020	Highlands	70	19.4	5.77	33.85
Highlands South Phase	2020	Highlands	74	21.0	3.23	59.53
OK Center Plateau Phase	2020	Highlands	150	20.2		7.88
Glenmore Phase	2020	Glenmore	380	22.1		15.7
TOTALS			**929**	**137.67**	**19.57**	**181.42**

The total area of the proposed development footprint is approximately 138 acres.

Access to the development will be from existing roads such as Glenmore Rd and Okanagan Centre Rd W, previously constructed roads from Phases 1 – 5.1 including Tyndall Rd, as well as newly constructed road extensions such as Beacon Hill Drive.

The Project will include public park areas and open green spaces (**Appendix 3**), roughly following the area's prominent wetlands, gullies and steep slopes. Wildlife crossings and funnel fencing should be incorporated into the road designs to allow wildlife access, particularly under the area's road system for continued connectivity between the wetlands in the central portion of the Project Area. A site plan showing the proposed lot and road layout is attached (**Appendix 1**).

2.0 ENVIRONMENTAL ASSESSMENT

Site visits were conducted between April 20 – 22, 2020 by Mary Ann Olson-Russello, M.Sc., R.P.Bio., Theresa Loewen, M.Sc., P.Ag, and Kyle Hawes, R.P. Bio., Natural Resource Biologists with Ecoscape. Subsequent visits were carried out in May 2020 to delineate ecologically sensitive talus slopes, cliffs, and wetland habitats. Other sources of information queried for the assessment include:

- District of Lake Country Official Community Plan (OCP);
- BC Conservation Data Centre (CDC) Species and Ecosystems Explorer;
- BC Habitat Wizard;
- Biogeoclimatic maps;
- Sensitive Ecosystem Inventory (SEI) and Terrestrial Ecosystem Mapping (TEM);
- Species at Risk Act Public Registry;
- Kelowna Wetland Inventory and Mapping; and,
- Provincial Best Management Practices (BMP).

2.1 Ecosystems and Vegetation Communities

The Project Area occurs within the Okanagan variant of the Ponderosa Pine biogeoclimatic zone, Very Dry Hot subzone (PPxh1) (Lloyd et al. 1990). Areas of the PP zone are the driest forested areas in B.C., with low snowfall and hot, dry, summers. The Project Area is a mosaic of steep slopes, talus, cliffs, gullies, open and closed conifer forest, grasslands, wetlands and riparian habitat. Ecosystems were refined for the Project Area adapting Terrestrial Ecosystem Mapping (TEM) and Sensitive Ecosystem Inventory (SEI) polygons (Iverson 2008). Polygon refinement involved finer scale community stratification into more specific areas at a 1:5000 scale. In total 81 community/habitat polygons were defined (**Table 3 and Figure 2**). Table 3 presents the ecosystem codes, their associated site series name, and provincial status.

Table 3. Ecosystem communities occurring within the Project Area.

Ecosystem Code	Site Series	Site Series Name	Provincial Status[1]
DM/FI07	08	Douglas-fir – Water birch – Douglas maple	Red
FB	00	Rough fescue – Bluebunch wheatgrass	Red
PF	02	Douglas-fir / Ponderosa pine – Pinegrass – Idaho fescue	Red
SA	00	Antelope brush – Selaginella	Red
DS	07	Douglas-fir / Ponderosa pine – Snowberry – Spirea	Blue
WB	00	Bluebunch wheatgrass - Balsamroot	Blue
PT	02	Ponderosa pine – Red three-awn	Blue
PW	01	Ponderosa pine – Bluebunch wheatgrass – Idaho fescue	Blue
SP	06	Douglas-fir / Ponderosa pine – Snowbrush - Pinegrass	Blue
CT/Wm05	00	Cattail marsh	Blue
BM/Wm06	00	Bulrush marsh	Blue
SW	N/A	Shallow water	Blue
Ws03	09	Willow – Sedge	N/A
SB	00	Selaginella – Bluebunch wheatgrass	N/A
SO	00	Saskatoon – Mock orange – Talus	N/A
CL	N/A	Cliff/bluff	N/A
ES	N/A	Exposed soil	N/A
RO	N/A	Rock outcrop	N/A
RW	N/A	Rural	N/A
RZ	N/A	Road surface	N/A
TA	N/A	Talus	N/A

1 Source: http://www.env.gov.bc.ca/cdc/
N/A: Non-listed **Blue:** Of special concern. **Red:** Endangered or threatened.

Five (5) different coniferous woodland ecosystems were identified in the Project Area, including DM/FI07 (Douglas fir – Water birch – Douglas maple), PF (Douglas-fir / Ponderosa pine – Pinegrass – Idaho fescue), DS (Douglas-fir / Ponderosa pine – Snowberry – Spirea), PT (Ponderosa pine – Red three-awn), PW (Ponderosa pine – Bluebunch wheatgrass – Idaho fescue), and SP (Douglas-fir / Ponderosa pine – Snowberry - Pinegrass). These are predominantly young forests, with sporadic mature trees and abundant snags and wildlife trees. Certain areas (specifically the SP at the north end of the Project Area) had a structural stage of pole sapling which can indicate recent logging activities (**Photos 1 - 2**). Younger stands such as this have lower environmental sensitivity.

Sparsely vegetated sites are associated with SO (Saskatoon – Mock orange talus), SA (Antelope brush – Selaginella), SB (Selaginella – Bluebunch wheatgrass), RO (Rock outcrop), and CL (Cliff/bluff) (**Photos 3 - 8**). Trees within these areas are classified with a structural stage 6/7 (mature or old forests).

A network of ponds, wetlands, and riparian communities exist within the Project Area (**Photos 9 - 11, Figure 1**). The ponds contain three (3) wetland associations including shallow water (SW) with submerged aquatic vegetation, bulrush marsh (BM/Wm06), and cattail marsh (CT/Wm05). Willow-sedge swamp (Ws03) and adjacent tall shrub riparian ecosystems including dominated by water birch, red-osier dogwood, and willow occur in moisture receiving depressions and around the fringe of the pond and marsh communities.

Anthropogenic sites include areas of previous disturbance, old gravel roads, and trails, were classified as ES (Exposed soil), RZ (road surface), and RW (rural) (**Photo 12**).

The DM, DS, SP, and SW communities are generally characterized by cooler aspects with higher moisture content, while PF, PT, PW, SO, SA, SB, and WB are generally characterized by warmer

aspects and lesser moisture content. The DM and PF communities are Red-listed in B.C., meaning that they are currently endangered or threatened. The DS, WB, PT, PW, SP, CT, and BM communities are Blue-listed in B.C., meaning they are of special concern due to loss and degradation throughout the region.

The coniferous woodlands that occur throughout the majority of the proposed development area are comprised of young to mature interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and ponderosa pine (*Pinus ponderosa*) stands. Interior Douglas-fir dominates on cooler-aspect slopes and within moisture receiving areas (**Photo 13**), while ponderosa pine dominates the warmer, drier, and ridge-top areas (**Photo 14**). Younger forests predominate the landscape, and while they have intrinsic ecological value and provide recruitment for older structural stages, the older structural stage forests are of higher conservation priority (Iverson, 2008).

A large number of veteran, wildlife trees, and snags (**Photos 15 - 23**) were noted throughout the Project Area, which are known to provide valuable habitat to multiple species, such as blue-listed Lewis's Woodpecker in the region. Snags and veteran wildlife trees should be retained where possible as they provide nesting opportunities for various bird species and potential roosts for bats. Coarse woody debris is scattered on the forest floor throughout the Project Area, providing habitat for various small mammals, herptiles, and other wildlife. Retention of some large coarse woody debris is recommended for the valuable wildlife habitat it provides.

A detailed vegetation survey was not conducted, however, vegetation was largely consistent with other adjacent upland areas with a greater prevalence of tall Oregon-grape (*Mahonia aquifolium*), common snowberry (*Symphoricarpos albus*), Saskatoon (*Amelanchier alnifolia*), arrow-leaved balsamroot (*Balsamorhiza sagittata*), and bunchgrasses (**Photos 24 – 25**). Additional native species common to the Project Area can be found in **Appendix 4**.

A detailed inventory of invasive vegetation and noxious weeds was not conducted, however observations during the site visits included great mullein (*Verbascum thapsus*) and diffuse knapweed (*Centaurea diffusa*), found primarily in areas of disturbance.

2.2 Wetland and Riparian Habitats

The wetlands, gullies, and moisture receiving areas in the Project Area are identified as Polygons 44, 67, 69, 70, 71, 74, and 75 (**Figure 3**)**.** These areas are biodiversity hotspots that are critical for supporting the biodiversity of the Lakestone area.

The isolated wetlands contain central shallow water habitats and have varying degrees of emergent marsh and riparian vegetation around the fringe, with extensive marsh communities consisting of both cattail and bulrush and submergent vegetation in the shallow water habitats. An example of the wetland in Polygon 67 is shown below.



Photo Plate: Showing pond/wetland communities - Polygon 44 (*left*) and Polygon 70 (*right*)

Below is a clip from **Figure 4** which shows the network of wetlands, gullies, and moisture receiving areas, and their proximity to development.



Figure Plate 1: Network of functionally connected wetlands, gullies, and moisture receiving areas

Maintaining connectivity between these areas and is essential to supporting the high ecological value of these ecosystems and the habitat they provide to a diversity of species, including many species at risk. See Section 4.7 for more on ecosystem connectivity and maintenance of movement corridors.

The common cattail marsh in the north outside of the Project Area, but within the existing Lakestone development (**Figure 1**), has an established trail that loops around the pond with an access point from Tyndall Road at the north end (**Photo 26**).

2.3 Wildlife

Detailed wildlife surveys were not conducted during the site assessment. The undeveloped nature of the area and connectivity to adjacent natural habitats suggest high potential for wildlife presence and use for a variety of species and life stages.

Wildlife observations during the field visits include evidence of mule deer, moose, coyote, cougar, black bear, chorus frogs, small mammals such as squirrels and chipmunks, and high potential for bats and snakes in the cliffs, talus, and sparsely vegetated areas. As such, there is a high risk of snake mortality on Tyndall Rd and future roads that do not have wildlife crossings or culverts.

The Project Area has high potential for reptiles, amphibians, and bats with overwintering habitat in the south and west facing slopes, wetlands, exposed rock features, extensive talus and adjacent riparian gullies and grasslands for feeding habitat (**Photos 3 – 11; 27 – 33**). These areas should be retained as much as possible for their high habitat value. **Table 4** presents a summary of herptile species with habitat associations within the Project Area.

Table 4. Summary of herptile species and habitat associations within the Project Area.

Species Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Amphibian	Long-toed salamander	*Ambystoma macrodactylum*	**Yellow**	**Not at Risk**	Wetland / Riparian
	Pacific chorus frog	*Pseudacris regilla*	**Yellow**	-	Wetland / Riparian
Reptile	Common garter snake	*Thamnophis sirtalis*	**Yellow**	-	Fractured bedrock / Riparian
	Great Basin gopher snake	*Pituophis catenifer deserticola*	**Blue**	**Threatened**	Rocky/Talus
	Northern alligator lizard	*Elgaria coerulea*	Yellow	Not at Risk	Shrub/Talus
	Rubber boa	*Charina bottae*	Yellow	**Special concern**	Fractured bedrock
	Western painted turtle	*Chrysemis picta*	**Blue**	**Special concern**	Wetland / riparian
	Western racer	*Coluber constructor*	**Blue**	**Threatened**	Fractured bedrock/ grassland
	Western rattlesnake	*Crotalus oreganus*	**Blue**	**Threatened**	Fractured bedrock/ grassland
	Western terrestrial garter snake	*Thamnophis elegans*	**Yellow**	-	Wetland / Riparian

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern: A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk: A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.

Endangered: A wildlife species facing imminent extirpation or extinction.
Data Deficient : A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

The open grassland and moisture-receiving areas provide suitable habitat for a variety of small mammals such as shrews, voles and mice. The cracks and crevices in the rocky outcrops and cliffs provide suitable roosting habitat and hibernacula for other small mammals such as bats. Snags and partially dead trees with cavities were noted throughout the Project Area, which also provide habitat for nesting or foraging small mammals. The grassland and forest habitats provide suitable habitat for mule deer, black bear and coyotes. **Table 5** lists common mammal species with habitat associations within the Project Area.

Table 5. Summary of mammal species and habitat associations within the Project Area.

Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
American black bear	*Ursus americanus*	Yellow	Not at Risk	Mixed Forest
Bushy-tailed woodrat	*Neotoma cinerea*	Yellow	-	Rocky Outcrop
Coyote	*Canis latrans*	Yellow	-	All
Meadow vole	*Microtus pennsylvanicus*	Yellow	-	Riparian
Mule deer	*Odocoileus hemionus*	Yellow	-	All
Northern pocket gopher	*Thomonys talpoides*	Yellow	-	Open grassland
Porcupine	*Erethizon dorsatum*	Yellow	-	Woodland
Red squirrel	*Tamiasciurus hudsonicus*	Yellow	-	Forest
White-footed deer mouse (North American deer mouse)	*Peromyscus maniculatus*	Yellow	-	All
White tailed deer	*Odocoileus virginianus*	Yellow	-	All
Yellow-pine chipmunk	*Neotamias amoenus*	Yellow	-	Shrubland

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern: A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk: A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Endangered: A wildlife species facing imminent extirpation or extinction.
Data Deficient : A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

Detailed surveys for bats were not conducted within the Project Area and it is uncertain which species may be present. However, the many rock outcrops, cliffs, and veteran trees and snags provide suitable roosting habitats and the open woodland and grassland provide suitable foraging habitat. Given the natural conditions and habitat availability within the subject property, it is likely that bat species occur, such as the Pallid bat, Spotted bat, Townsend's Big-eared Bat, Western small-footed myotis, California myotis, Long-eared myotis, Little brown myotis, Fringed myotis, Hoary bat and Silver-haired bat. Conservation of critical habitats would help prevent potential impacts to these sensitive species. In general, these habitats occur in High to Very High ESA value areas. Section 2.4, Table 7 lists the species of bats with habitat associations within the Project Area. Additional nocturnal surveys for bats are recommended.

Although a detailed avian survey was not conducted, a diversity of bird species was observed in the Project Area, as denoted by an Asterix (**Table 6**), including additional species with the potential to occur in the Project Area.

Table 6. Summary of bird species and habitat associations within the Project Area.

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Passerine (perching bird)	Alder flycatcher	*Empidonax alnorium*	Yellow	-	Riparian
	American crow*	*Corvus brachyrhynchos*	Yellow	-	All Types
	American goldfinch*	*Carduelis tristis*	Yellow	-	All Types
	American robin*	*Turdus migratorius*	Yellow	-	All Types
	Barn swallow*	*Hirundo rustica*	**Blue**	**Threatened**	Riparian/Buildings
	Black-billed magpie*	*Pica pica*	Yellow	-	All Types
	Black-capped chickadee*	*Poecile atricapillus*	Yellow	-	Mixed and coniferous forest
	Black-headed grosbeak	*Pheucticus melanocephalus*	Yellow	-	Broadleaf/Riparian
	Brewer's blackbird	*Euphagus cyanocephalus*	Yellow	-	Grassland/forest
	Brown-headed cowbird*	*Molothrus ater*	Yellow	-	All Types
	Bullock's oriole	*Icterus galbula*	Yellow	-	Riparian/broadleaf
	Cassin's vireo*	*Vireo cassinii*	Yellow	-	Woodlands/Forest edge
	Chipping sparrow*	*Spizella passerina*	Yellow	-	Coniferous Forest
	Clark's nutcracker*	*Nucifraga columbiana*	Yellow	-	Coniferous Forest
	Common raven*	*Corvus corax*	Yellow	-	Coniferous Forest
	Dark-eyed junco*	*Junco hyemalis*	Yellow	-	Forest/Shrubland
	Dusky flycatcher*	*Empidonax oberholseri*	Yellow	-	Forest/Shrubland
	Eastern kingbird	*Tyrannus tyrannus*	Yellow	-	Forest edge / fields
	European starling*	*Sturnus vulgaris*	Exotic	-	Rural
	Golden-crowned kinglet*	*Regulus satrapa*	Yellow	-	Coniferous Forest
	Hammond's flycatcher*	*Empidonax hammondii*	Yellow	-	Mixed and Coniferous Forest
	House finch*	*Carpodacus mexicanus*	Yellow	-	Rural
	House wren	*Troglodytes aedon*	Yellow	-	Forest/Shrubland
	Lazuli bunting*	*Passerina amoena*	Yellow	-	Riparian/broadleaf
	Least flycatcher	*Empidonax minimus*	Yellow	-	Shrubland /open forest
	Marsh wren*	*Cistothorus palustris*	Yellow	-	Wetland
	Mountain bluebird	*Sialia currucoides*	Yellow	-	Forest/Shrubland
	Mountain chickadee	*Poecile gambeli*	Yellow	-	Mixed Forest
	Nashville warbler*	*Vermivora ruficapilla*	Yellow	-	Broadleaf/Riparian
	Northern shrike*	*Lanius borealis*	Yellow	-	Open forest/shrubland
	Orange-crowned warbler*	*Vermivora celata*	Yellow	-	Woodlands/riparian shrubs
	Purple finch*	*Haemorhous purpureus*	Yellow	-	Mixed and Coniferous Forest
	Pine siskin	*Carduelis pinus*	Yellow	-	Coniferous Forest
	Pygmy nuthatch*	*Sitta pygmaea*	Yellow	-	Coniferous Forest
	Red-breasted nuthatch*	*Sitta canadensis*	Yellow	-	Mixed Forest
	Red-eyed vireo	*Vireo olivaceus*	Yellow	-	Deciduous Forest
	Red-winged blackbird*	*Agelaius phoeniceus*	Yellow	-	Wetland
	Ruby-crowned kinglet*	*Regulus calendula*	Yellow	-	Mixed and Coniferous Forest
	Savannah sparrow	*Passerculus sandwichensis*	Yellow	-	Open Grassland
	Say's phoebe	*Sayornis saya*	Yellow	-	Forest/Shrubland
	Song sparrow*	*Melospiza melodia*	Yellow	-	Broadleaf/Riparian
	Spotted towhee* (formally Rufous sided towhee)	Pipilo maculatus	Yellow	-	Broadleaf and shrub thickets

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
	Swainson's thrush	*Catharus ustulatus*	Yellow	-	Coniferous Forest
	Townsend's solitaire*	*Myadestes townsendi*	Yellow	-	Coniferous Forest
	Townsend's warbler*	*Dendroica townsendi*	Yellow	-	Mixed Forest
	Tree swallow	*Iridoprocne bicolor*	Yellow	-	All habitats
	Vesper sparrow*	*Pooecetes gramineus*	Yellow	-	Shrubland/ Grassland
	Violet-green swallow*	*Tachycineta thalassina*	Yellow	-	All habitats
	Warbling vireo	*Vireo gilvus*	Yellow	-	Broadleaf/shrub thickets
	Western bluebird	*Sialia mexicana*	Yellow	-	Open grassland/forest edge
	Western meadowlark	*Sturnella neglecta*	Yellow	-	Open grassland
	Western kingbird	*Tyrannus verticalis*	Yellow	-	Forest edge/fields
	Western tanager*	*Piranga ludoviciana*	Yellow	-	Mixed and open coniferous forest
	Western wood-pewee*	*Contopus sordidulus*	Yellow	-	Mixed and Coniferous Forest
	White crowned sparrow*	*Zonotrichia leucophrys*	Yellow	-	Open grassland
	Wilson's warbler*	*Wilsonia pusilla*	Yellow	-	Broadleaf/Riparian
	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	Yellow	-	Wetland and riparian
	Yellow-rumped warbler*	*Dendroica coronata*	Yellow	-	Mixed Forest
Falconiformes (hawks, eagles, falcons)	American kestrel	*Falco sparverius*	Yellow	-	Mixed forest/open grassland
	Cooper's hawk	*Accipiter cooperii*	Yellow	Not at Risk	Mixed Forest
	Northern harrier	*Circus cyaneus*	Yellow	Not at Risk	Open Riparian / grassland
	Osprey*	*Pandion Haliaetus*	Yellow	-	Open/mature forest
	Red-tailed hawk*	*Buteo jamaicensis*	Yellow	Not at Risk	Mixed Forest
	Sharp-shinned hawk*	*Accipiter striatus*	Yellow	-	Open/mature forest
Anseriformes (ducks, swans, geese)	Mallard*	*Anas platyrhynchos*	Yellow	-	Wetland/ riparian
Ciconiiformes (Herons, new world vultures)	Great blue heron	*Ardea herodias*	**Blue**	-	Wetland
	Turkey vulture*	*Cathartes aura*	Yellow	-	All habitats
Apodiformes (Hummingbird)	Anna's hummingbird*	*Stellula calliope*	Yellow	-	Forests
	Rufous hummingbird	*Selasphorus rufus*	Yellow	-	Woodlands
Strigiformes (Owls)	Great grey owl	*Strix nebulosa*	Yellow	NAR	Coniferous Forest
	Great-horned owl*	*Bubo virginianus*	Yellow	-	Open Forest / grassland
Galliformes (Quail, Fowl, Pheasents)	California quail*	*Callipepla californica*	Yellow	-	Open shrub
	Dusky grouse	*Dendragapus obscurus*	Yellow	-	Mature open forest
	Ring-necked pheasant	*Phasianus colchicus*	Exotic	-	All habitats
	Ruffed grouse	*Bonasa umbellus*	Yellow	-	Mixed and Coniferous Forests
Piciformes (Woodpeckers)	Lewis's woodpecker*	*Melanerpes lewis*	**Blue**	**Threatened**	Woodlands
	Hairy woodpecker	*Picoides villosus*	Yellow	-	Woodlands
	Northern flicker*	*Colaptes auratus*	Yellow	-	All habitats
	Pileated woodpecker	*Dryocopus pileatus*	Yellow	-	Dense, mature forest
	Red-naped sapsucker	*Sphyrapicus nuchalis*	Yellow	-	Mixed and Coniferous Forests
Columbiformes (Pigeons, doves)	Mourning dove*	*Zenaida macroura*	Yellow	-	Open grassland

Bird Group	Common Name	Scientific Name	BC Status[1]	COSEWIC Listing[2]	Habitat Association
Charadriiformes (Shorebirds)	Common snipe	*Gallinago gallinago*	Yellow	-	Wetland
	Killdeer	*Charadrius vociferus*	Yellow	-	Riparian/Open grassland
	Spotted sandpiper	*Actitis Macularia*	Yellow	-	Wetlands
Caprimulgiformes (Poorwills, nighthawks)	Common poorwill	*Phalaenoptilus nuttallii*	Yellow	Data Deficient	Forest/Shrubland
	Common nighthawk	*Chordeiles minor*	Yellow	**Threatened**	All habitats

Observed in the Project Area

2.4 Species And Ecosystems At Risk

Species at risk are identified in the context of provincial and national ranking systems. The provincial ranking system applies to species that have been assessed by the BC Conservation Data Centre (CDC). The national ranking system applies to species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The CDC mapping service was reviewed for occurrences of species at risk within one kilometer of the subject property. Query results included Species and Ecosystems at Risk polygons, Species at Risk Critical Habitat Areas, and Wildlife Species Inventory (WSI), and are as follows:

- Object ID 245323, Critical Habitat ID 110302, is associated with critical habitat for the provincially Red-listed Desert Nightsnake (*Hypsiglena chlorophaea*) and encompasses the subject property.
- Object ID 245208, Critical Habitat ID 110187, is associated with the critical habitat for the provincially Blue-listed Western Rattlesnake (*Crotalus oreganus*) and encompasses the subject property.
- Object ID 245438, Critical Habitat ID 110417, is associated with critical habitat for the provincially Blue-listed Great Basin Gophersnake (*Pituophis catenifer deserticola*) and encompasses the subject property.
- Object ID 9599987, Occurrence ID 10214, is associated with occurrence data for the provincially red-listed American Badger (*Taxidea taxus*) and encompasses the subject property.
- Object ID 9592538, Occurrence ID 12963, is associated with occurrence data for the provincially blue-listed ecological community, Common Cattail Marsh (*Typha latifolia Marsh*), found in the southern wetland on the subject property.
- Object ID 41665, Masked Occurrence (Secured CDC data in this area).

The BC Ministry of Environment's Species and Ecosystem Explorer was queried to identify plant and wildlife species potentially present in the region; search terms used to query this database are provided in the footnotes of **Tables 7 and 8,** below.

Table 7. Summary of vertebrate species at risk with the potential to occur in the Project Area based on the suitability of habitats for each species.

Species Group	Scientific Name	Common Name	Provincial Status[1]	COSEWIC Listing[2]	Suitability of Habitats in Project Area and likelihood of occurrence
Amphibians	*Anaxyrus boreas*	Western toad	Blue	SC (2012)	High
	Lithobates pipiens	Northern Leopard Frog	Red	E (2009)	Low
	Spea intermontana	Great Basin Spadefoot	Blue	T (2007)	Moderate
Birds	*Aechmophorus clarkii*	Clark's Grebe	Red	-	Nil
	Aechmophorus occidentalis	Western Grebe	Red	SC (2014)	Nil
	Aeronautes saxatalis	White-throated Swift	Blue	-	High
	Ammodramus savannarum	Grasshopper Sparrow	Red	-	Nil
	Ardea herodias herodias	Great Blue Heron, *herodias* subspecies	Blue	-	High
	Asio flammeus	Short-eared Owl	Blue	SC (Mar 2008)	Nil
	Athene cunicularia	Burrowing Owl	Red	E (Apr 2017)	Nil
	Bartramia longicauda	Upland Sandpiper	Red	-	Low
	Botaurus lentiginosus	American Bittern	Blue	-	Low
	Buteo lagopus	Rough-legged Hawk	Blue	-	Moderate
	Buteo platypterus	Broad-winged Hawk	Blue	-	Low
	Buteo swainsoni	Swainson's Hawk	Red	-	High
	Butorides virescens	Green Heron	Blue	-	Low
	Calcarius pictus	Smith's Longspur	Blue	-	Low
	Catherpes mexicanus	Canyon Wren	Blue	-	Nil
	Chondestes grammacus	Lark Sparrow	Blue	-	Low
	Chordeiles minor	Common Nighthawk	Yellow	SC (May 2018)	High
	Coccothraustes vespertinus	Evening Grosbeak	Yellow	SC (Nov 2016)	Moderate
	Coccyzus americanus	Yellow-billed Cuckoo	Red	-	Low
	Contopus cooperi	Olive-sided Flycatcher	Blue	SC (May 2018)	Moderate
	Cypseloides niger	Black Swift	Blue	E (2015)	Low
	Dolichonyx oryzivorus	Bobolink	Blue	T (2010)	Nil
	Dryobates albolarvatus	White-headed Woodpecker	Red	E (2010)	Low
	Empidonax wrightii	Gray Flycatcher	Blue	NAR (1992)	Low
	Eremophila alpestris merrilli	Horned Lark, *merrilli* subspecies	Blue	-	Low
	Euphagus carolinus	Rusty Blackbird	Blue	SC (Apr 2017)	Moderate
	Falco mexicanus	Prairie Falcon	Red	NAR (1996)	Low
	Falco peregrinus anatum	Peregrine Falcon, anatum subspecies	Red	NAR (2017)	Moderate
	Hirundo rustica	Barn Swallow	Blue	T (May 2011)	High
	Hydroprogne caspia	Caspian Tern	Blue	NAR (1999)	Low
	Icteria virens	Yellow-breasted Chat	Red	E (Nov 2011)	Low
	Larus californicus	California Gull	Blue	-	Nil
	Limnodromus griseus	Short-billed Dowitcher	Blue	--	Low
	Limosa haemastica	Hudsonian Godwit	Red	T (2019)	Low
	Megascops kennicottii macfarlanei	Western Screech-Owl, *macfarlanei* subspecies	Blue	T (May 2012)	Low
	Melanerpes lewis	Lewis's Woodpecker	Blue	T (Apr 2010)	Moderate
	Melanitta perspicillata	Surf Scoter	Blue	-	Nil
	Numenius americanus	Long-billed Curlew	Blue	SC (2011)	Nil
	Nycticorax nycticorax	Black-crowned Night-heron	Red	-	Low
	Pelecanus erythrorhynchos	American White Pelican	Red	NAR (1987)	Nil
	Phalacrocorax auritus	Double-crested Cormorant	Blue	NAR (1978)	Nil
	Phalaropus lobatus	Red-necked Phalarope	Blue	SC (2014)	Low
	Pluvialis dominica	American Golden-Plover	Blue	-	Nil

Species Group	Scientific Name	Common Name	Provincial Status[1]	COSEWIC Listing[2]	Suitability of Habitats in Project Area and likelihood of occurrence
	Podiceps nigricollis	Eared Grebe	Blue	-	Low
	Psiloscops flammeolus	Flammulated Owl	Blue	SC (Apr 2010)	Moderate
	Recurvirostra americana	American Avocet	Blue	-	Nil
	Sphyrapicus thyroideus thyroideus	Williamson's Sapsucker, thyroideus subspecies	-	E (2017)	Moderate
	Sterna forsteri	Forster's Tern	Red	DD (1996)	Nil
	Tympanuchus phasianellus columbianus	Sharp-tailed Grouse, columbianus subspecies	Blue	-	Nil
	Tyto alba	Barn Owl	Red	T (2010)	Low
Mammals	*Antrozous pallidus*	Pallid Bat	Red	T (2010)	Moderate
	Aplodontia rufa	Mountain Beaver	Yellow	SC (2012)	Low
	Corynorhinus townsendii	Townsend's Big-eared Bat	Blue	-	Low
	Euderma maculatum	Spotted Bat	Blue	SC (Nov 2014)	High
	Gulo gulo luscus	Wolverine, luscus subspecies	Blue	SC (2014)	Low
	Lasionycteris noctivagans	Silver-haired Bat	Yellow	-	Moderate
	Lasiurus cinereus	Hoary Bat	Yellow	-	Moderate
	Lepus townsendii	White-tailed Jackrabbit	Red		Nil
	Myotis californicus	Californian Myotis	Yellow		Moderate
	Myotis ciliolabrum	Western Small-footed Myotis	Blue	-	Moderate
	Myotis evotis	Long-eared Myotis	Yellow	-	Moderate
	Myotis lucifugus	Little Brown Myotis	Yellow	E (Nov 2013)	High
	Myotis thysanodes	Fringed Myotis	Blue	DD (May 2004)	High
	Oreamnos americanus	Mountain Goat	Blue	-	Nil
	Ovis canadensis	Bighorn Sheep	Blue	-	Nil
	Pekania pennanti	Fisher	Blue	-	Low
	Perognathus parvus	Columbia Plateau Pocket Mouse	Blue	-	Low
	Reithrodontomys megalotis	Western Harvest Mouse	Blue	SC (Apr 2007)	Moderate
	Sorex merriami	Merriam's Shrew	Red	-	Low
	Sorex preblei	Preble's Shrew	Red	-	Moderate
	Sylvilagus nuttallii	Nuttall's Cottontail	Blue	SC (Nov 2016)	Nil
	Taxidea taxus	American Badger	Red	E (Nov 2012)	Moderate
Reptiles	*Charina bottae*	Northern Rubber Boa	Yellow	SC (Apr 2016)	High
	Chrysemys picta pop. 2	Painted Turtle - Intermountain - Rocky Mountain Population	Blue	SC (2016)	High
	Coluber constrictor	North American Racer	Blue	T (Nov 2015)	High
	Crotalus oreganus	Western Rattlesnake	Blue	T (May 2015)	High
	Hypsiglena chlorophaea	Desert Nightsnake	Red	E (2011)	Low
	Pituophis catenifer deserticola	Gopher Snake, deserticola subspecies	Blue	T (Apr 2013)	High
	Plestiodon skiltonianus	Western Skink	Blue	SC (Nov 2014)	Moderate

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Search type: Animals AND Species Subgroups: Amphibians (Frogs, Toads, Newts & Salamanders) OR Reptiles & Turtles (Lizards, Skinks, Snakes, & Turtles) OR Birds, All Species OR Birds, Species Breeding in BC OR Mammals AND BC Conservation Status: Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern) AND 'Municipalities': Lake Country (Restricted to Red, Blue, and Legally designated species) AND Habitat Subtypes: Cliff, Conifer Forest – Dry,

Grassland, Marsh, Riparian Shrub, Riparian Forest, Rock/Sparsely Vegetated Rock, Talus, Roadside/Ditch, Urban/Suburban (Restricted to Red, Blue, and Legally designated species) AND BGC Zone: PP.

Table 8. Summary of invertebrate species at risk with the potential to occur within the subject Project Area.

Common Name	Scientific Name	Provincial Status[1]	COSEWIC Listing[2]	Likelihood of being found on the property
Attenuate Fossaria	*Galba truncatula*	Blue	-	Low
California Hairstreak	*Satyrium californica*	Blue	-	Low
Checkered Skipper	*Pyrgus communis*	Blue	-	Nil
Common Sootywing	*Pholisora catullus*	Blue	-	Low
Badlands Tiger Beetle	*Cicindela decemnotata*	Red	-	Nil
Half-moon Hairstreak	*Satyrium semiluna*	Red	E (2006)	Low
Immaculate Green Hairstreak	*Callophrys affinis*	Blue	-	Moderate
Lance-tipped Darner	*Aeshna constricta*	Blue	-	Nil
Lilac-bordered Copper	*Lycaena nivalis*	Blue	-	Moderate
Monarch	*Danaus plexippus*	Blue	E (2016)	Low
Mormon Fritillary, erinna subspecies	*Speyeria mormonia erinna*	Red	-	Moderate
Mormon Metalmark	*Apodemia mormo*	Red	E (2014)	Moderate
Nevada Skipper	*Hesperia nevada*	Blue	-	Nil
Pale Jumping-slug	*Hemphillia camelus*	Blue	-	High
Sagebrush Tiger Beetle	*Cicindela pugetana*	Blue	-	Nil
Sandhill Skipper	*Polites sabuleti*	Red	-	Moderate
Satyrium Californica	*California Hairstreak*	Blue	-	Low
Sonora Skipper	*Polites sonora*	Blue	NAR (2016)	Low
Silver-spotted Skipper, clarus subspecies	*Epargyreus clarus clarus*	Blue	-	Low
Twelve-spotted Skimmer	*Libellula pulchella*	Blue	-	Low
Viceroy	*Limenitis archippus*	Red	-	Low
Western Pondhawk	*Erythemis collocata*	Blue	-	Low

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Search type: Animals AND Species Subgroups: Invertebrates AND BC Conservation Status: Red (Extirpated, Endangered, or Threatened) OR Blue (Special Concern) AND Regional Districts: Central Okanagan (CORD) (Restricted to Red, Blue, and Legally designated species) AND Habitat Subtypes: Cliff, Conifer Forest – Dry, Grassland, Marsh, Riparian Shrub, Riparian Forest, Rock/Sparsely Vegetated Rock, Talus, Roadside/Ditch, Urban/Suburban (Restricted to Red, Blue, and Legally designated species) AND BGC Zone: PP.

2.5 Environmentally Sensitive Areas (ESAs)

An evaluation rubric was derived from the Regional District of Central Okanagan Terms of Reference (RDCO, 2006) used to perform an Environmental Sensitivity (ES) analysis to categorize the defined ecosystem/habitat polygons in the Project Area based on the degree of environmental sensitivity. Evaluation criteria included: provincial CDC status (i.e., Red or Blue listed), rare and endangered species occurrence potential, landscape condition (i.e., connectivity, fragmentation), successional stage, regional rarity, relative biodiversity, and level of disturbance.

The four categories of environmental sensitivity are described below along with relative retention expectations. The degree of retention is based on the continuous (0-100) score that each polygon received in the ES analysis:

- **Very High (ESA 1):** These areas represent extremely high ecological value and typically contain rare or critical habitat areas for sensitive or at-risk species, undisturbed or pristine ecosystems and habitats, and biodiversity hotspots (e.g., wetlands, old growth forest). They substantially contribute to the regional habitat function and connectivity and are highest priority for conservation.
    - **80 – 100% retention:** Core conservation areas. Allocation for development depends on identification of non–sensitive sites e.g. for minimal impact road crossings. If development should occur within these areas (Only after it proves impossible or impractical to maintain the same level of ecological function) compensation will promote no net loss to the habitat (typically with a 3:1 replacement of equivalent functioning habitat).
- **High (ESA 2):** These areas contribute to the regional biodiversity and connectivity of the surrounding landscape but lack critical habitats for at risk species (e.g., riparian areas, mature forest). Development should generally avoid these areas to conserve the important features or to allow potential progression to the Very High category (e.g., mature forest becoming old growth). Encroachment into these areas should be compensated for by restoration in other areas to work towards achieving a no net loss of High value habitats.
    - **40 – 80% retention:** Low intensity public use, cluster development to maintain the function of site. If development is pursued in these areas portions of the habitat should be retained and integrated to maintain the contiguous nature of the landscape. Some loss to these ESAs can be offset by habitat improvements to the remaining natural areas found on property.
- **Moderate (ESA 3):** Ecosystems of moderate significance represent disturbed habitats or fragmented features with the potential to return to High value through natural succession (e.g., young or fragmented forest, degraded habitats). Moderate areas contribute to the diversity of the landscape; however, their condition and adjacency may limit significant function. These areas will benefit from restoration and enhancement activities which will facilitate succession to higher value habitats.
    - **20 – 40% retention:** Important features or remnant stands/sites with intrinsic ecological value. Maintain important features within (e.g., tree patches, rock outcroppings, drainages and corridors). If development is pursued in these areas the impacts should be offset by habitat improvements in other more sensitive natural areas found on property.
- **Low (ESA 4):** These areas contribute little to no value with regard to habitat diversity and have limited potential for supporting significant wildlife (e.g., heavily impacted or disturbed sites). Development is typically focused on these areas based on their limited contribution to regional biodiversity and limited capacity to return to high value through natural succession. These areas may be restored through intensive remediation and management practices.
    - **0 – 20% retention**: Development is encouraged to be focused in these areas. Retained areas may offer some opportunity for some ecological function and/or enhancement/restoration.

The ESA composition of the Project Area is summarized in **Table 9** and depicted on **Figure 3**.

Table 9. Percent composition of ESAs within the Project Area.

ESA Value	ESA Area (m^2)	Percentage of Project Area (%)
Very High (ESA 1)	8,515	0.6
High (ESA 2)	916,656	69
Moderate (ESA 3)	402,469	30
Low (ESA 4)	6,914	0.4
Total	**1,334,554**	**100**

Environmental sensitivity analysis indicates that 0.4% of the Project Area is represented by Low (ESA 4) communities, based upon the presence of exposed soils and encroachment of invasive plant species (**Figure 3**). 30% of the Project Area is represented by Moderate (ESA 3) communities made up of recently harvested pole saplings, based upon non-critical open and closed woodland and grassland. 69% of the Project Area is represented by High (ESA 2) communities, based upon critical open woodland and sparsely vegetated features such as cliffs and rocky outcrops. 0.6% of the Project Area is represented by Very High (ESA 1) communities, based upon critical habitat features of riparian and open water ponds and wetlands. These Very High communities are mostly concentrated in the central region of the Project Area.

3.0 IMPACT ASSESSMENT

The proposed development will impact approximately 42% (138 acres) of the Project Area (**Table 10**). About 89 acres (27%) of the development occurs within High-value ESAs and 48 acres (14%) of the development occurs in Moderate ESAs. Very High and Low ESAs had nominal losses less than 1%. The Project plan aims to retain as much of ESA 2 as possible, with development focused as much as possible in areas of ESA 3 (**Figure 4**).

The proposed development will result in the loss of provincially Red-listed "endangered or threatened" (DM/Fl07, FB, PF, SA) and Blue-listed "special concern" (DS, WB, PT, PW, SP, CT/Wm05, BM/Wm06) ecological communities within the Project Area. Retention should be targeted toward High ESAs and associated ecosystems. Development in the Project Area should focus on areas with trees of structural stage 4 (pole/sapling), and seek to retain and protect areas of intact grasslands, mature/veteran/wildlife trees, and habitat features such as rock outcrops/talus, large woody debris (LWD) and snags wherever possible.

Table 10. Impact assessment of proposed development on identified ESAs

Environmental Sensitivity Category	Total (m^2)	Undisturbed Area (outside development) (m^2)	Disturbed Area (within development) (m^2)	ESA relative loss (%)
Very High (ESA 1)	8,515	5,677	2,838	<1%
High (ESA 2)	916,656	558,219	358,438	27%
Moderate (ESA 3)	402,469	208,999	193,470	14%
Low (ESA 4)	6,914	4,553	2,361	<1%
Total	**1,334,554**	**777,448**	**557,106**	**42%**

The following section summarizes the potential environmental impacts associated with the Project. Potential environmental impacts include:

- Loss of and perforation and fragmentation of coniferous woodland and associated habitats.
- Potential to directly or indirectly impact wildlife and wildlife habitat during earthworks, roadworks and tree clearing, including disruption of migration, breeding, or other behavior as a result of noise, impacts to air quality, and alterations to existing wildlife habitat and cover.
- Potential for water quality impairments to the pond and wetland habitats from improper stormwater management.
- Potential for the release of deleterious substances (e.g., fuel, oil, hydraulic fluid) to the environment during clearing, grubbing, and site servicing works or as a result of improper storage, equipment re-fueling, and/or poorly maintained equipment.
- Disturbance beyond the proposed development footprint if the areas are not clearly and accurately delineated in the field prior to initiating construction activities.
- Potential to introduce or facilitate the spread of non-native and invasive plant species resulting from ground disturbance.
- While we have estimated 42% for the extent of disturbance, actual disturbance may be slightly greater. All attempts should be made to ensure that works do not greatly exceed the extent of disturbance.

4.0 MITIGATION MEASURES AND RECOMMENDATIONS

In general, connectivity between the adjacent wetland communities must be maintained, therefore disturbance should be limited. The development footprint occurs primarily within High (ESA 2) and Moderate (ESA 3) ESAs, and to a lesser extent ESA 1 (Very High) and ESA 4 (Low). *See Section 4.7 for more detailed mitigation measures regarding connectivity between wetland habitats and wildlife crossings.*

Recommendations to avoid or minimize the potential impacts that may arise during the proposed construction works are summarized below and based on Best Management Practices (BMP).

- Disturbance beyond the proposed development footprint should be avoided. Clearly delineate with flagging and snow fence (where appropriate) the development extents to mitigate the risk of clearing/disturbance beyond what has been indicated in the development plan.
- Any applicable permitting / approvals must be obtained from the District of Lake Country and the Province of BC prior to construction activities within the Project Area. Copies of permits/approvals and this report must be kept onsite at all times.
- Any applicable permitting / approvals must be obtained from the District of Lake Country prior to construction activities within the Project Area. Copies of permits/approvals and this report must be kept onsite at all times.

- Construction activities must be contained within the development footprint within the Project Area.
- It is important that the civil contractor and environmental monitor have a startup meeting to discuss earthworks, as this stage of construction poses the greatest risk.
- All works should generally conform to the following Best Management Practices for British Columbia:
  - Develop with Care Environmental Guidelines for Urban and Rural Land Development (BC MoE 2014)
  - Best Management Practices for Recreational Activities on Grasslands in the Thompson and Okanagan Basins (BC MoEWLAP 2004)
  - Best Management Practices for Amphibian and Reptile Salvages in British Columbia (BC MoE 2016)
  - Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (BC MoE 2014)
  - Guidelines for Raptor Conservation during Urban and Rural Land Development in British Columbia (BC MoE 2013)
  - Best Management Practices Guidelines for Bats in British Columbia (BC MoE 2016)
  - Standards and Best Management Practices for Instream Works (BC MoEWLAP 2004)

4.1 Clearing and Grubbing

Clearing, stripping, and grubbing limits must be clearly marked in the field prior to construction and minimized wherever possible. Unnecessary impacts to native vegetation and soils must always be avoided. Important wildlife habitat, including veteran trees, snags, and other important features, will be identified by the environmental monitor (EM) prior to construction works. Native vegetation, including trees, shrubs, and groundcover, should be retained to mitigate the establishment of invasive plants and to maintain the existing ecological value sustained within the Project Area.

- A meeting between the EM and civil contractors must occur prior to any earthworks. The development extents, general practices, and full extent of cuts and fills should be discussed, to try and ensure that the works are generally consistent with this impact statement.
- Flagging or snow fencing must be used to clearly delineate the construction disturbance limits prior to the commencement will also be used to clearly identify setbacks and buffers associated with other identified environmentally sensitive areas (e.g., wildlife trees, nests).
- **Section 34 of the *Wildlife Act* protects all birds and their eggs, and Section 34(c) protects their nests while they are occupied by a bird or egg**.
  - If tree or shrub clearing activities are required during the identified avian nesting period (i.e., March 15 to August 15), pre-clearing surveys must be conducted by the EM to identify active nests and other critical habitat features, such as burrows, dens,

etc. Surveys will focus on songbird, raptor and heron nests, stick nests, and snags and cavities that may be used over multiple years or year-round (i.e., winter resident and hibernating species).

- If active nests are found within the clearing limits, a buffer will be established around the nest until such time that the EM can determine that nest has become inactive. The size of the buffer will depend on the species and nature of the surrounding habitat. Buffer sizes will generally follow provincial BMP guidelines or other accepted protocol (e.g., Environment Canada). In general, a minimum 20 m buffer will be established around songbird nests or other non-sensitive (i.e., not at risk) species.
- Clearing and other construction activities must be conducted within 72 hours following the completion of the pre-clearing nest surveys. If works are not conducted in that time, the nest surveys are considered to have expired and a follow-up survey will be completed to ensure that no new nests have been constructed.

- Prevention of the spread of non-native and invasive species can be achieved by limiting disturbance to soils and native vegetation where possible. Areas that have previously been disturbed should be restored with native plantings or grass seeding. Infestation areas must be controlled with regular manual removal of weeds (e.g., mowing, pulling).
- In the event that land and/or natural vegetation is disturbed or damaged beyond the development footprint area, these areas will be restored and/or replanted with plant material indigenous to the area under the direction of the EM.
- Exposed soils must be seeded immediately following any activities that result in disturbance to native vegetation and soils. Grass seed mixes must be comprised of native species, appropriate for the environmental conditions and certified as Canada #1 Grade by Agriculture Canada to minimize the weed seed count. A recommended seed mix can be found in **Table 11**.

Table 11. Restoration Grass Seed mix

Seed Weight	Botanical Name	Common Name
40%	*Pseudoroegneria spicata*	Bluebunch wheatgrass
25%	*Festuca campestris*	Rough fescue
15%	*Festuca idahoensis*	Idaho fescue
10%	*Lolium perenne*	Perennial ryegrass
5%	*Poa secunda*	Sandberg bluegrass
4%	*Koeleria macrantha*	Junegrass
1%	*Poa compressa*	Canada bluegrass

4.2 Tree Protection

A large number of veteran trees, wildlife trees, and snags were noted throughout the Project Area, which are known to provide valuable habitat to multiple species, such as blue-listed Lewis's Woodpecker in the region. Snags and veteran wildlife trees should be retained where possible as they provide nesting opportunities for various bird species and potential roosts for bats. Coarse woody debris is scattered on the forest floor throughout the Project Area,

providing habitat for various small mammals, herptiles, and other wildlife. Retention of some large woody debris (LWD) is recommended for the valuable wildlife habitat it provides.

Specific measures should be made for protecting tree species within the property, particularly those of high value such as mature/veteran trees, wildlife trees, and large snags. Since the majority of the trees are outside of the limit of disturbance, it is anticipated that there should be minimal disturbance to these trees, and that efforts will be made to retain the trees that do occur within development. The following recommendations are proposed for any future development proposed within the property:

- Trees with high wildlife value, such as veteran trees (mature trees greater than 60cm DBH) and snags (standing dead trees with cavities, coarse woody debris), must be conserved for their habitat value for a range of species including birds, bats, and other small mammals.

- Equipment/machinery used must not be operated or stored within the drip line of the trees and equipment must not come into contact with the tree, which could result in physical damage to the bark or limbs.
- If roots are damaged or exposed with excavation activities, the roots must be cut clean with a saw to minimize the potential for disease and mortality.
- Soil and other construction materials must not be stockpiled adjacent the tree boles or beneath the tree dripline.

4.3 Erosion and Sediment Control

The mitigation described below should be followed as required to provide erosion and sediment control during future construction works.

- Works involving ground disturbance should not be conducted during heavy rains wherever feasible to reduce the potential for sediment and erosion issues. Exposed soils and stockpiles must be stabilized and covered where appropriate using geotextile fabric, poly sheeting, tarps, or other suitable materials to reduce the potential for erosion and/or mobilization of sediment resulting from rainfall, seepage, or other sources of surface water flows. Exposed embankments shall be covered and stabilized as soon as possible.

- At the beginning of construction, limits of disturbance should be reviewed with the QEP and contractor to determine necessary locations of silt fence to mitigate the risk of siltation to natural areas and specifically Okanagan Lake. Silt fence must be staked into the ground and trenched (minimum of 10 cm) to prevent flow underneath the fence. Alternatives to silt fencing include earthen berms, or other associated techniques and can be utilized under the direction of the EM, where appropriate to do so.

- Erosion and sediment control measures should be installed at all low points, where water may concentrate during a storm event. These areas are likely ever changing on an active construction site and should be field reviewed by the Environmental Monitor at a minimum of every two weeks. Field inspections should focus on implementation of key erosion and sediment control techniques best suites to mitigating erosion or

sediment release from or within the construction footprint. Recommendations of the EM must be implemented within 24 hours of being made, or prior to any foreseen storm events, whichever occurs first.

- It is the contractor's responsibility to inspect all mitigation measures daily and additional measures will be installed, maintained, and repaired or replaced as required using a field-fit, adaptive management approach.

- The contractor should have the following erosion and sediment control measures readily available onsite:

    - Several rolls of non-woven geotextile fabric of various grades

    - Several rolls of silt fencing with sufficient wooden stakes to allow for installation

    - Pumps of appropriate size and hoses

    - Tarps, poly sheeting and sandbags

- Other suitable erosion control measures may include; slope drains and interceptor ditches, earthed berms, check dams, grass seeding, and mulch. Hay bales and straw are a wildlife attractant and are not desirable mitigation measures based on the potential to disperse non-native and invasive plant material.

- Stockpiled soils and fill material must be stored away (i.e., >30 m) from watercourses, ditches, and other aquatic habitats to prevent sediment laden runoff. Stockpiles must not be allowed to slough beyond the disturbance limits at any time.

- Road surfaces adjacent to the project area must be kept clean and free of fine materials. Sediment accumulation upon the road surfaces must be removed (i.e., swept or scraped) on a regular basis and disposed of appropriately.

- The release of silt, sediment, sediment-laden water, or any other deleterious substance into any ditch, watercourse, ravine, or other drainage feature must be prevented at all times. Similarly, there is to be no sediment release into areas of vegetation growth or sensitive areas in levels that would adversely alter growing or hydraulic conditions.

- During construction, the EM should review all erosion and sediment control measures at least every 2 weeks, although high risk work such as work below the PNB of watercourses will likely require more frequent if not full-time monitoring. A site inspection should also occur prior to foreseen weather events that may cause problems, such as prior to winter freeze up or prior to spring thaw as examples.

- The contractor must implement all erosion and sediment control recommendations within a 24-hour period to ensure that the site is stable.

- If any concrete works are required; sediments, debris, concrete, concrete fines, or wash water associated with pouring of the concrete must not come into contact with any ditching, watercourse or municipal storm drain system.

- Excess concrete from pouring must be taken offsite and disposed of or recycled appropriately and must not be discarded or deposited within the subject property or adjacent lands.

- Ensure that onsite machinery is in good operating condition, clean and free of leaks, excess oil or grease. Any equipment that will be used for works below the PNB must only use environmentally friendly hydraulic fluid.

- No equipment fueling or servicing is to be undertaken within 30 m of any watercourses/wetlands whenever possible.

- Silt fencing will be installed as directed by the EM in a field-fit manner, as required. Silt fence must be staked into the ground and trenched a minimum of 15 cm to prevent flow underneath the fence and must remain taut to prevent material from moving over the fence. Silt fencing should contain sufficient storage capacity to collect runoff and sediment deposition during storm events. Silt fencing will be monitored on a regular basis and any damages or areas where the integrity and function of the fencing has been compromised should be repaired or replaced promptly. Silt fence must remain in place where required until the completion of the project.

- Erosion and sediment control should incorporate the measures described below to mitigate risks during construction works. The plan is generally based upon provincial BMPs and other specifications and includes the following principles:

    - Construction works should, when possible, be conducted during periods of warm, dry weather with minimal forecasted precipitation;

    - Construction works should be scheduled to reduce the overall amount of time soils are exposed;

    - Exposed soils should be hydroseeded as soon as possible following excavation to prevent invasive species establishment;

    - Natural drainage patterns should be maintained where possible;

    - Existing native vegetation should be retained where possible;

    - Stormwater and sediment-laden runoff should be directed away from exposed soils within the construction area;

    - Sediment-laden water should not be directed to any surface water feature, gully, or other drainage system;

    - Slopes should be stabilized as soon as possible following disturbance;

    - Exposed soils along slopes must be stabilized and covered where appropriate using geotextile fabric, poly sheeting, tarps, or other suitable materials to reduce the potential for erosion resulting from rainfall, seepage, or other unexpected causes;

- Other erosion and sediment control measures should be implemented, inspected, maintained, and/or replaced as required to provide appropriate mitigation.

4.4 Emergency Spill/Response Plan

Spills of deleterious substances can be prevented through awareness of the potential for negative impacts and with responsible housekeeping practices onsite. Maintenance of a clean site and the proper use, storage and disposal of deleterious liquids and their containers are important to mitigate the potentially harmful effects of spills and/or leaks. The following BMP are adapted from Chilibeck *et al*. (1992) to provide guidance in the control of deleterious substances.

- Ensure that onsite machinery is in good operating condition, clean, and free of leaks, excess oil or grease.
- Equipment and tools used for concrete works must be washed offsite away from any watercourses. Concrete waste water must not be washed into any watercourse or the storm water system (i.e. must not be poured in a location that drains into municipal catch basins and subsequently into watercourses).
- Spills occurring on dry land will be contained, scraped and disposed of appropriately. Contaminated material will be stored on tarps and covered to prevent mobilization and will be disposed of in accordance with the *Environmental Management Act*.
- Copies of contact phone numbers for notification of all of the required authorities in the event of a spill/emergency response will be kept posted and clearly visible onsite.
- Spill containment kits should be kept readily available on-site during construction in case of the accidental release of a deleterious substance to the environment. Any spills of a reportable amount of a toxic substance must be immediately reported to Ecoscape at 250-491-7337 and the **Emergency Management BC's 24-hour hotline at 1-800-663-3456.**

4.5 Stormwater Management and Wetland Protection

- No untreated stormwater should be discharged to any natural ponds, wetlands, or riparian habitats. Any discharges to a waterbody will require a Section 11 under the Water Sustainability Act.
- Wetland habitats within the subject property provide critical habitat for small mammals, snakes, amphibians, and a broad diversity of invertebrate fauna, which play an important role in ecological processes. Inputs of untreated stormwater to any of the wetlands may have negative effects on these communities. Stormwater runoff should not be directly discharged into any of the existing wetlands / shallow open water areas due to the potential for degrading the aquatic communities.
- The stormwater management plan for the development must aim at maintaining existing drainage patterns, rates and flows without directly introducing runoff into aquatic environments. Run-off flows must not be directed away from natural receiving basins, which may result in a loss of wetland and moisture receiving ecosystems. This can be accomplished by the creation of a stormwater management plan, incorporating

guidelines from Chilibeck (1992) and the BC Stormwater Planning Guidebook. In particular, BMP practices typically emphasize the use of in-ground stormwater disposal methods to direct stormwater runoff into underlying soils.

- Turbid water management may be required as sediment from excavations has the potential to enter the wetland system during works. If dirty water is encountered, the following recommendations are to be implemented:

- At the point of discharge, appropriate erosion and sediment control measures must be established to prevent erosion.

- Water quality sampling will be conducted in situ with a portable HACH 2100P Turbidimeter to measure ambient Nephelometric Turbidity Units (NTU) and/or a Hanna HI98129 portable pH meter. If sampling of total suspended solids (TSS) is deemed necessary, samples will be collected in 1 litre bottles and analyzed ex situ at a reputable laboratory (e.g., CARO). Other alternative, calibrated meters or laboratories may also be used. Turbidity levels will be monitored as required and must conform to provincial guidelines;

- During clear flow periods, induced turbidity should not exceed 8 NTU above background levels at any given time and no more than an average of 2 NTU above background levels over a 30-day period;

- During turbid flow periods, induced turbidity should not exceed background levels by more than 5 NTU at any time when background turbidity is between 8 and 50 NTU. When background exceeds 50 NTU, turbidity should not be increased by more than 10% of the measured background level at any one time.

- pH levels will also be monitored as required. Levels must conform to ministry of environment and climate change strategy (ENV) guidelines (2018).

- Emergency measures must be implemented if downstream pH has changed more than 1.0 pH unit, measured to an accuracy of +/- 0.2 pH units from the background level, or is recorded to be below 6.5 or above 9.0 pH units.

4.6 Air Quality & Greenhouse Gas Reduction

Dust control can be achieved by reducing the spatial extents and amount of time that soils are exposed to construction activities. Reducing traffic speed and volume can also reduce dust concerns. Surface and air movement of smoke and dust during project activities can be mitigated through preventive measures and design criteria.

- Where suitable, exposed soils should be watered as required to suppress dust. Sediment-laden runoff water must not be conveyed to the storm drain system, off the project site, or over steep slopes. Oil and other petroleum products must not be used for dust suppression.

- Idle time of construction equipment and contractor vehicles should be kept to a minimum to reduce the release of greenhouse gases. The contractor should inform

and educate employees and sub-contractors on the importance of minimizing idling time and develop guidelines to direct the practice of reducing unnecessary idling.

- If possible, alternate energy sources should be considered during development of the site, such as solar panels and ground source heating and cooling. Other options for greenhouse gas reducing features include rainwater recycling systems, landscaping with native species, and utilizing water efficient products.
- All road surfaces along Okanagan Centre Road East, Tyndall Road, and other access roads must be kept clean and free of fine materials (i.e., swept or scraped) regularly to prevent the increase of airborne particulate matter.

Table 12 outlines the Greenhouse Gas Reduction measures recommended by the District of Lake Country's OCP. The checklist is required to be completed for Development Permit applications.

Table 12. DLC GHG Reduction and Conservation Factors Checklist			
GHG Factor and Description	**Yes**	**No**	**N/A**
Has site density been maximized for subdivisions?	X		
Has the building footprint been minimized in order to allow for maximum green space?	X		
Have lots been oriented to maximize solar orientation of building envelopes? Have buildings been oriented to maximize solar gain? (Partial)	X	X	
Is the subdivision laid out to minimize the length and amount of infrastructure (such as sewer & water lines and roads)?	X		
Does the layout allow for alternative transportation options and transit?	X		
Is the subdivision laid out to maximize site connectivity to nearby amenities and services?	X		
Do the materials and colors used in building construction minimizer heat absorption? Is the roof not a dark color?	X		
Are large windows sheltered by overhands which maximize solar input during winter months?	X		
Do proposed buildings incorporate green roofs, living walls or other measures to reduce heat gains cause by hard surfaces?		X	
Are alternative energy sources being proposed in large scale structures?			X
Do buildings have a south oriented roof to allow for future use of solar panels? (Partial)	X	X	
Are there opportunities for natural ventilation and airflow incorporated into the building?	X		
Do building materials encourage thermal massing and seasonal thermal energy storage?		X	
Are building envelopes well sealed and energy efficient?	X		
Is vegetation low maintenance and require minimal irrigation?	X		
Is the enhanced landscaping located along the south and west facing parcel boundaries to create shade?		X	
Is rainwater recycling included in landscape designs?		X	
Have porous material been maximized throughout the landscaping?	X		
Do water features use recirculation systems as opposed to once through systems?			X
Are opportunities for local food production and public food gardens incorporated into larger developments and subdivisions?			X

4.7 Habitat Remediation and Enhancement

The loss of rare, sensitive, at risk and core habitats from construction activities must be carefully considered prior to development. Habitat loss has a cumulative effect on wildlife species and ecological communities which may lead to negative effects to identified species at risk.

The noise, vibrations, and pollution associated with construction activities have the potential to disrupt important wildlife activities including migrating, foraging, and breeding. Timing and proximity to environmentally sensitive areas that are more likely to support sensitive species are important considerations to reduce impacts to wildlife during both the construction and occupation stages of the development.

Construction activities have the potential to cause direct harm to wildlife. In particular, small wildlife species that are less motile or that tend to seek refuge in snags, coarse woody debris, or within rock outcrops, talus, or other natural debris, are vulnerable as they are less likely to vacate the subject property prior to construction activities taking place. All wildlife, including bird and small mammal nests that occur along the ground, in live and dead trees, or within rock crevices, are protected by the provincial Wildlife Act and federal Migratory Birds Convention Act. Raptor and heron nests that are used over numerous breeding seasons are protected whether they are active or not.

Snags and Wildlife boxes

- Bird houses should be installed on trees throughout the Project Area, particularly in areas where wildlife trees or snags have been removed. These bird houses are to compensate for lost cavity nesting opportunities due to tree removal. Bird box design and installation are specific to the bird species. The number and location of bird boxes will be determined by the QEP at the time of construction startup.
- A list of species-specific designs and considerations can be found at:

  The Cornell Lab of Ornithology: Nestwatch

  The Canadian Wildlife Federation
- Bat boxes should be installed adjacent to ponds. The exact number and locations will be established by the QEP at the time of construction startup. It is recommended that bat boxes be installed on poles in open areas to maximize the opportunity for bats to find the boxes. Bat box design and installation should conform specifications outlined in Building Homes for Bats: A Guide for Bat Houses in British Columbia (2015), which can be found at:

  Community Bat Programs in BC

  An example of bird and bat box designs has been included as **Appendix 5**.

Revegetation

- Invasive Species Management and Restoration are addressed in Sections 4.9 and 4.12, respectively.
- Weed management and erosion control must occur in all areas disturbed during development. At a minimum, hydro-seed or loose grass seed must be applied to re-vegetate areas that have been disturbed.

- Hydroseed and/or grass seed with mulch must be applied to exposed soils following construction. Grass seed mixes should be native to the Okanagan and certified as Canada #1 Grade by Agriculture Canada to minimize the weed seed count. Fodder species such as clover and alfalfa must not be included in the mixture. The seed mixture must contain native species appropriate for the ecological conditions and will be reviewed by the EM prior to application. Grass seed should not be applied during periods of extremely hot and/or dry weather (i.e., July and August).
- If additional disturbance occurs outside the development footprint, these areas will need to be addressed by the EM and restored with native plantings and/or hydroseeding.
- Retention of some coarse woody debris within the Project Area is recommended for the wildlife habitat value and slope stabilization it provides.
- Plant salvages of existing native species within the limit of disturbance should be considered for future restoration of the Project Area (**Appendix 6**).

Wildlife Surveys

At the start of each phase of the Project, wildlife inventories and salvages (where applicable) are required prior to development commencing in order to survey each phase for species occurrences and habitat features. Ideally, surveys will be conducted in the spring and the fall when feasible.

Avoidance of Hibernaculum

Habitat for sensitive and at-risk herptiles including the Great Basin Gopher Snake, North American Racer, Western Rattlesnake and Rubber Boa were identified onsite during the field inventory. The rock outcrops and talus slopes in the Project Area, particularly any south and west facing slopes, provide ideal habitat for snakes and must be given careful consideration to avoid conflicts and habitat destruction. Additional spring snake surveys are recommended to document locations of critical habitat for these species that should be retained within the Project Area. Movement corridors and retention areas should focus on retention of critical snake habitat and linkages to adjacent natural areas. Should snakes be discovered during construction, Ecoscape must be contacted immediately to conduct a snake salvage. The Province has issued a draft BMP document of Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia (**Appendix 7**), which will provide additional guidance and recommendations for the Project.

Western Rattlesnake habitat is believed to be strongly associated with rock outcrops, talus slopes, shrub-steppe / grassland, riparian and ponderosa pine habitats (SIRART 2008). Winter hibernacula (dens) are typically located within south facing rock outcrop associated with talus slopes which also provide important basking habitat in the spring and fall (SIRART, 2008). As such, these habitats should be avoided by the development and connectivity maintained with adjacent habitats.

The ESA mapping (**Figure 3**) provided by Ecoscape is meant to reflect the important association of talus and rock outcrop habitats and to maintain suitable habitats associated with the at risk herptile occurrences.

Other sensitive snakes known to occur or that have the potential to occur within the subject property, including gopher snakes, racers, western skink, rubber boa, and great-basin spadefoot have similar habitat associations as the western rattlesnake (e.g., talus, rock outcrop, hibernacula) (SIRART 2008). As such, the avoidance of suitable habitats and mitigation of

development activities for the western rattlesnake will benefit these species as well. Avoidance of the most suitable habitats and maintenance of connectivity with adjacent lands will also prevent the isolation of critical habitats and fragmentation of the subject property.

In general, the development planning should attempt to avoid rock outcrops, talus, cliffs, and other rocky and sparsely vegetated sites that are suitable for important life history stages for the sensitive reptile species identified within the subject property (MELP 1999; MWLAP 2004a; MWLAP 2004b). Coarse woody debris and large rocks should be conserved where possible. Wetland, riparian, and other aquatic habitats should be avoided to conserve the critical habitat they provide to identified reptile and amphibian species.

Contractors, construction workers, property owners and the general public should be educated about the presence of the sensitive herptile species that occur within the subject property and shown how to limit disturbance and re-locate individuals if necessary. Signage should be installed informing the public / property owners about the presence of these species and the importance of protecting them and their habitat.

Road planning and construction should avoid maximum retention areas and movement corridors. Construction activities near critical habitats should be avoided between April and October when snakes are most active (SIRART 2008). Roads are known to lead to snake mortalities from basking or crossing (MWLAP 2004b).

Known locations of sensitive herptile species should be monitored during development and construction and salvage of individuals conducted as required by QEP's to limit disturbance and mortality.

Ecosystem Connectivity and Maintenance of Movement Corridors

Connectivity between occurrence locations and suitable habitats must be maintained within the Project Area. This will prevent the arbitrary buffering of potentially less important habitat and instead focus on critical habitats required to sustain the species within or adjacent to the subject property, such as talus slopes and rocky outcrops that provide hibernacula and denning areas and other areas suitable for migratory and dispersal corridors.

Constructed roadways within the subject property have the potential to impact wildlife movement. Habitat fragmentation as a result of development affects numerous ecological processes across multiple spatial and temporal scales, including shifts in habitat use, altered population dynamics of species, and changes in species compositions. Fragmentation of habitats can ultimately result in displacement or the local extirpation (i.e., extinction at a local scale) of species. Connectivity between natural areas should be maintained to preserve habitat for resident species.

In order to maintain connectivity at the site, the development designs should incorporate, where feasible, exclusion fencing (e.g., drift fence and funnel fencing) and customized crossings (e.g., ecopassage tunnels, minimum 600 box culverts, and arch culverts) at key corridors and habitat linkages where road crossings may lead to wildlife mortalities or reduced migration potential. Proposed areas for these crossing can be found in **Figure 5**. Ecoscape must review the crossing designs to ensure an adequate size is provided and ensure natural ambient light is provided throughout the length of the crossing. The wildlife crossings must be wildlife specific and not a dual purpose wildlife crossing / stormwater management culvert. The proposed crossings providing a movement corridor between development phases must be an adequate size to allow larger mammals to travel through the crossing.

Example designs for an ecopassage can be found at http://www.acowildlife.us/at500.html. Example of designs for wildlife fencing can be found at http://www.acowildlife.us/fence.html.

Culverts must be designed to allow for natural ambient light throughout the culvert and should be specific for wildlife and not a dual purpose wildlife / stormwater culvert. The exact design and size of the crossings must be reviewed and approved by Ecoscape prior to implementation. Upon completion of the spring snake surveys a review of the proposed culvert locations will be undertaken with adjustment in the number of culverts and locations completed by Ecoscape.

In addition to wildlife crossings, signage is recommended along the roadsides in the Project Area and the greater Lakestone development to raise public awareness and facilitate education, and discourage human disturbance during and post-construction of habitat features, ecosystems, and wildlife.

4.8 Rockfall Mitigation

- The prominent cliff areas should be designated as No Disturb Areas to protect important habitat for bats including the federally endangered little brown myotis. Therefore, requirements for rockfall mitigation in these cliff habitats has been mitigated by avoiding development beneath.
- Rockfall mitigation will be required in areas of proposed development near cliff and talus features. Rock scaling (by hand) should be conservative – taking care to preserve cracks and fissures that do not present imminent risk and enhancing downslope secondary stop measures to intercept any potential rockfall. A more detailed rockfall mitigation strategy will be discussed at the time of construction startup.
- Rock scaling and any additional measures should be reviewed onsite with the environmental monitor/biologist prior to initiation.

4.9 Invasive Species Management

A noxious weed management plan for each phase of the Project must be prepared by a Qualified Environmental Professional prior to development. Ahead of detailed designs for each phase, general practices include:

- Ongoing invasive species control will be required within any areas with exposed/disturbed soils in the first few years until vegetation becomes established. Species that are aggressive have the potential to outcompete native species.
- Invasive plant species should be hand pulled or brushed/mowed using mechanical means. Mowing or brushing of invasive plant species should only occur before they have flowered or gone to seed. The use of chemical treatments is not recommended, particularly since herbicides can kill native species and due to plantings associated with stormwater runoff which enters watercourses untreated.
- The contractor will ensure that all equipment and vehicles are washed and free of weed seeds prior to mobilization and de-mobilization. Vehicles and equipment should not be stored, parked, or staged within weed infested areas if possible. Contractor clothing

should also be inspected daily for signs of weed seeds. If found, weed seeds should be disposed of in a contained refuse bin for offsite disposal.

- Care must be taken to ensure that invasive species removal does not impact existing or planted native tree and shrub species.
- Invasive plant species must be disposed of in a landfill; however, invasive species material must not be composted in the yard waste section of the landfill. Invasive plant species must not be transported to or deposited in other natural areas.

4.10 Site Clean Up

- Effective site cleanup and restoration refers to returning a site to a state resembling the original habitat characteristics. Protection of existing ecosystems is generally much more efficient than ecosystem enhancement and restoration following construction. As per the District of Lake Country OCP, ESA 3 areas will benefit from restoration and enhancement activities which will facilitate succession to higher value habitats.
- Silt fencing and other temporary mitigation features must be removed upon substantial completion of construction works. All equipment, supplies, waste, and other non-biodegradable construction materials must be removed from the site following completion of construction activities.

4.11 Environmental Monitoring

An environmental monitor (EM) should be retained during construction activities at the discretion of the District of Lake Country. The EM will be an appropriately qualified environmental professional (QEP) to guide and document compliance with BMPs, mitigation measures, and other recommendations and provide guidance for implementation of best practices (e.g., erosion and sediment control, restoration) throughout each phase of construction. In the event that greater disturbance occurs due to unforeseen circumstances, the EM will recommend measures to protect/restore the natural integrity of the site. If the District of Lake Country requires monitoring, the following schedule is recommended;

- For each phase of development, a pre-construction meeting should be held between the EM and the contractor(s) undertaking the work onsite to ensure a common understanding of the mitigation measures and best practices required for the project. Copies of relevant permits and this report must be kept readily available at the site for reference while the work is being conducted. Site delineation must be in place prior to project startup. At the start of each phase, the EM will conduct any relevant inventories, identify veteran and wildlife trees, wildlife crossings, and provide general monitoring throughout each phase of construction.
- The EM will be authorized to halt construction activities should an incident arise that is causing undue harm (unforeseen or from lack of due care) to terrestrial resource values.
- Construction activities should be monitored on a monthly basis and more regularly during high risk activities (e.g. clearing and grubbing, concrete pours, large material excavations) until the completion of the project.

- Regular monitoring reports will be submitted to the primary contractor, client, and the District of Lake Country. Once construction and restoration are complete, a substantial completion site visit and report will be undertaken by the EM.

4.12 Restoration, Performance and Maintenance Bonding

At this stage, a formalized landscape plan or restoration plan has not been prepared given the preliminary design stage of the Project. Once formal designs have been finalized for the Project, a detailed Restoration Plan including security bonding must be prepared by a Qualified Environmental Professional. Ecoscape must review and approve any plans prior to implementation. Restoration Plans will be prepared for each phase of the Project to include a site-specific assessment of ecosystems, aspect, slope, and soils to provide a species planting list, intended ecosystem target species, and a planting plan that will be adapted at the time of construction based on site conditions observed and implemented in a field-fit manner.

Restoration bonding will be prepared individually for each phase and will include:

- Species planting list
- Installed plant costs
- Grass seed mix, amount, and cost
- Habitat feature installation (coarse woody debris, etc.)
- Maintenance (irrigation, labour)
- Invasive species management
- Environmental monitoring

5.0 CONCLUSION

This Environmental Assessment report has been prepared to address the Natural Environment Development Permit guidelines as described in the District of Lake Country Official Community Plan (DLC OCP), related to the proposed Lakestone project in Lake Country, BC. Based on the site assessment and proposed site plans, the primary environmental concern is for the conservation and maintenance of habitat features within the Project Area and the functionality and connectivity of the Project Area's high value ecosystems such as wetlands, gullies, and cliff/talus communities. As the Project progresses, detailed assessments, inventories and surveys will be needed for each phase as the designs and specifications are developed.

The impact of the Project on environmentally sensitive areas (ESAs) will results in a loss of 27% of ESA 2 (High) and 14% of ESA 3 (Moderate) in the Project Area. Recommended mitigation measures must be incorporated into the design and construction, and the development footprint must be limited to the areas proposed as least disturbance to high ESA values in order to meet the intent of the Development Permit guidelines as described in the DLC OCP.

Provincial regulations and best management practices will provide suitable guidance in the development of avoidance, mitigation and/or compensation strategies for the sensitive habitats described in this report. Appropriate mitigation planning should provide reasonable protection to maintain the ecological integrity of the Project Area. Other potential negative impacts associated with construction can be appropriately mitigated by adhering to the recommended mitigation measures, best management practices, construction standards, and applicable District of Lake Country Development Permit guidelines and government regulations, as described in this report.

6.0 CLOSURE

This letter has been prepared for the exclusive use of Macdonald Lakeshore Properties LP. for the proposed Lakestone development in Lake Country, BC.

This report has been prepared with the understanding that all available information on the past, present, and proposed conditions of the site have been disclosed. Macdonald Lakeshore Properties LP. has acknowledged that in order for Ecoscape to properly provide the professional service, Ecoscape is relying upon full disclosure and accuracy of this information.

If you have any questions or comments, please contact the undersigned at your convenience.

Respectfully submitted,
ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.

Prepared By:



Theresa Loewen, M.Sc., P.Ag.
Environmental Scientist / Agrologist
Direct Line: (250) 491-7337 ext. 214
Email: tloewen@ecoscapeltd.com

Reviewed By:



Jason Schleppe, M.Sc., R.P.Bio.
Senior Natural Resource Biologist
Direct Line: (250) 491-7337 ext. 202
Email: maolson-russello@ecoscapeltd.com



Kyle Hawes, B.Sc., R.P.Bio.
Senior Natural Resource Biologist
Direct Line: (250) 491-7337 ext. 203
Email: khawes@ecoscapeltd.com

7.0 REFERENCES

Aresco, M. 2003. Highway Mortality of Turtles and Other Herpetofauna at Lake Jackson, Florida, USA, and the Efficacy of a Temporary Fence/Culvert System to Reduce Road Kills. Recent Work, Road Ecology Centre, John Muir Institute of the Environment, UC Davis. Retrieved February 12, 2019 at: https://longpointcauseway.com/library/Lake%20Jackson%20Florida%20-%20Aresco.pdf

B.C. Conservation Data Centre, 2018. BC Species and Ecosystems Explorer. B.C. Ministry of Environment Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (Accessed: May 23, 2018).

Chilibeck, B., G. Chlslett, G. Norris. 1992. Land Development Guidelines for the Protection of Aquatic Habitat. Prepared for the Department of Fisheries and Oceans Canada. Retrieved February 12, 2019 at: http://www.dfo-mpo.gc.ca/Library/165353.pdf

Grods, J. 2012. Environmental Assessment of Lakestone 2012 Master Plan. Makonis Consulting Ltd.

Iverson, K. 2008. Sensitive Ecosystems Inventory: Kelowna, 2007. Volume 2: Terrestrial Ecosystem, Terrain, Terrain Stability, and Surface Erosion Mapping and Expanded Legend. Prepared for City of Kelowna, British Columbia.

Lloyd, D., K. Angove, G. Hope, and C. Thompson, 1990. A guide to site identification and interpretation for the Kamloops Forest Region. Land Management Handbook No. 23. February 1990. BC Ministry of Forests.

Macdonald Lakeshore Properties LP. 2020. Lakestone 2020 Master Plan Environmental Impact Statement. Macdonald Communities Limited, pp. 67.

Polster, D., J. Cullington, T. Douglas, and T. Hooper, 2014. Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia. Prepared for the BC Ministry of Environment. Victoria (BC).

PHOTOGRAPHS



Photo 1. View of the north end of the Project Area with various structural stages including pole sapling. All photos taken April 20 – 22, 2020.



Photo 2. View of the north end of the Project Area with various structural stages including pole sapling.



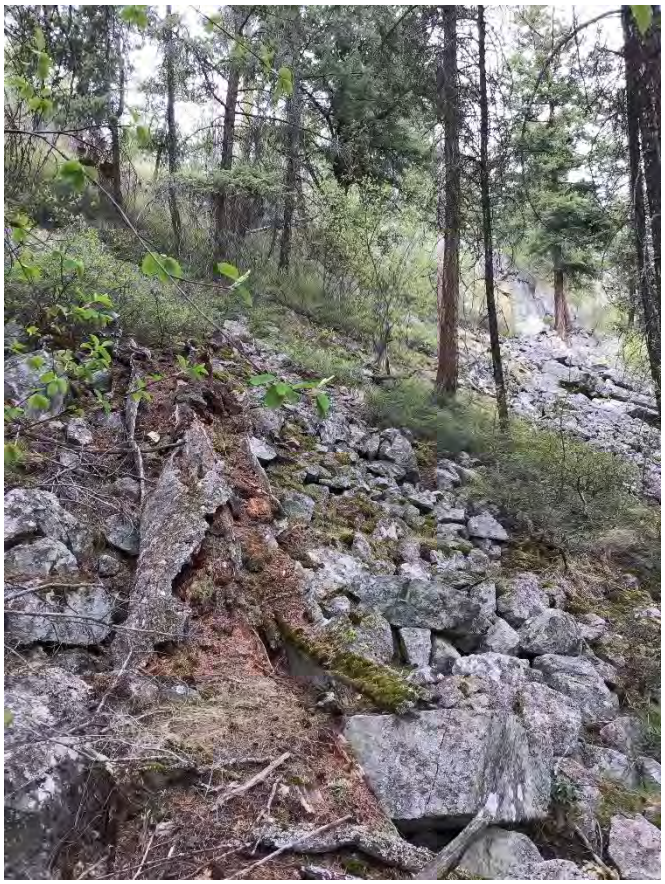
Photo 3. View of rock outcrop/sparsely vegetated ecosystem.



Photo 4. View of talus slope on the western extent of the Project Area.



Photo 5. View of rock outcrop on the eastern extent of the Project Area (photo facing east).





Photos 6 and 7. View of talus slope and cliff feature on the east side of the Project Area.



Photo 8. View of cliff/bluff feature at the western extent of the project area alongside Tyndall Rd.



Photo 9. View of open pond and wetland ecosystem (common cattail marsh) in the southern area of the Project Area



Photo 10. View of open pond and wetland ecosystem in the southern area of the Project Area.



Photo 11. View of open pond and wetland ecosystem in central area of the Project Area.



Photo 12. View of previous disturbance (walking trail) in the Project Area.



Photo 13. View facing east downslope of the Project Area with interior Douglas-fir and Saskatoon.



Photo 14. View facing east on the ridge top of the Project Area with ponderosa pine, arrow-leaf balsamroot, and Saskatoon.




Photos 15 and 16. View of veteran / wildlife trees throughout the Project Area.



Photo 17. View of veteran / wildlife trees throughout the Project Area.




Photos 18 and 19. View of veteran / wildlife trees throughout the Project Area.



Photo 20. View of veteran / wildlife trees throughout the Project Area.





Photos 21 and 22. View of veteran / wildlife trees throughout the Project Area.



Photo 23. View of veteran / wildlife trees throughout the Project Area.



Photo 24. View of native vegetation including arrow-leaf balsamroot, bunchgrasses, ponderosa pine, and interior Douglas fir.



Photo 25. View of native vegetation including tall-Oregon grape and Saskatoon.



Photo 26. View of open pond and wetland ecosystem (common cattail marsh) in the north, outside of the Project Area but within the Lakestone development.



Photo 27. View of frog species found within the Project Area.



Photo 28. View of moisture receiving areas within the Project Area.



Photo 29. View of moisture receiving areas within the Project Area.



Photo 30. View of facing east of gulley within the Project Area.



Photo 31. View of gulley within the Project Area.



Photo 32. View of gulley within the Project Area.



Photo 33. View of wetland within the Project Area.

FIGURES

FIGURE 1
Site Location, Wetland Information and Species at Risk Occurrences

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

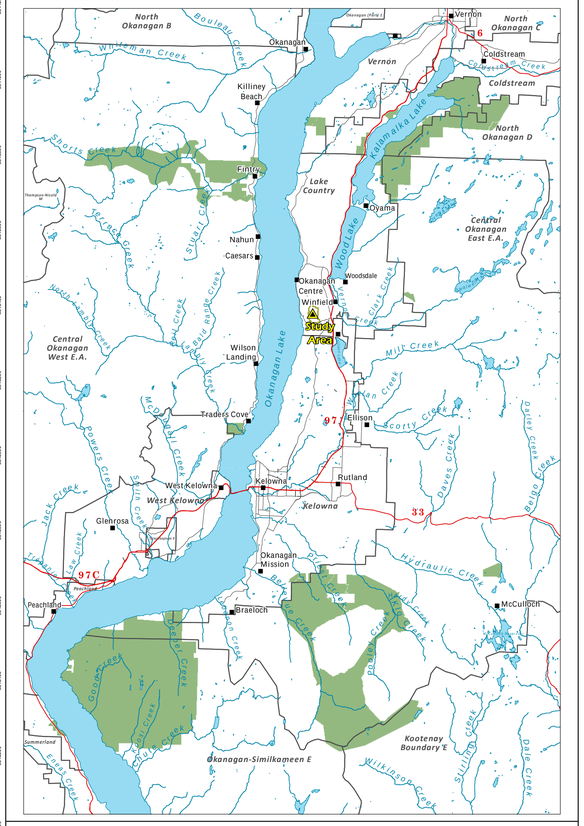
LEGEND

- Study Area
- Phasing Plan
- Cadastre
- Wetland and Riparian Communities
- Okanagan Critical Habitat (Species at Risk)
- BC Conservation Data Center (CDC) Polygons*
- Streams
- Wildlife Species Inventory (Survey)
- Wildlife Species Inventory (Incidental)

*A large Okanagan Critical Habitat polygon covers the entire map and subject property area representing the following wildlife species but is not shown on this figure:
- Western Rattlesnake (*Crotalus oreganus*)
- Desert Nightsnake (*Hypsiglena chlorophaea*)
- Great Basin Gophersnake (*Pituophis catenifer deserticola*)

Large Conservation Data Centre (CDC) polygons include:
- American Badger (*Taxidea taxus*)

Regional Location of Subject Property



DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd.

FIGURE 2
Ecosystem Polygons

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	January 4, 2021

LEGEND

- Study Area
- Cadastre
- Ecosystem Polygons
- Contour (10 Metre)
- Streams

Ecosystem Polygon Key

2402 ← Polygon Number
Decile (60%) → 6PFks6C ← Stand Modifier (C)
Ecosystem Unit (PF) → PFks3 ← Structural Stage (3)
Site Modifiers (wc) → PFwc6Ckc ← Seral Stage (kc)

Ecosystem Units

CL	Cliff
DM	Douglas fir - Water birch - Douglas maple
DS	Dougas fir - Ponderosa pine - Snowberry - Spirea
ES	Exposed Soil
FB	Rough fescue - Bluebunch wheatgrass
FI07	Fd - Water birch - Douglas maple
PF	Dougas fir - Ponderosa pine - Pinegrass - Idaho fescue
PT	Ponderosa pine - Red three-awn
PW	Ponderosa pine - Bluebunch wheatgrass - Idaho fescue
RO	Rock Outcrop
RW	Rural
RZ	Road surface
SA	Antelope brush - Selaginella
SB	Sellaginella - Bluebunch wheatgrass
SO	Saskatoon - Mock Orange - Talus
SP	Dougas fir - Ponderosa pine - Snowbrush - Pinegrass
SW	Shallow Water
TA	Talus
WB	Bluebunch wheatgrass - Balsamroot
Wm05	Cattail Marsh
Wm06	Bulrush Marsh
Ws03	Willow - Sedge

Site Modifiers

c	Coarse-textured soils
g	Site occurs in a gully
j	Gentle to moderate slope (slope < 25%)
k	Cool aspect (25% - 100% slope, 135° - 285°)
r	Ridged or ridge crest
s	Shallow soils (20-100 cm to bedrock)
v	Very shallow soils (<20 cm to bedrock)
w	Warm aspect (25% - 100% slope, 135° - 285°)

Structural Stage

2	Herb
3	Shrub/Herb
3b	Shrub/Herb - Tall Shrub
4	Pole Sapling
5	Young Forest
6	Mature Forest
7	Old Forest

Stand Modifiers

B	Broadleaf
C	Coniferous
M	Mixed

Disturbance Modifiers

Le	Forest harvesting (group selection, single tree, strip)
Ll	Land clearing (includes abandoned agriculture)

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

0 50 100 200 300 400 500
Meters

FIGURE 3

Environmental Sensitivity Analysis

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

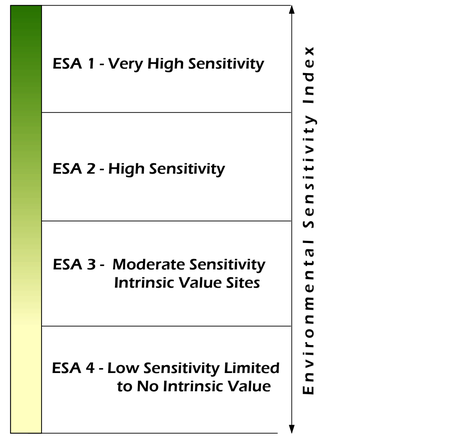
LEGEND

- Subject Property
- Cadastre
- Streams and Rivers
- Contour (10 Metre)

Environmental Sensitivity Rating

- Very High (ESA 1)
- High (ESA 2)
- Moderate (ESA 3)
- Low (ESA 4)

Environmental Sensitivity Gradient



DISCLAIMER

The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

FIGURE 4
Impact Assessment

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

LEGEND

- Subject Property
- Cadastre
- Phasing Plan
- Limit of Disturbance
- Proposed Development Roads/Lots
- Proposed Development Easement
- Streams and Rivers

Proposed Limit of Disturbance [557271 m²]

Proposed Development Roads/Lots

Summit Phase

East Ridge

Highlands Central

Highlands West

Highlands East

Highlands South

OK Centre Plateau

Chase Residential

Glenmore Industrial

Okanagan Lake

LONG RD
BEACON HILL DR
CHASE RD
KEL-VERN CRES
OKANAGAN CENTRE RD E
SEATON RD
READ RD
SANTINA RD
DICK RD
CENTRESTONE DR
BENCHLAND DR
TYNDALL RD
SLATEVIEW CRES
LIMESTONE DR
LAKESTONE DR
GRANITE RD
FINCH RD
STUBBS RD
HERITAGE DR
MCCOUBREY RD
OKANAGAN CENTRE RD W
GLENMORE RD
SHANKS RD

0 50 100 200 300 400 500
Meters

Source: Esri, Maxar, Geolay, EarthStar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

FIGURE 5
Crossings and Signage

Project:	Environmental Assessment
Location:	District of Lake Country
Project No.:	20-3272
Prepared for:	Alpine Consultants Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Robert Wagner, GIS Specialist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Field Visit:	July, 2020
Map Date:	December 23, 2020

LEGEND

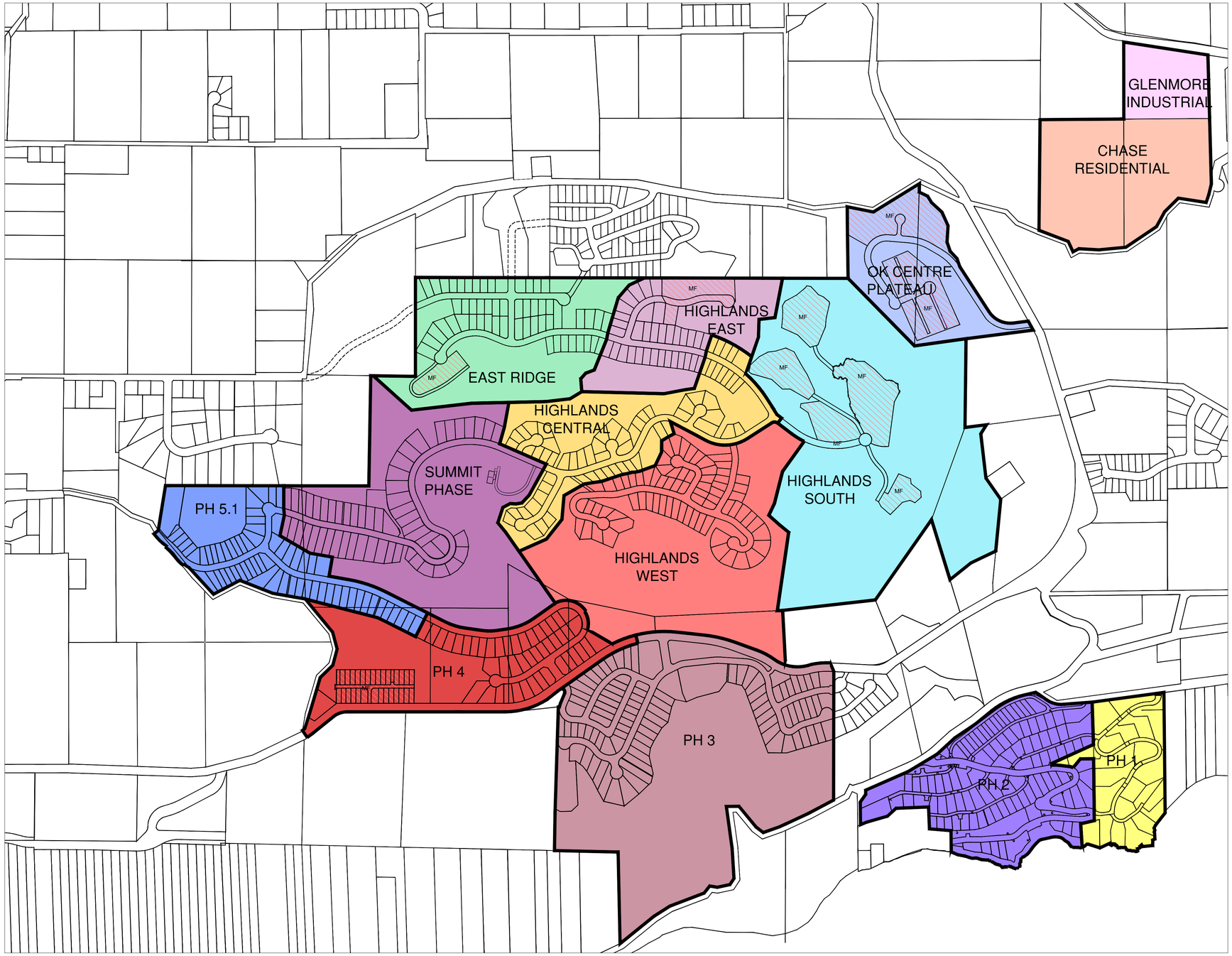
- Subject Property
- Cadastre
- Phasing Plan
- Limit of Disturbance
- Proposed Development Roads/Lots
- Proposed Development Easement
- Streams and Rivers
- Arch Culvert
- Box Culvert
- Ecopassage Tunnel
- Wildlife Crossing Signage

DISCLAIMER

The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

APPENDIX 1:
Lakestone 2020 Master Plan Phasing



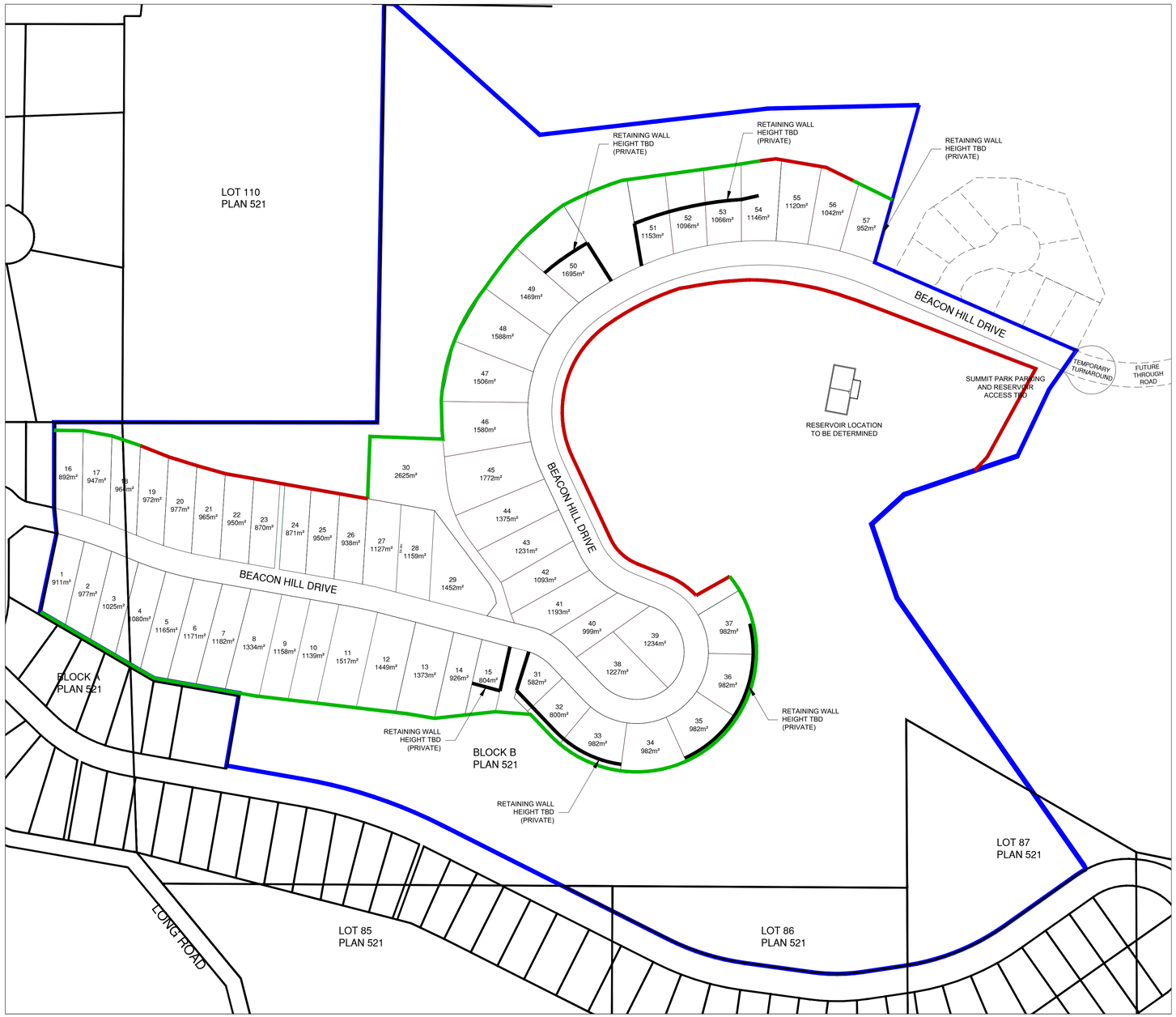
PHASING PLAN

ALPINE CONSULTANTS LTD

FIG.1

FILE LOCATION: F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - MP Figures\PROD-MPFIG 1-3.dwg PRINTED ON: 11/18/2020 9:25 AM

APPENDIX 2:
Lakestone Summit Phase



LEGEND:

- LIMIT OF DISTURBANCE - FILL EXTENT
- LIMIT OF DISTURBANCE - CUT EXTENT
- RETAINING WALL

NOTE:
LIMIT OF DISTURBANCE EXTENTS DO NOT INCLUDE DEVELOPMENT EXTENTS FOR PARKS, TRAILS, AND ASSOCIATED WORKS

FILE LOCATION: F:\1 Projects\4029 Summit\4029-4 Drawings\4029-41 Current Drawings\CIVIL\3 - PRODUCTION\PROD-PLR.dwg PRINTED ON: 11/18/2020 8:59 AM

NO.	YY/MM/DD	BY	REVISION	CH'KD

ALPINE CIVIL ENGINEERING

BASE	JP
DESIGN	JP
APPROVED	JBK
DATE	2020/10/30
SCALE	1:1500

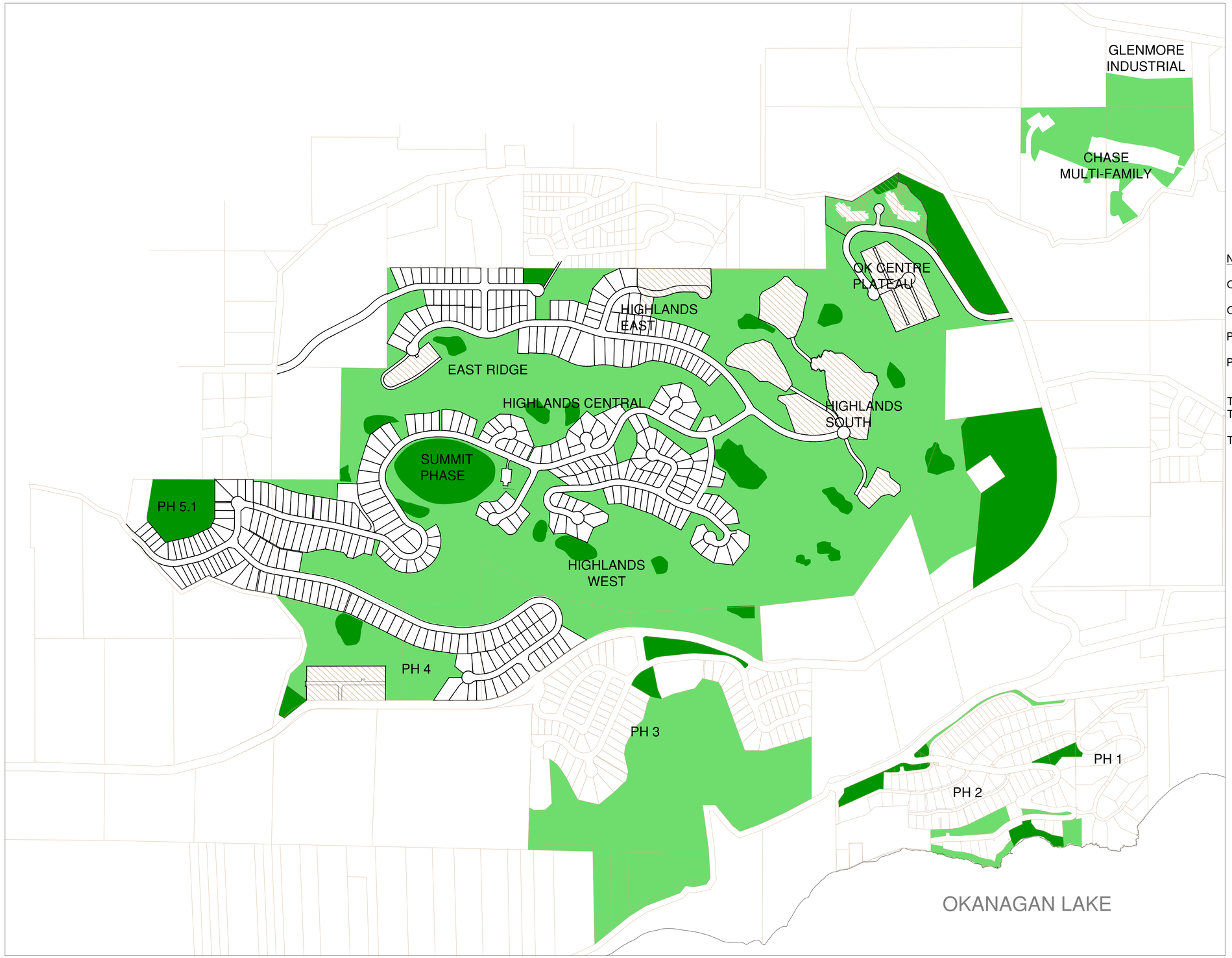
DISTRICT OF LAKE COUNTRY
DESIGN AND CONSTRUCTION

LAKESTONE SUMMIT PHASE
LAKESTONE MASTER PLANNED COMMUNITY
LIMIT OF DISTURBANCE

The location of existing underground utilities are shown in an approximate way only & have not been independently verified by the owner or its representative. The contractor shall determine the exact location of all existing utilities before commencing work, and agrees to be fully responsible for any and all damages which might be occasioned by the contractor's failure to exactly locate and preserve any and all underground utilities.

DRAWING NO. 1
REV. NO. 0
SHEET NO. 1 OF 1

APPENDIX 3:
Proposed Parks and Open Space Areas



NOTES:

OPEN SPACE-

OPEN SPACE AREA- 99.84ha

PARKS-

PARKS AREA- 11.54ha

TOTAL DEVELOPMENT AREA- 202.12ha
TOTAL PARKS & OPEN SPACE AREA- 111.38ha (55%)

TOTAL DEDICATED PARKS AREA- 8.9ha

PARKS &
OPEN SPACE

ALPINE
CONSULTANTS LTD

FIG.11

FILE LOCATION: F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODUCTION\1 - MP Figures\PROD-MPFIG.11.dwg PRINTED ON: 7/29/2020 9:13 AM

APPENDIX 4:
Common native plant species occurring within the Project Area

Appendix Table 1 below lists native vegetation observed during the site visits, as well as common species which are known to occur within the Project Area. Please note this is not an exhaustive list, as a detailed inventory was not conducted.

Appendix Table 1. Common native plant species occurring within the Project Area.

Family	Scientific Name	Common Name	Provincial Status [1]	COSEWIC Listing [2]
Trees				
Betulaceae	*Betula occidentalis*	Water birch	Yellow	N/A
Salicaceae	*Populus tremuloides*	Trembling aspen	Yellow	N/A
	Populus trichocarpa	Black cottonwood	Yellow	N/A
Pinaceae	*Pinus ponderosa var. ponderosa*	Ponderosa pine	Yellow	N/A
	Pseudotsuga menziesii var. glauca	Interior Douglas-fir	Yellow	N/A
Shrubs				
Asteraceae	*Chrysothamnus viscidiflorus ssp. lanceolatus*	Rabbitbrush	Yellow	N/A
Berberidaceae	*Berberis aquifolium*	Tall Oregon grape	Yellow	N/A
Caprifoliaceae	*Symphoricarpos albus*	Common snowberry	Yellow	N/A
Cornaceae	*Cornus sericea*	Red-osier dogwood	Yellow	N/A
Cupressaceae	*Juniperus communis var. depressa*	Dwarf juniper	Yellow	N/A
	Juniperus scopulorum	Rocky Mountain juniper	Yellow	N/A
Ericaceae	*Arctostaphylos uva-ursi*	Kinnikinnick	Yellow	N/A
Hydrangeaceae	*Philadelphus lewisii*	Mock orange	Yellow	N/A
Rosaceae	*Amelanchier alnifolia*	Saskatoon	Yellow	N/A
	Rosa nutkana	Nootka rose	Yellow	N/A
	Spirea lucida	Birch-leaved spirea	Yellow	N/A
Sapindaceae	*Acer glabrum*	Douglas maple	Yellow	N/A
Herbs				
Anacardiaceae	*Toxicodendron rydbergii*	Poison ivy	Yellow	N/A
Asteraceae	*Arnica cordifolia*	Heart-leaved arnica	Yellow	N/A
	Eurybia conspicua	Showy aster	Yellow	N/A
	Balsamorhiza sagittata	Arrowleaf balsamroot	Yellow	N/A
Lamiaceae	*Prunella vulgaris*	Self-heal	Yellow	N/A
Liliaceae	*Fritillaria affinis*	Chocolate lily	Yellow	N/A
Onagraceae	*Epilobuim brachycarpum*	Tall annual willowherb	Yellow	N/A
Rosaceae	*Fragaria virginiana*	Wild strawberry	Yellow	N/A
	Potentilla anserina ssp. anserina	Silverweed	Yellow	N/A
Grasses				
Poaceae	*Calamagrostis rubescens*	Pinegrass	Yellow	N/A
	Pseudoroegneria spicata	Bluebunch wheatgrass	Yellow	N/A

1 Source: http://www.env.gov.bc.ca/cdc/
Yellow: Not considered at risk. **Blue:** Of special concern. **Red:** Endangered or threatened.
2 Source: http://www.cosewic.gc.ca/
Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction. **Special Concern:** A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats. **Not at Risk:** A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances. **Endangered:** A wildlife species facing imminent extirpation or extinction. **Data Deficient:** A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

APPENDIX 5:
Bird and Bat Box Designs







Building Homes for Bats

A Guide for Bat Houses in British Columbia

INSIDE THIS HANDBOOK

- Key Features of Effective Bat Houses
- Bat House Designs
- Optimal Bat House Location
- Tips for Installing a Bat House
- Frequently Asked Questions about Bat Houses

Revised January 2017

community bat programs of BC

Contents

Background 1
Key Features of Effective Bat Houses 2
Bat House Designs 8
Optimal Bat House Location 12
Enhancing Bat Habitat on a Community Scale 16
Frequently Asked Questions About Bat Houses 17
Resources 20
APPENDIX 1: Register Your Bat House 21
APPENDIX 2: Annual Bat Count Information 22
APPENDIX 3: Bat House Plans 23

Acknowledgments

This document was prepared by Juliet Craig and updated by Mandy Kellner for the BC Community Bat Program. The information is adapted from "The Bat House Builder's Handbook" by Bat Conservation International but has been adapted to BC based on expert opinion. Very special gratitude to Mike Sarell, Cori Lausen, and Greg Falxa for sharing their knowledge and expertise on bat house design and placement. Special thanks to Doug Burles, Katie Calon, Christian Englesoft, Purnima Govindarajulu, Margaret Holm, Leigh Anne Isaac, Tanya Luszcz, Paula de la Vega, Cory Olsen, and Peter Ommundsen for their comments and thoughtful reviews. We are grateful to Julianne Leekie, Fairwinds Design, for developing the graphics and Dr. Greg Utzig for preparing the climate maps. We are indebted to our partners, the BC Conservation Foundation and BC Ministry of Environment.

This project was undertaken with the financial support of the Government of Canada. Ce projet a été réalisé avec l'appui financier du gouvernement du Canada. The BC Community Bat Project network recognizes the Habitat Conservation Trust Foundation and anglers, hunters, trappers and guides who contribute to the Trust for making a significant financial contribution to support the BC Community Bat Project. Without such support, this project would not have been possible. We also gratefully acknowledge the financial support of Columbia Basin Trust which supports efforts to deliver social, economic and environmental benefits to residents of the Columbia Basin, and of the Regional District of Central Kootenay's Kootenay Lake Local Conservation Fund.



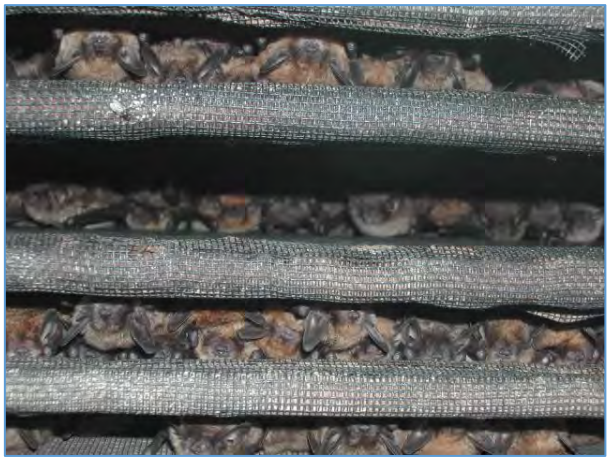
This version was updated in January 2017. Please see our website for updated versions: www.bcbats.ca.

Background

Bats are an essential component of healthy ecosystems and provide important control of agricultural and forest insect pests as well as flying insect populations. Two species of bats are federally endangered, and over half of the 16 bat species in British Columbia are considered to be “at risk” due to habitat loss and degradation, intentional extermination, wind turbines, pollution, climate change, and White-Nose Syndrome (WNS), a devastating disease that has decimated bat populations in the eastern parts of North America and has now been confirmed on the west coast.

Bats need our help, through protection of individuals and enhancement of habitat. You can support bat populations in your area by preserving snags (dead trees) and planting trees that will mature and provide roosting habitat. Installing a bat house is also a great way to enhance habitat for bats in your backyard. A bat house is a structure designed to provide bats with a warm, dry and safe summer roost site. Similar to birdhouses, they are often wooden “boxes” that can be installed on a high structure like a tall post or a building. Many people want bats because they want to promote backyard biodiversity or help control insects (particularly mosquitoes). Some people install bat houses in coordination with evicting bats from a building so that the bats will have an alternate roost site and the eviction will be more successful. Although **bat houses do not provide the same opportunities as natural roost structures for bats**[1], they are still an excellent option for increasing summer roosting habitat where natural features are limited or where bats are already in a human-made roost. In general, preservation of diverse natural features should be a priority; however, having safe, appropriate roosting habitat may help bats recover from the impacts of WNS and other threats, and in human-altered landscapes, bat houses may help fill this need.

Bat houses are often for sale in BC at garden centres, hardware stores, craft markets and other locations, or they are home-built. Whether you buy or build a bat house, ensure that it meets the criteria for good bat house design (see section *Key Features of Effective Bat houses*). Standardized information for bat houses in BC has only recently become available, and commercially-available bat houses may not meet these new criteria for size or design. Design is important, but it is also essential to install the bat house in an optimum location for success (see section *Optimal Bat House Location*).

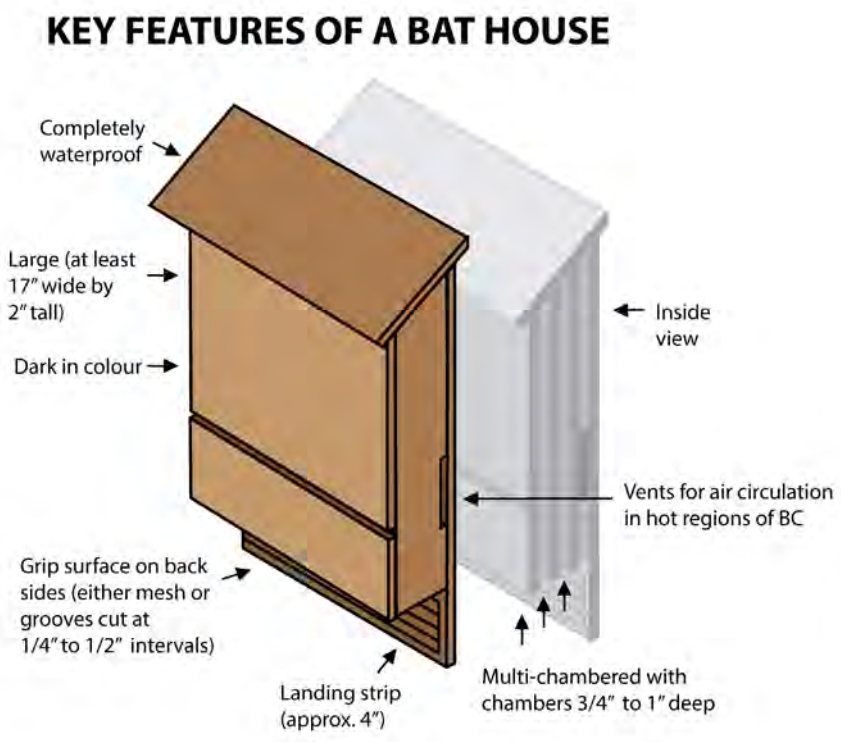


[1] Lausen, C.L. and Barclay, R.M.R. 2006. The benefits of living in a building: Comparing maternity colonies of big brown bats (*Eptesicus fuscus*) in rock crevice and building roosts. *Journal of Mammalogy* 87: 362-370.

The purpose of this document is to provide information about effective bat house design and placement for private landowners in BC. There is still much for us to learn about how bats determine which roost is most suitable, so try experimenting by putting bat houses in different locations, varying the dimensions, or staining one and not the other. Monitor occupancy by bats in summer by looking for guano under the bat house or observing the bat house at dusk to see if bats fly out. Register your bat house and report your results to the BC Community Bat Program (Appendix 1 or http://bcbats.ca/index.php/bat-houses/register-your-bat-house) so we can continue to improve the information in this document.

Key Features of Effective Bat Houses

There are several factors to consider when building or purchasing a bat house. Factors that influence success in attracting bats include the design, size, number of chambers, chamber spacing, surface roughness, and presence of vents and landing strip. Other factors to consider when selecting a style are cost, size of the bat colony (if you are excluding bats from a building), and location options. The most common designs on the market are bat boxes, rocket boxes and condos (see *Bat House Designs* section).



Size

Many bat houses sold in BC are too small for our temperate climate. For bat houses, **bigger IS better**! A larger house will provide a wider range of temperatures inside, allowing bats to choose a site that suits their needs (see side bar *Some Like It Hot!*). Bat boxes should be at least 24"[2] tall and 17" wide and have a landing strip of at least 4". Rocket boxes should be at least 3' tall and have at least 1' of linear roost space (meaning that each of the four sides would be at least 3" wide).

Chambers

Chambers are the cavities that bats actually roost within. Chambers should be carefully spaced to ¾" (for most bat species) or 1" (for Big Brown Bats). Bat houses with wider chambers don't hold heat as well and can attract wasps, and smaller chambers do not provide adequate roosting space. **Multiple chambered bat houses not only provide added roosting space, but also give bats the opportunity to select an appropriate temperature by moving between chambers.** This range in temperature is particularly important during heat spells when bat pups can otherwise die from overheating.

Movement Between Chambers

Holes or gaps in the dividers between chambers allow bats to move between chambers inside the bat house. These gaps can be developed by leaving a 1" gap about ½ way up the divider (so the divider is made out of two pieces of wood rather than one), or drilling holes about ½ way up (usually two 1 ½" diameter holes per divider)[3].

Some Like It Hot!

Bats require certain temperature ranges, depending on their sex, and whether they are raising a pup or not. Bats have the interesting ability to go into torpor (taking on the temperature of their surroundings, similar to cold-blooded animals like snakes). In doing so, they don't have to use their precious fat stores to generate heat for their bodies. When raising pups, adult females prefer warm roosts; males, which tend to roost alone during the day, are more likely to select cool roost locations. A female's need for warmth changes throughout the season, from pregnancy through to weaning her pup, and can also fluctuate on a daily basis depending on whether she is trying to nurse a pup, or save energy. The more chambers a bat house has, the greater its variety of microclimates and the more likely bats can find conditions suitable to their differing needs. Multi-chambered roosts can also attract more bats, which will raise roost temperatures and allow bats to reduce heat loss through huddling.

[2] Although Canada uses metric measurements, the building industry still uses imperial so that is what is used to describe building sizes and materials.
[3] Greg Falxa, personal communication.

Materials

For wood bat houses, a combination of cedar and exterior-grade plywood is best. Plywood for the exterior of the bat house should be at least ¾" thick with at least four plies. Pressure-treated wood should not be used due to the chemicals it may contain. Also, it can warp over time preventing use of the chambers. Be sure to use exterior-grade screws (not nails), staples, and hardware. Caulk any cracks and seams to ensure that water does not enter the house and to provide a good thermal habitat for the bats.

Landing Strip

A place for bats to land is a key feature of a bat house. Bat houses that do not have a landing strip or that have a slippery surface are usually ineffective. Landing strips should be at least 4" high and the width of the bat house, and have a rough surface.

Rough Surface

All areas where bats will be hanging (including the landing strip and one side of each chamber) should have a rough enough surface that bats can easily grip. Plywood on its own is too slippery. There are several methods that can be used to create a rough surface:

- **Score the wood** by cutting grooves (1/16" to 1/32" deep) at ½" intervals. This method creates excellent grip and has proven to be very effective although it is time consuming to build.
- **Affix fiberglass mesh** (door screen) onto the wood. This method has commonly been used in BC and is effective but there are concerns that the staples will corrode over time and guano (droppings) or bats can get trapped beneath. It is best to hide the staples between chamber spacers or on the edges of the divider plates. Avoid using metal screen since it corrodes and develops sharp points.
- Utilize a **naturally rough substrate** to build the chambers (such as rough cedar) which may be effective if it is heavily textured with deep grooves.
- **Mix a gritty substance with non-toxic stain** to create a roughly textured surface[4]. For example, paint boards with latex paint, sprinkle ground up cork or walnut shells (available as walking surface non-slip treatment) and then paint another layer of latex paint. This method is relatively simple yet effective. A blender can be used to grind the cork, and ground walnut shells are available through jewelry polishers or at home building supply centers for applying to decks while being painted.[4]
- **Use a low grit sandpaper** on a power sander[5].
- Make a "scouring pad" by putting many screws or nails through a board (like the bristles of a hair brush) and **"rake" this nail or screw pad** over the wood to create grooves[4.]

[4] Greg Falxa, personal communication.

[5] Justin Stevenson, RD Wildlife Management, personal communication.

Mounting Brackets or Lips

Since large bat houses are quite heavy once they are built, installation can be challenging. Building a bat house with installation in mind (such as creating lips on the edges or top of the bat house to drill screws through) can make it easier. A mounting bracket can also be built onto the bat house or onto the structure to which it will be attached.

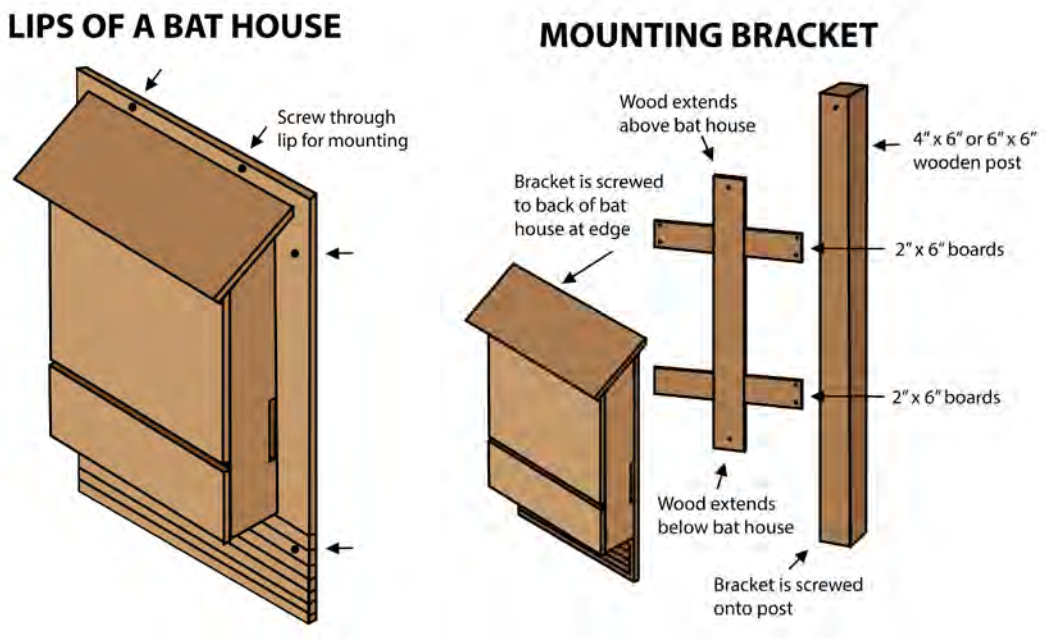


DIAGRAM SHOWING LIPS (LEFT) AND MOUNTING BRACKET (RIGHT) FOR MOUNTING BAT HOUSE.

Vents (in hotter regions of BC)

Although not necessary in all regions of BC, vents allow air movement and increase the range of temperatures inside a roost. During intense heat, vents may be important for preventing extreme temperatures inside the bat house. Vents are approximately ½" wide, and can be placed approximately 1/3 of the length of the bat house up from the bottom. The front vent should be as wide as the house. In hot areas of BC, including the Kootenays, Okanagan and Thompson/Fraser, vents are recommended whereas in the rest of the province, they are optional.

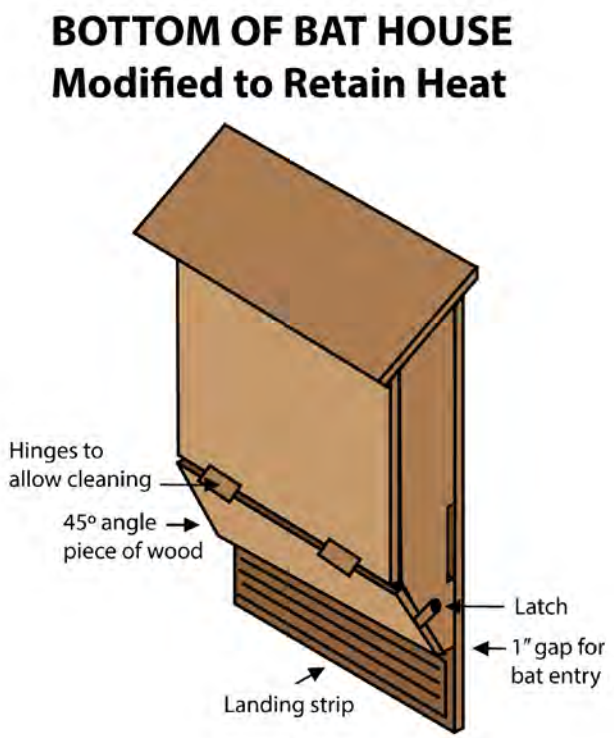
Overheating

In hotter parts of the province, bat houses may overheat. Regular observation of your bat house can reveal if it is too hot at times, and needs to be relocated to a cooler site - an overly-hot house will cause bats to cluster at the lowest exit point during the day, or even lead to death of bats, although mortalities may be due to many causes. Never touch dead bats with your bare hands, and report any mortality to your community bat program at 1-855-922-2287. Several community bat projects are conducting research into temperatures in bat houses, to improve our understanding of bat preferences. If you are

interested in having your bat house monitored or installing temperature monitoring equipment, contact your local community bat program to discuss.

Retaining Heat (in cooler/ northern regions of BC)

In northern BC, bat houses should be designed to retain heat. Vents should not be used. A partial bottom can be added that is at an angle of 45° or greater to reduce guano build-up and that leaves a 1" entry gap at the back (see diagram). Since guano may accumulate inside this flap, consider adding a hinge to allow for annual cleaning.



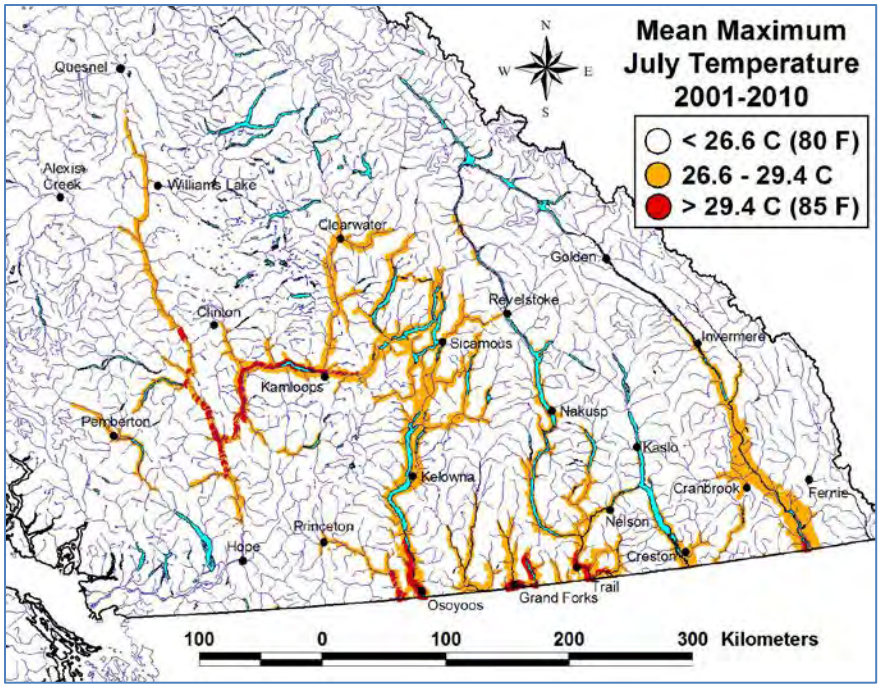
Stain Colour

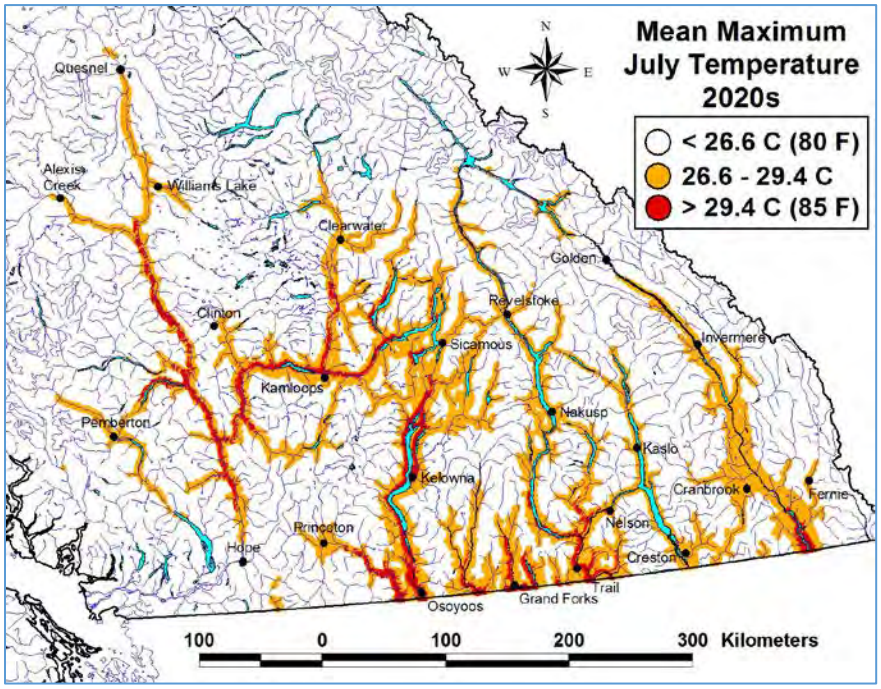
Avoid oil paints or other stains with strong odours or Volatile Organic Compounds (VOCs), which are off-gassing chemicals, since they can be harmful and/or repel bats. Use a water-based stain. Consider using all-natural products such as the "Tall Earth" stain[6]. Some people choose not to stain their bat house and leave it as natural wood and these bat houses have also been successful. Although mentioned in some construction plans, **staining the interior is neither required nor recommended** (unless you are using the stain as part of roughening the surface – see *Rough Surface* section above, or are installing the house immediately outside of a window, as staining may reduce smells associated with the bat house).

Warmth is a key feature of effective bat houses. In areas where the mean maximum July temperature is less than 29°C (85°F), bat houses should be stained black or dark colours, and areas from 29°C to 35°C (85°F to 95°F), the colour should be a lighter colour[7]. Based on climate data from 2000 to 2010, the only regions of the province where bat houses should not be stained black or dark are lower elevations in the Kootenays, Okanagan and Caribou (see temperature maps, below). In these regions, bat houses should be a lighter colour such as beige, light or medium brown, or even natural wood colour (e.g. transparent wood protector).

[6] http://tallearth.com/

[7] Tuttle, M. D., M. Kiser, and S. Kiser. 2004. *The Bat house Builder's Handbook: Second Edition*. Bat Conservation International, Austin, Texas. Available online: http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf





TEMPERATURE MAPS OF PREDICTED MEAN MAXIMUM JULY TEMPERATURE FOR SOUTHERN BRITISH COLUMBIA FROM 2000 TO 2010 (TOP) AND PREDICTED FOR 2020'S (BOTTOM). STAIN BAT HOUSES A MEDIUM BROWN COLOUR IN AREAS THAT ARE SHADED. IN ALL OTHER AREAS, STAIN THEM BLACK. MAP PREPARED BY GREG UTZIG[8].

[8] Mapping by: G. Utzig, P.Ag. Kutenai Nature Investigations Ltd. 2015. Climate data extracted from ClimateBC v5.21 based on a 1 km provincial grid.

Bat House Designs

There are several designs of bat houses that are known to be effective in BC. Most bat houses have one to four roosting chambers. Plans can be found in Appendix 2 or at www.bcbats.ca.

Bat Boxes



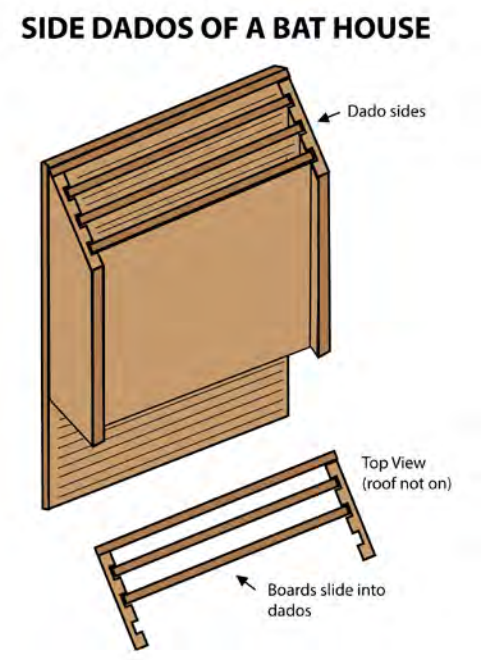
Four-chambered Nursery Box

Four-chambered nursery boxes offer ample roosting space and provide bats with the opportunity to move between chambers with changes in temperature. Multiple-chambered bat boxes can hold hundreds of bats and are more successful than single-chambered bat houses. Bat boxes can be installed on buildings or posts. An ideal set-up is to put two multi-chambered bat boxes back to back on a post – leaving a gap between them creates further roosting space.

Useful adaptations to this design:

Lips: An adaptation to the design that may be useful is to lower each chamber and the roof on the back board so there is an upper lip or make chambers slightly narrower so that there is a lip on either edge of the bat house for easier installation (see *Mounting Brackets or Lips* section).

Dados: Some woodworkers prefer to cut grooves (dados) in side boards rather than use separate spacers to create the chambers (see diagram to right). Mass production cutting plans[9] using dados for woodworking programs or bat house builders are available by contacting info@bcbats.ca.



Larger size: All bat houses can potentially be built larger. For example, large multi-chambered or single-chambered bat houses can be built approximately 50" high (double the height of the small ones) by 24" wide. They can be built as a single chamber or multiple-chambered style with the potential to hold thousands of bats. Large multi-chambered bat boxes are an excellent design for extremely large bat colonies in BC, such as colonies of over 2,000 bats. To build one, adapt the designs above to make the bat house taller or wider.

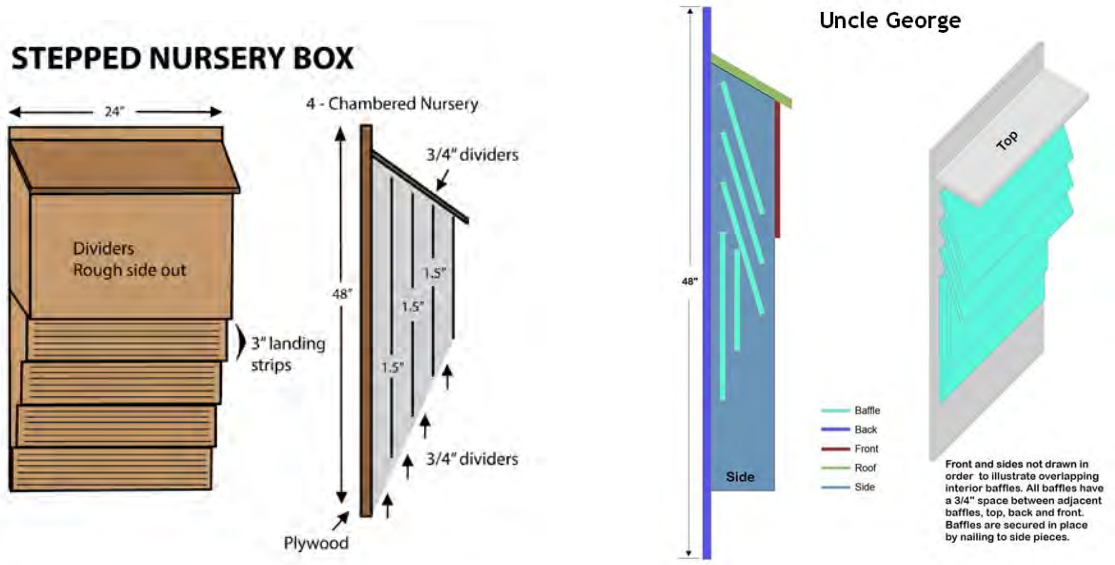
Runways: Ideally, back to back multi-chambered nursery boxes should have a little 'hallway' or other connection between the boxes at the back. If they are mounted back to back with no space in between, this could simply be a hole cut through the backs of

[9] Prepared by Donald Liszt, Woodworking Instructor, Stanley Humphries Secondary School

the bat houses approximately half way up (see *Mounting Structure* section). If the bat houses are separated by a pole or post, this could be a PVC pipe or other tube that creates an access.

Stepped Nursery Box

The Stepped Nursery Box is an adaptation that has each chamber slightly shorter from the back to the front so the bat house forms "steps" of chambers and each chamber has its own landing strip[10]. An "Uncle George" design has been described for the Pacific Northwest where chambers are angled approximately 20° from vertical[11] but research on the use of this design indicates that they are not used as well-used as maternity roost sites except by California Myotis[10]. Although regular or stepped maternity boxes appear to be more successful[10] , there is still the potential for experimentation with all these designs in BC, particularly where they are installed on buildings.



Single-Chamber Bat Box

Single-chamber (small) bat boxes **are ideally at least 2' wide and 2' high**. Although they are easier to make than other designs, we do not recommend these houses. Observations in the Kootenays have indicated that single-chambered bat boxes are more often used by males or non-reproductive females[12]. These bat houses occasionally provide a roost space for up to 50 bats. *They must be installed on the side of a heated building to be effective*. Since they don't offer the temperature gradient that multi-chambered bat houses do, they can also become "bat traps" in hot spells, with pups getting too hot and dying. Although single chambered bat boxes may be simpler to construct, cost less and are less heavy to mount in high places, **multi-chambered bat houses are safer for bats and more effective as roost sites.**

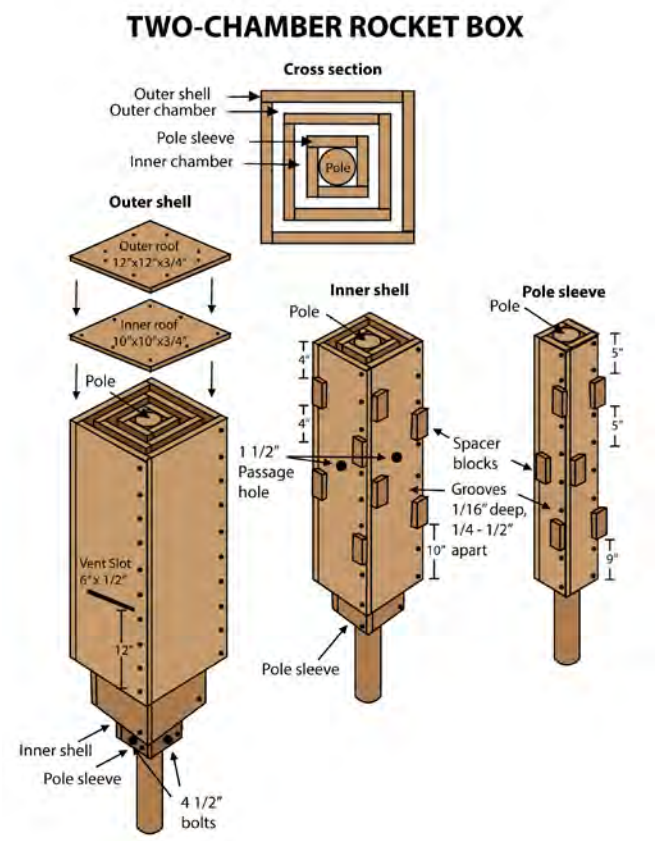
[10] Greg Falxa, personal communication.
[11] http://cascadiaresearch.org/bats/BatBoxPreference_screen-view.pdf
[12] Juliet Craig, personal observation.

Rocket Boxes

Another form of bat house is the rocket box. Two-chambered rocket boxes have been extremely successful on the coast of BC, especially for Yuma Myotis, a common bat species. There are two styles of rocket boxes.

Two-chambered Rocket Box

Two-chambered rocket boxes are usually 3 ft. (1 m) tall and contain concentric roosting chambers around a post or pole. By increasing the number of square roosting chambers, the rocket box becomes wider and can house more bats as well as provide more micro-climate options. Installation of this bat house style simply requires fixing the post in the ground and putting the bat house on as a "cap". These bat houses are extremely effective in attracting roosting bats which is likely because the chambers face all cardinal directions and thus provide a multitude of microclimates within the bat house. For example, bats could follow the warmth of the sun's radiation throughout the day by shifting inside the box. On very hot days, they can also avoid the heat by moving to the north side of the box.





Simple Rocket Box

Simple rocket boxes are made from a 4" by 4" post that has wedges cut into it and is then covered by an outer plywood box. The materials are cheap and they are easy to construct. *However, their success rate has not yet been determined in BC.* As there are less microclimate options, it is possible this style would be less popular than a double or multi-chambered rocket box.

Bat Condos



Bat condos are very large structures that can potentially house thousands of bats. They are costly and time consuming to build but can house large colonies of bats (more than 6,000). Because they provide a variety of microclimates, bat condos are designed for use by multiple species of bats, and both males and females. Condos typically provide roosting chambers towards the outside of the structure (e.g. under planking), in addition to roosting chambers inside the structure. Bat condos are generally built on poles that elevate the structure well above the ground. The increased height has multiple benefits such as providing bats with a sufficient height off the ground for take-off and landing, avoiding predation, and decreasing the likelihood of potential vandalism and disturbance.

There are many different designs, including 'mini condos', and 'bat motels'. In BC, where climate is colder, the designs should be modified to partially close chambers to trap air and thus increase roosting temperatures. Decreasing gap size between roosting boards will also help trap warm moist air when bats are roosting as a group. Additionally, creating purposeful gaps between exterior boards or planks during construction can increase the variety of microclimates created for bats in the structure. Bat condos can be considered when there are large bat colonies being evicted from a building, for wildlife and restoration projects, and for increased insect control. If you are considering building a bat condo, contact your local community bat program to discuss options.

Slabs



Slabs are a wooden board or metal flashing secured on a wall of a building under the eaves that provides a dry crevice for roosting on the exterior of the building. Short strips of wood can be used as spacers to create the roosting chamber (approx. ¾"). The overhanging roof of the building should protect the roost from precipitation but it is important that the top of the chamber be sealed to trap heat. One slab/sheet of wood will create a single chambered roost or they can be layered to create multiple chambers. The length of the roost can be as long as one wishes to make it and the entire roost can be made of scrap lumber. These types of bat houses mimic the conditions that wall or shingle roosting bats often use. Guano and urine can mark the wall of the building so installing slabs on outbuildings and not on homes may be preferable. One may have to compromise on choosing the best aspect (e.g. south) versus which side of the building is acceptable to become marked (e.g. east or west).

Gable Vents

Gable vent covers may provide roosting habitat for bats. These slotted structures cover the openings that allow airflow from attic spaces, and are installed over existing vents and tough screening to ensure that bats do not enter the attic. Airflow from the attic helps warm the bat house. Adjusting the size of the slats will accommodate different species (3/4" for Little Brown or Yuma Myotis, 1" for Big Brown). Some houses may come with slotted gable vents – in this case, ensure that the screening is solid, to ensure that bats do not enter the attic. Other houses may require a retro-fit to add a bat-friendly vent cover. As with slabs, these bat houses may result in guano or urine staining of the wall below the structure.

Optimal Bat House Location

The location of a bat house is critical to its success. There are many factors to consider when selecting a site including solar exposure, habitat, mounting, obstacles, protection from predators, and wasps. In summary, bat houses should be placed:

- at least 10' (3 m) high but 12' to 20' is better,
- south, east or west facing to ensure correct sun exposure,
- in an uncluttered location that does not have branches, buildings, or poles in front of it, and
- away from lights or high wind.





NURSERY BAT BOX ON SHED (LEFT) AND TWO-CHAMBERED ROCKET BOX ON POST (RIGHT). PHOTOS COURTESY OF JULIET CRAIG AND ALYSIA DOBIE.

Height

The base of a bat house should be at least 3 m (10') above the ground although 12' to 20' is better. The height is measured from what a bat would perceive as the "ground' which may be the roof of a shed or other building if the bat house is mounted above a structure (such as a lower roof) rather than the ground.

Sun exposure

An important criterion for bat house location is sun exposure. If you have several possible sites to choose from, observe the site during the summer to determine sun exposure (this could change depending on the time of the year). Bat houses placed on a post should face due south to allow for the best temperature gradient. Bat houses placed on buildings may face east, west or south, depending on the ideal hours of direct sun (see below).

For the hottest regions of BC including lower elevations of the Okanagan, Kootenay, and Thompson areas (shaded red in temperature maps) select sites with approximately 6 hours of direct sun each day (e.g. away from direct afternoon sun). Ideally a bat house in these hot regions will face east or south-east, to be exposed to morning sun and not the hot afternoon sun. A spot with afternoon shade is ideal. For warmer regions of BC (shaded orange in temperature maps), place bat houses in areas with 6 to 10 hours of direct sun. In all other areas of BC, place bat houses to receive as much sun as possible (at least 10 hours). In most regions of BC, bat houses should be placed in direct sun, facing south or southeast, to receive at least 10 hours of direct exposure each day.

Obstacles

Bats like a clear path to fly out of their house so that they can detect predators and easily avoid obstacles. Bat houses should be placed in open areas where there is no or little clutter such as on a post in the middle of a field or on the side of a building with no obstructions for at least 5 m. If a bat house is mounted on a tree (not recommended), the branches should be de-limbed below and around the bat house to create an open, uncluttered area.

Habitat

Ideally, bat houses should be situated near good foraging and drinking habitat such as streams, rivers, lakes or ponds. Bat houses within 400 m of a larger pond or lake have been known to have great success than those farther away[13]. However, it is still worth installing a bat house in areas away from water since bats can travel many kilometres each night to drink and forage. Forest openings are good settings for placing a bat house as they have good solar exposure and are uncluttered. If a bat house is being installed in combination with bat exclusion from a building, you may wish to try several bat houses in different locations including at least one near the current roost site. However, placing a bat house where bats are exiting and entering the building is not always the best location, depending on solar exposure, clutter, and other factors. It is more important for the bat house to be in a high, uncluttered and warm location than it is to be near the current roost site. Avoid mounting bat houses close to bright lights and select sites that are free from heavy winds.

[13] Tuttle, M. D., M. Kiser, and S. Kiser. 2004. *The Bat house Builder's Handbook: Second Edition*. Bat Conservation International, Austin, Texas. Available online: http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf

Protection from Predators

House cats are one of the largest predators of bats in BC, although raptors, weasels, and other animals may prey on bats. Predation can be avoided by mounting a bat house up high, since cats may be able to kill bats if the access point to the bat house is too low. A slippery sheet-metal guard can be wrapped on the bottom of a wooden post or tree to deter cats or other ground-based predators. To reduce predation by raptors, try to mount the bat house at least 20' (6 m) from the nearest tree branches, wires or other potential perches for aerial predators. Bat houses on stand-alone poles should have multiple nails in the top to deter predatory birds from perching on top.





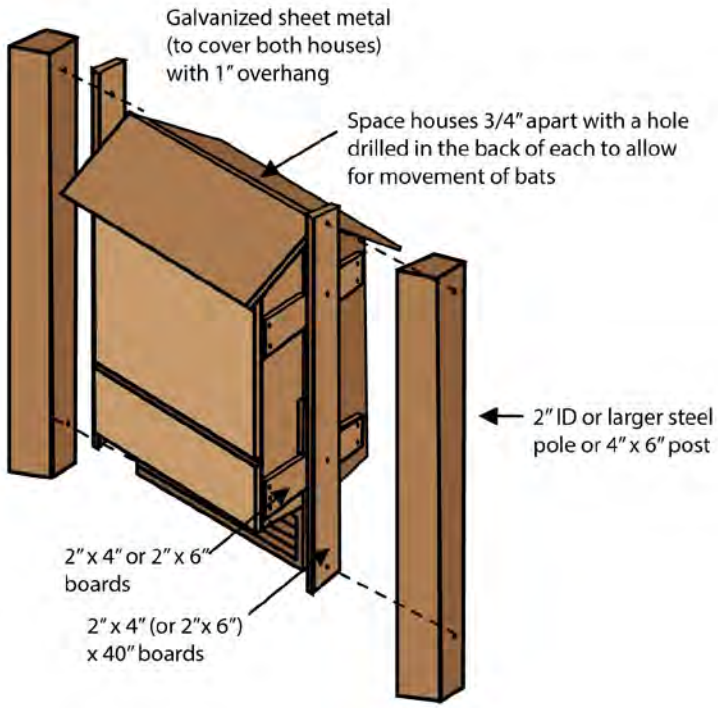
OWL ON BAT HOUSE (LEFT) AND GUARD FOR NON-FLYING PREDATORS (RIGHT). BAT HOUSES MOUNTED ON POLES SHOULD HAVE SPIKES ON TOP TO PREVENT AERIAL PREDATORS FROM PERCHING. PHOTOS COURTESY OF MICHELLE EVELYN (LEFT) AND RICK O'NEILL (RIGHT).

Interaction with People and Pets

Bat houses should be placed high enough to avoid direct contact between people (e.g. curious children) and pets. To minimize the chance of young children coming into contact with a bat that may fall from the roost, bat houses and condos in public spaces, such as parks and school grounds, should be placed in sites that do not experience a high level of human activity. This site selection will also reduce potential vandalism and disturbance issues.

Mounting Structure

Bat houses can be successfully placed on poles or posts or on the sides of buildings or outbuildings. **Bat houses mounted on wood, brick, or stone buildings with good solar exposure are good choices** since the building helps radiate heat into the bat house during the evenings. Mounting on a building is critical for single-chambered bat houses.

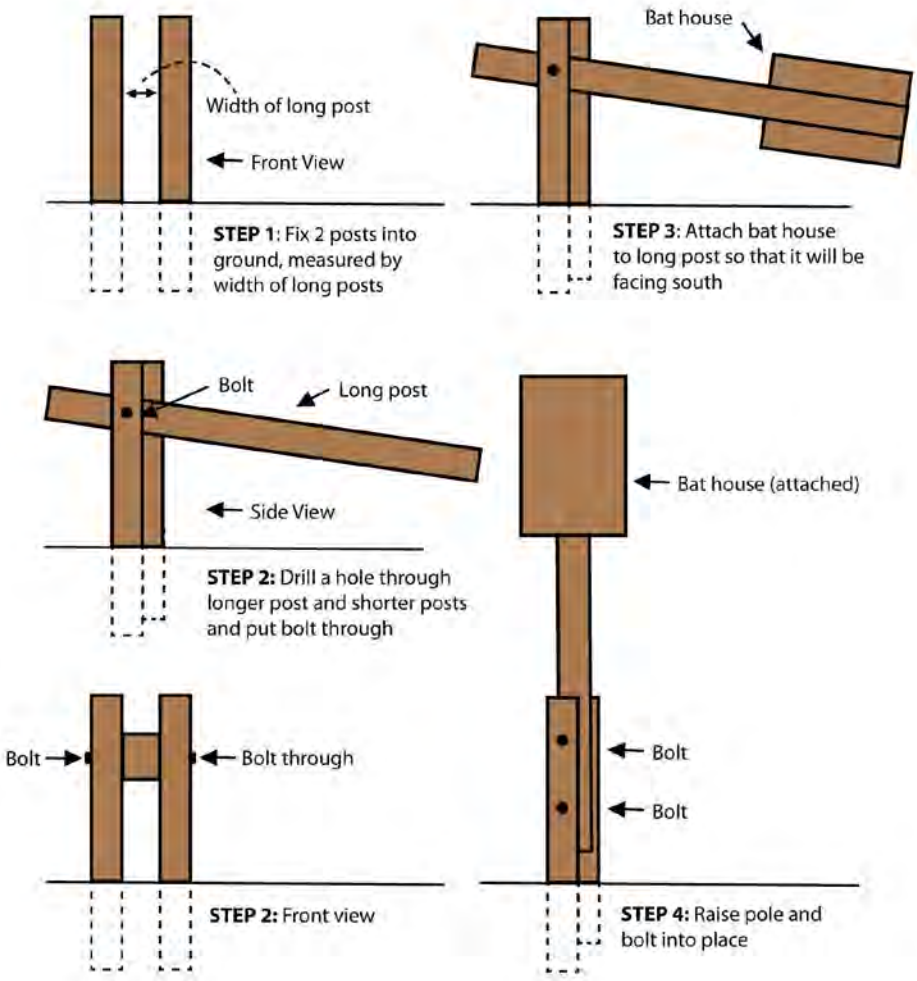


Bat houses mounted on 20' (6 m) poles (wooden, 4' by 4' or metal) put 4' in the ground have been successful since they can be mounted high, face any direction, and placed free of clutter. **An ideal scenario for bat-boxes is to mount two multi-chambered bat houses back to back on a pole** so that one faces north and the other faces south (see diagram) with opportunities for bats to move between then (see *Movement Between Chambers section*). The bottom of the posts can be braced to make them more secure and prevent them from being blown over. Any house mounted on a single post should have the post very securely planted and braced, as swaying of the bat house in wind may make it unappealing to bats, and possibly dangerous to humans!

Trees and snags are not recommended since they are more difficult for bats to find, more vulnerable to predators, and usually receive less sun exposure. However, trees that are significantly de-limbed (to act as poles) are successful. Although power and telephone poles are usually in excellent locations, these structures are not permitted since they prevent maintenance activities.

Tips for installation

To install a pole or a post for a bat house, consider fixing one or two short posts in the ground and then levering a tall pole up (see figure below). Another option is to mount an eye hook to the roof of the bat house and then hoist it into position for securement.



INSTALLATION OF A POLE-MOUNTED BAT HOUSE.

Enhancing Bat Habitat on a Community Scale

Community considerations for bat conservation should emphasize habitat conservation and restoration, including planting of bat-friendly tree species such as cottonwood, in conjunction with discussions about creating supplementary artificial roosting habitat. Communities can take a larger-scale approach, and should definitely consider bat condos. A community event to build many bat houses, a condo, or even a bat barn, can draw upon volunteers for donation of wood, supplying of tools, and labour for construction. These houses can then be erected strategically in the community to ensure a distribution of houses with different microclimates. For example, having two bat houses (e.g. north and south facing) on the same pole may be more beneficial than having each bat house on its own pole away from each other. The community construction of a bat condo should definitely be considered in areas where there is ample foraging habitat to support a large population of bats.

Frequently Asked Questions About Bat Houses

Do all bat species use bat houses?

No, many species of bats in BC only roost in natural structures such as trees, cliffs and caves. However most of the bat species that use buildings, most commonly the Little Brown Myotis, Yuma Myotis and Big Brown Bat, will also use bat houses. One exception is the Townsend's big-eared bat, a rare species in BC that roosts in buildings but requires large cavernous roosts and not the small chambers found in conventional bat houses. In Washington, California Myotis and Silver-haired Bats also regularly use bat houses[14].



TOWNSEND'S BIG-EARED BATS ROOST IN LARGE, CAVERNOUS STRUCTURES. PHOTO BY PAIGE ERICKSON-MCGEE

When should I put up a bat house?

Although a bat house can be installed at any time of year, bats are likely to move into a bat house when they first return from winter hibernation in April or May. If the bat house is being installed in combination with eviction, install the bat house at least two to six weeks before the actual exclusion.

How long until bats move into my bat house?

The success of a bat house depends on the design, location, and whether or not there are bats in the neighborhood looking for a roost site. When a bat house is installed in combination with exclusion of a colony from a building, it has a high chance of being successful. In other situations, it may take time before the bat house is used. Weathering of the wood may influence the suitability of the bat house.

I've had a bat house for years but never had any bats. Why not?

First, check the bat house design. Does it have a landing strip, multiple chambers, and some sort of "grip" for the bats inside? Is it stained an appropriate colour and placed in a high, open location? Is it a good design for this region, meaning that it has multiple narrow chambers and is quite large? If the bat house is a good design and in a good location, then it could simply be that there isn't currently a colony of bats seeking a summer roost site. However, if a colony of bats is evicted from their roost site, either intentionally (e.g. exclusion from a building), or unintentionally (e.g. a large tree falls down, rock feature

[14] Greg Falxa, personal communication.

is disturbed), they may require a new roost site. If the bat house appears to be suitably designed and placed yet still not occupied by bats, then leave the bat house for at least three years before replacing it or moving it to an alternative location.

Are there tricks to attracting bats to bat houses?

Besides ensuring a good design and location for the bat house, there are few other attractants. There is no evidence to support the practice of scenting the bat house with bat guano to improve the likelihood of occupation where a colony is to be excluded. If bats are being excluded from an attic, the bat house could be left inside the attic for several weeks before installing it so that is absorbs the smell of the colony; again, there is no evidence that this is necessary or effective. Guano from other locations should definitely not be applied to new bat houses, in the interest of controlling the spread of any bat diseases or parasites.

How can I tell if bats are using my bat house?

Look under the bat house for guano after several days of dry weather. If it is difficult to see, lay a light plastic sheet or piece of cardboard under the bat house for several days to catch any falling guano. Alternatively, set up a permanent monitoring structure such as a screen platform. Never place a bucket or any other container that bats cannot get out of under a bat house unless you put in a stick or some other object that bats can use to crawl out. If bats are using the bat house as a day or maternity roost, they can usually be observed departing within 30 minutes of dusk in good weather. In summer, watch the bat house for at least fifteen minutes before sunset to 30 minutes after for signs of use. If bats are using the bat house, participate in the **Annual BC Bat Count**





SCREEN TO CATCH GUANO UNDER BAT HOUSE CAN BE USED TO MONITOR THE BAT HOUSE FOR ACTIVITY AS WELL AS COLLECT GUANO FOR GARDENING (LEFT). PHOTO COURTESY OF GREG FALXA. BC RESIDENTS MONITOR BAT HOUSE AT DUSK (RIGHT). PHOTO COURTESY OF JULIET CRAIG.

Should I be concerned about the guano under the bat house?

There are no known health risks associated with bat guano in BC. In some areas of North America, a disease called histoplasmosis is associated with inhalation of bird and bat guano. Fortunately there are no documented cases of locally-acquired histoplasmosis in humans or animals in BC, indicating that the risk of acquiring this disease in this province is minimal. However, surveillance for this fungus in bat guano in BC has been limited so if you do have to clean up bat guano, particularly in an enclosed space, spritzing the area with water to keep the dust down and wearing a mask is suggested. For more information on histoplasmosis see www.ccohs.ca/oshanswers/diseases/histopla.html.

Will having bat houses in my yard interfere with attracting birds?

Bats and birds use different habitats for food and shelter so they do not compete. Installing a bat house does not affect attracting birds to your yard and often swallow boxes and bat houses are used in combination for insect reduction.

Does a bat house require maintenance?

A solidly-built, caulked, and painted bat house will require little maintenance. Wasp nests can be a problem for bats. Limiting the size of chambers to ¾" helps reduce occupation by wasps as does ensuring partitions are built to the roof of the bat house (without a gap at the top). During winter months, check the bat house and remove wasp nests by banging out each chamber using a broom handle or a paint roller extension pole.

Where can I get a bat house?

Check with your local bat project to find out if there is someone locally selling bat houses, or if your community bat project has funding to cover your bat house materials or donate a bat house to you. Look at your local garden, nature, or hardware store to ask if they sell them, but ensure that they meet the criteria of good bat house designs in BC. See the list of "Bat house Sources" in the Resources section of this document. Another option is to build your own bat house or have someone handy build it for you. Bat house plans are found at the end of this document or on the website www.bcbats.ca.

How do I register my bat house?

Please consider registering your bat house to help us learn more about bat preferences! You can find a registration form in Appendix 1, on our website at http://bcbats.ca/index.php/bat-houses/register-your-bat-house, or call the Community Bat Program at 1-855-9BC-BATS (1-855-922-2287). We will be interested in knowing what type of house, what colour, how high you mounted it, what direction it faces, how long it has been in place, and if it is occupied by bats.

How can I participate in the Annual Bat Count?

If you have bats in your bat house or another structure, and you enjoy watching them, please consider counting them as they exit to be a part of the Annual BC Bat Count (Appendix 2). Instructions and data forms can be downloaded from http://bcbats.ca/index.php/get-involved/participate-in-the-bc-bat-count or inquire with your local community bat project.

Resources

BC Community Bat Program

- www.bcbats.ca

Bat house design and placement

- Bat house Builders Handbook
  - http://www.batcon.org/pdfs/BHBuildersHdbk13_Online.pdf
- Bat Conservation International
  - http://www.batcon.org/resources/for-specific-issues/artificial-roosts
- Organization for Bat Conservation
  - http://www.batconservation.org/
- Bat Conservation and Management
  - http://www.batmanagement.com/Batcentral/batcentral.html

Bat house Plans

- Four-chambered nursery bat box: http://www.batcon.org/pdfs/bathouses/FourChamberNurseryHousePlans.pdf
- Single-chambered bat house: http://www.batcon.org/pdfs/bathouses/SingleChamberBHPlans.pdf
- Two-chambered rocket box: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context=icwdmother
- Simple rocket box: http://www.batsnorthwest.org/rocketbox_plans.pdf
- Bat Can (for purchase): http://batmanagement.com/Ordering/batboxes/batcan/batcan.html
- Gable vent cover: http://www.batguys.com/resources/suburban-bat-house.html

Bat house Installation

- http://www.batmanagement.com/Batcentral/boxinstall/install1.html
- https://www.batcon.org/pdfs/bathouses/InstallingYourBatHouseWoodenPostSteel%20Pole.pdf

Bat house Sources

Check with your local community bat project first since there may be a local builder/source.

- Canadian Bat Houses (http://canadianbathouses.com/)
- Urban Nature Store (http://www.urbannaturestore.ca/wild-birding/other-wildlife/bats-bat houses/) – the larger models
- Backyard Bird Centre (http://backyardbird.ca/collections/bat houses) – the larger models
- Natural Insect Control (http://www.naturalinsectcontrol.com/product.php?id=000000307)
- Lee Valley Tools (http://www.leevalley.com/en/wood/page.aspx?p=70692&cat=2,51555&ap=1) – bat house needs to be stained an appropriate colour. Available in-store only at Victoria, Coquitlam and Vancouver
- Amazon Canada (several designs – look for key features) e.g. http://www.amazon.ca/Looker-Bat-Triple-Chamber-House-Triple/dp/B000FLTO6A/ref=pd_sim_86_6?ie=UTF8&dpID=41xeZ3H4huL&dpSrc=sims&preST=_AC_UL160_SR160%2C160_&refRID=0N3BEMVC6NCQ8D3ZZ5P2

APPENDIX 1: Register Your Bat House

Since little is currently known about the optimal characteristics of bat houses in BC, we encourage you to report on the success (or lack of success… these data are important too!) of your bat houses. By registering your bat house and reporting on its success, you can be part of an ongoing project to identify the characteristics of successful bat houses. If you have a bat house, please let us know!

You can fill out this form online at http://bcbats.ca/index.php/bat-houses/register-your-bat-house , or print it, fill it in, and mail to BC Community Bat Program, Attn: Mandy Kellner, Box 8617, Revelstoke, BC, V0E 2S2 or scan and email to info@bcbats.ca .

Your name _____

Your email _____Your phone _____

Nearest town _____ When did you install your bat house? _____

Did you put the house up as part of an exclusion from your own house? Yes ☐ No ☐ Unknown ☐

Have you ever seen signs that your bat house has been occupied? (check for guano (droppings) below the house, listen for squeaks, or watch the house at dusk – you cannot always see the bats inside)
Yes ☐ No ☐ Unknown ☐

How big is your bat house? (e.g. 80cm*8-cm*20cm, 4 chambers) _____

What kind of house is it and how many chambers does it have ? (e.g. 3-chamber maternity)
_____

What colour is your bat house? (e.g. painted or stained black, brown) _____

What direction is your bat house facing ? (e.g. south-west)_____

What is your bat house installed on? (e.g. pole, side of shed, side of house) _____

How high up is the top of your bat house? _____

How much open space is around your bat house (distance to nearest branches, obstacles)? _____

How close is the nearest freshwater body (lake, pond, creek, river)? _____

Has anyone done any testing to determine which species of bats are using your house?
DNA testing ☐ acoustic surveys ☐ mist net surveys ☐ dead bat sample☐ no testing☐

If so, what species were detected?
Big Brown ☐ Little Brown ☐ Yuma ☐ California Myotis ☐ Townsends ☐ I don't know ☐

The Annual BC Bat Count is an important province-wide bat monitoring effort. Volunteers across BC count bats emerging from known roosts 1-2 times between Jun 1 and 21 (before pups can fly) and 1-2 times between Jul 21 and Aug 15 (when pups are flying with their moms). Would you be interested in including your house in the count?
Yes, I would like to participate ☐ Yes, if a Community Bat team member can help ☐
No, my house has never been occupied and is not suitable ☐ No, I do not wish to participate☐
May we contact you by email or phone in the future to get updates on use of your bat houses? Yes ☐ No ☐

Participate in the BC Annual Bat Count

WHAT: A citizen-science program in B.C. to annually monitor bat roost sites.

WHY: Half the bat species in BC are considered to be of conservation concern. Even the common little brown bat is being proposed for designation as an "endangered" species because of high mortality rates from the disease, White Nose Syndrome. The disease is not yet in BC but is predicted to arrive in the next decade. To be able to effectively manage and conserve bats in the face of the many threats, we need to know how their population numbers are doing year to year. The BC Bat Count will contribute towards gathering this important information.

WHO: Anyone who is interested in collecting valuable information to help monitor our bat populations.

WHERE: A roost site (such as abandoned houses, attic, barns, church steeples, bridges, bat-houses and other structures) on your property or somewhere else.

WHEN: Ideally, participants conduct four bat counts per summer - **two between June 1 and 21** (before pups can fly) and **two more between July 21 and August 15** (when pups are flying and exiting the roost). Doing all four bat counts will allow us to best compare data from year to year and between sites. If it is difficult to do four counts, consider the following options:

- Level 1: ***Bat Reporter*** - 1 count over the summer (try between July 21 – August 15)
- Level 2: ***Bat Tracker*** - 1 count between June 1 – 21 and one count between July 21 - August 15
- Level 3: ***Bat Enthusiast*** – 2 counts between June 1 – 21 and 2 counts between July 21 – August 15

HOW:

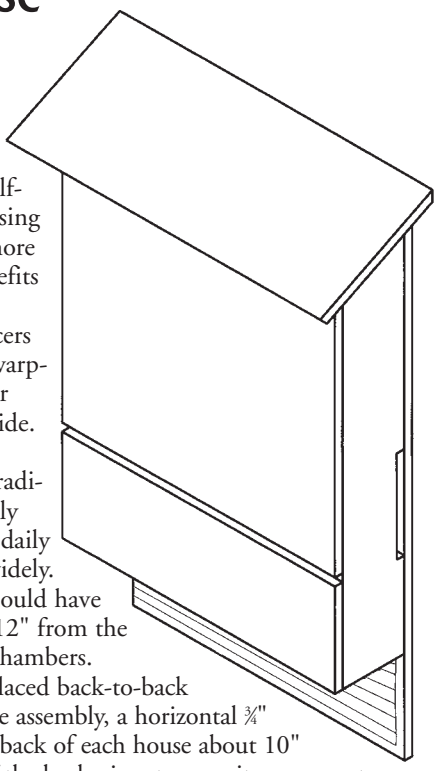
- Check www.bcbats.ca "Get Involved" tab for most recent data forms and instructions.
- Arrive at your bat roost by sunset. Bats may begin to emerge around sunset and so don't be late! Some species may emerge closer to civil twilight so don't worry if it takes a little while to see the first one.
- Count bats for one hour or until it is too dark to see, whichever comes first.
- The air temperature should be at least 12°C with low wind speed. Some bats will not fly if the weather is too cold, windy or drizzly, and roost emergence counts under non-ideal weather conditions will underestimate population size.
- Sit or stand outside so that the bats' exit point is visible from a comfortable distance. More than one person might be needed if bats are exiting from multiple points. Try to have the light sky behind the bats exit point, to make it easier to count.
- Tally the bats as they fly out for their nightly insect-eating. You may wish to use a hand "clicker" to make counting easier, or video the emergence to count later on your screen.

For more information: www.bcbats.ca or 1-855-9BC-BATS

APPENDIX 3: Bat House Plans

Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

Four-chamber Nursery House



Materials (makes two houses) • *Diagrams on pages 12 & 13*

½ sheet (4' x 4') ½" AC, BC or T1-11 (outdoor grade) plywood
½ sheet (4' x 4') ⅜" AC or BC (outdoor grade) plywood
Two pieces 1" x 6" (¾" x 5½" finished) x 8' pine or cedar
One lb. coated deck or exterior-grade screws, 1⅝"
20 to 25 coated deck or exterior-grade screws, 1¼"
20 to 25 exterior-grade screws, 1"
One quart dark, water-based stain, exterior grade
One quart water-based primer, exterior grade
Two quarts flat water-based paint or stain, exterior grade
One tube paintable latex caulk
Black asphalt shingles or galvanized metal
12 to 20 roofing nails, ⅞"

Recommended tools

Table saw or circular saw
Variable-speed reversing drill
Screwdriver bit for drill
Tape measure or yardstick
Caulking gun
1½" hole saw or spade bit
Paintbrushes
Hammer (optional)
Tin snips (optional)
Bar clamp (optional)
Sander (optional)

Construction

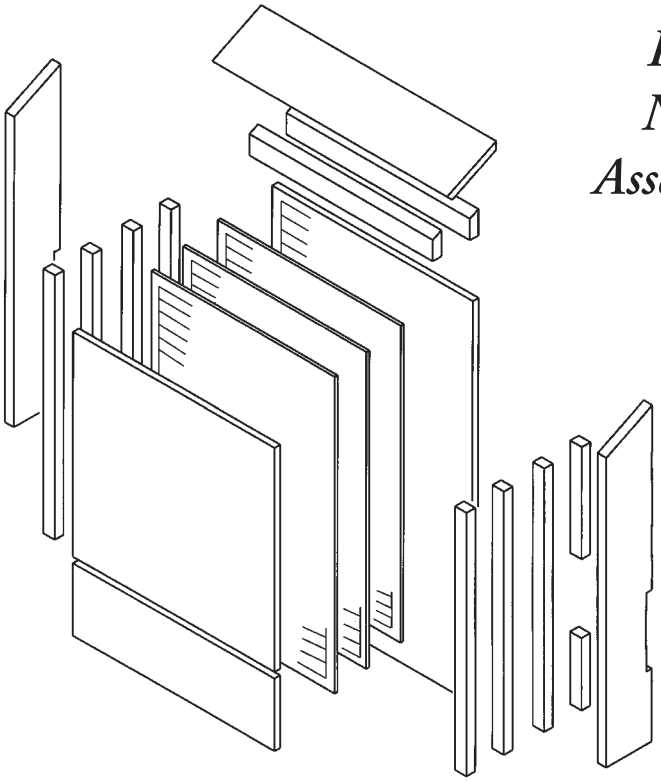
1. Measure, mark and cut out all wood according to the sawing diagrams on pages 12 and 13.
2. Roughen interior and landing surfaces by cutting horizontal grooves with sharp object or saw. Space grooves ¼" to ½" apart, cutting 1/32" to 1/16" deep.
3. IF DESIRED, apply two coats of dark, water-based stain to interior sur-faces. Do not use paint, as it will fill grooves.
4. Attach side pieces to back, caulking first. Use 1⅝" screws. Make sure top angles match.
5. Attach 5" and 10" spacers to inside corners per drawings on page 12. Use 1" screws. Roost chamber spacing will be ¾" (front to back). Do not block side vents.
6. Place first roosting partition on spacers even with bottom edge of roof. Place 20" spacers on partition and screw to first spacers (through partition), using 1⅝" screws.
7. Repeat step 6 for remaining spacers and partitions.
8. Attach front to sides, top piece first (caulk seams). Be sure top angles match (sand if necessary). Leave ½" vent space between top and bottom front pieces. A bar clamp may be useful if sides have flared out during construction.
9. Attach roof supports to the top inside of front and back pieces with 1" screws. Don't let screws protrude into roosting chambers.
10. Caulk around all top surfaces, sanding first if necessary to ensure good fit with roof.
11. Attach roof to sides and roof supports with 1¼" screws. Caulk around roof and side joints to further guard against leaks and drafts. Don't let screws protrude into roosting chambers.
12. Paint or stain exterior three times (use primer for first coat).
13. Cover roof with shingles or galvanized metal.

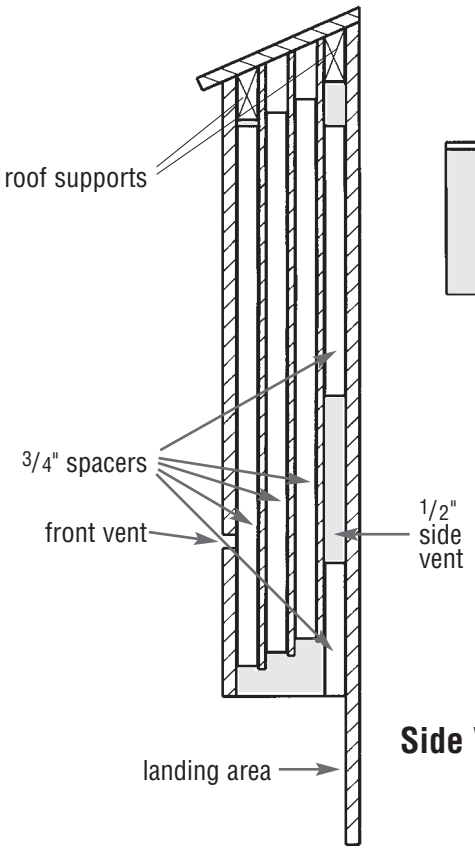
Optional modifications

1. These nursery-house dimensions were chosen to permit construction of two bat houses per half-sheet of plywood. Increasing house width to 24" or more or adding partitions benefits bats and attracts larger colonies. Additional spacers are required to prevent warping of roost partitions for houses more than 24" wide.
2. Taller bat houses provide improved temperature gradients and may be especially useful in climates where daily temperatures fluctuate widely. Bat houses 3' or taller should have the horizontal vent slot 12" from the bottom of the roosting chambers.
3. Two bat houses can be placed back-to-back mounted on poles. Before assembly, a horizontal ¾" slot should be cut in the back of each house about 10" from the bottom edge of the back piece to permit movement of bats between houses. Two pieces of wood, 1" x 4" x 10¾", screwed horizontally to each side, will join the two boxes. Leave a ¾" space between the two houses, and roughen the wood surfaces or cover the back of each with plastic mesh. One 2" x 4" x 40" vertical piece, attached to each side, over the horizontal pieces, blocks light but allows bats and air to enter. Use a 2" x 6" vertical piece if securing houses with U-bolts to metal poles. A galvanized metal roof that covers both houses protects them and helps prevent overheating. Eaves should extend about 3" in front in southern areas and about 1½" in the north.
4. Ventilation may not be necessary in cold climates. In that case, the front of the bat house should be a single, 23"-long piece. Far-northern bat houses may also benefit from a partial bottom to help retain heat. Slope the sides and bottom at an angle of 45° or greater to reduce guano build-up. Leave a ¾" entry gap at the back and be sure the bottom does not interfere with access to the front crevices. A hinged bottom is required to permit annual cleaning.
5. Durable plastic mesh can be substituted for roughening. Attach mesh to backboard, landing area and one side of each partition after staining interior, but prior to assembly. Use ⅛"- or ¼"-inch HDPE plastic mesh [such as Internet product #1672 (1-800-328-8456; www.internetmesh.net)] and attach every two inches with 3/16" Monel® or stainless steel staples.
6. Make partitions removable by attaching small cleats with thumbscrews to the bottom of side pieces for support. Spacer strips are unnecessary if grooves for partitions are cut in the side pieces with a router or dado saw blade.

FIGURE 4

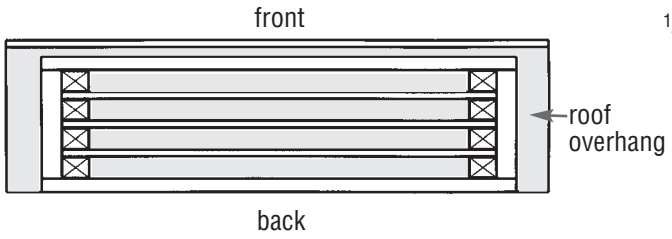
Four-chamber Nursery House Assembly Diagrams

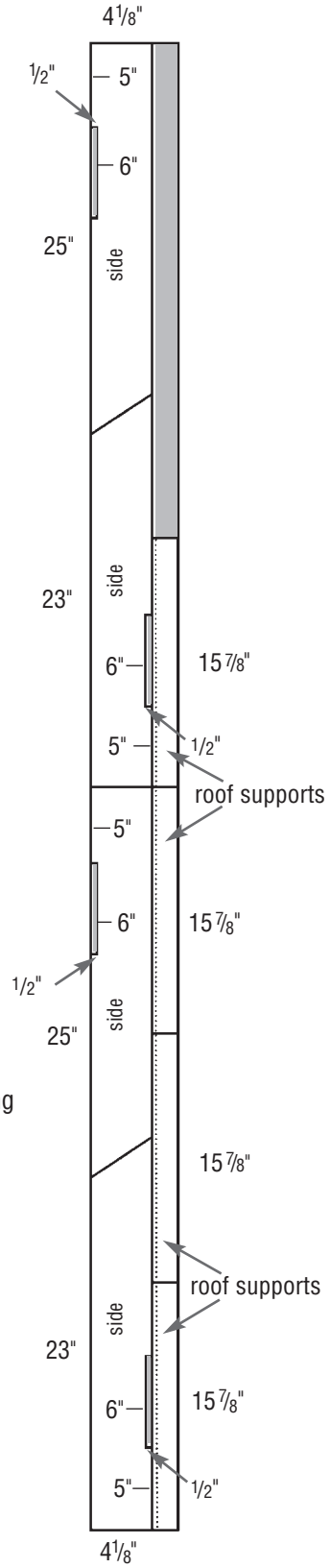




Side View

Bottom View

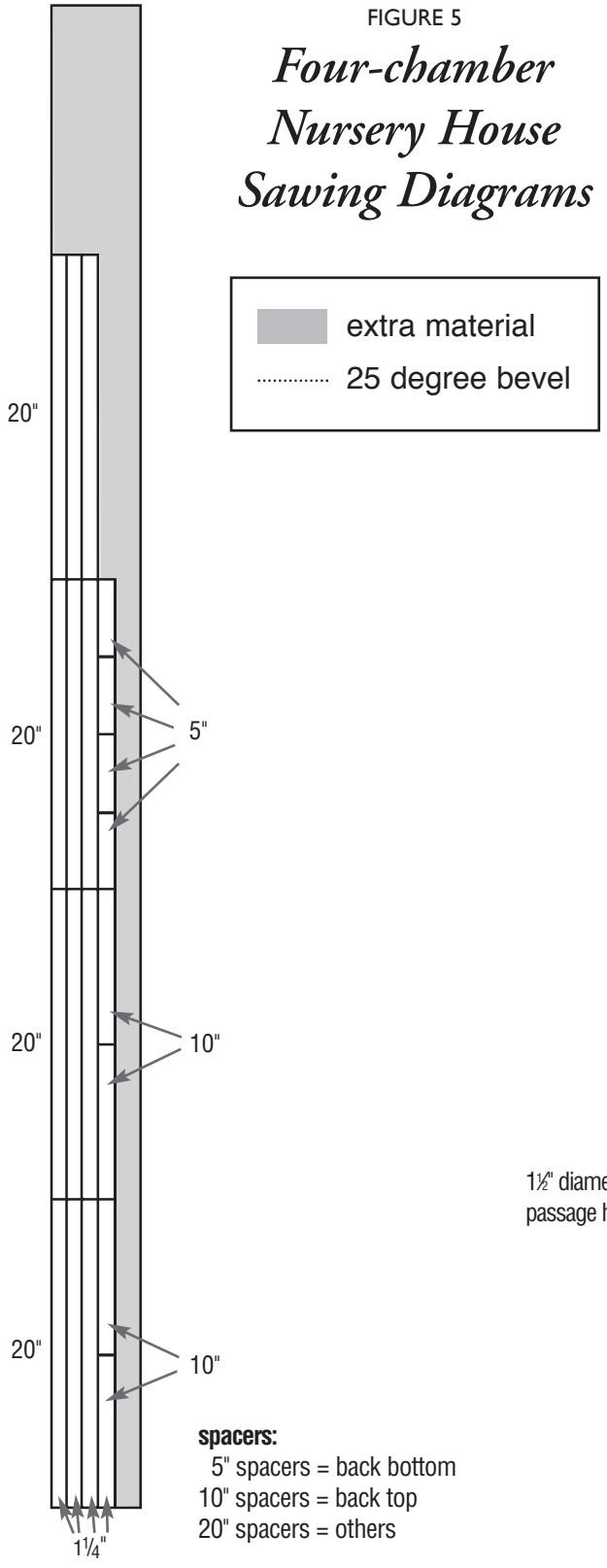




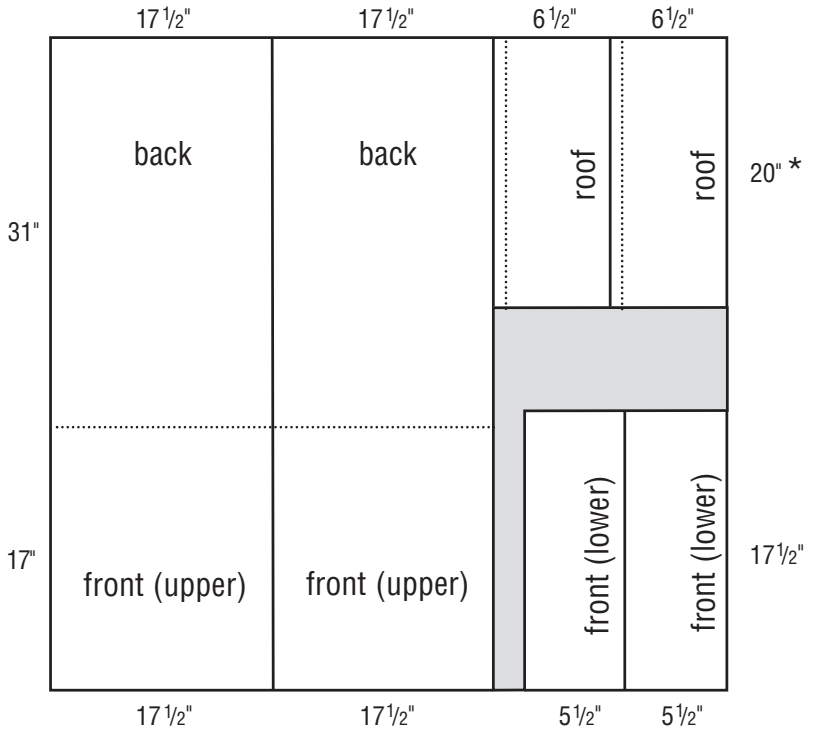
1" x 6" x 8' board

FIGURE 5

Four-chamber Nursery House Sawing Diagrams

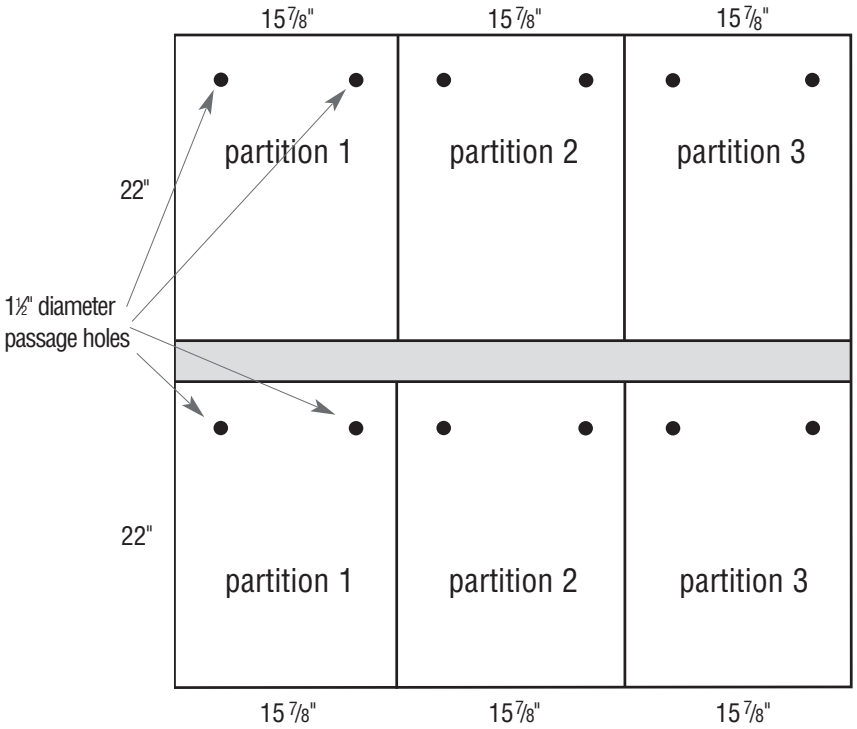


1" x 6" x 8' board



4' x 4' x ½" plywood

* 19" if mounted between two poles



4' x 4' x ⅜" plywood

Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

Two-chamber Rocket Box

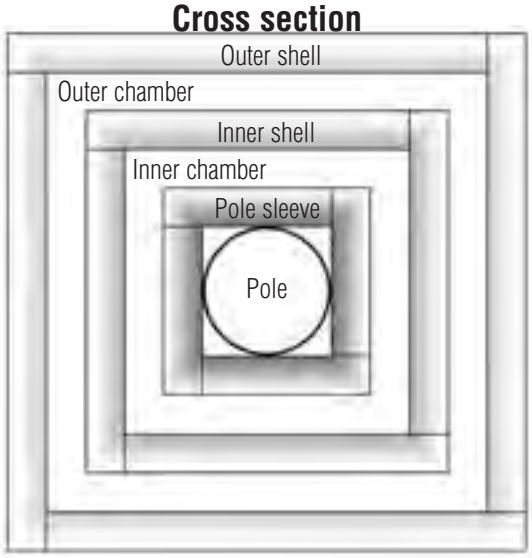
Materials (makes one house)

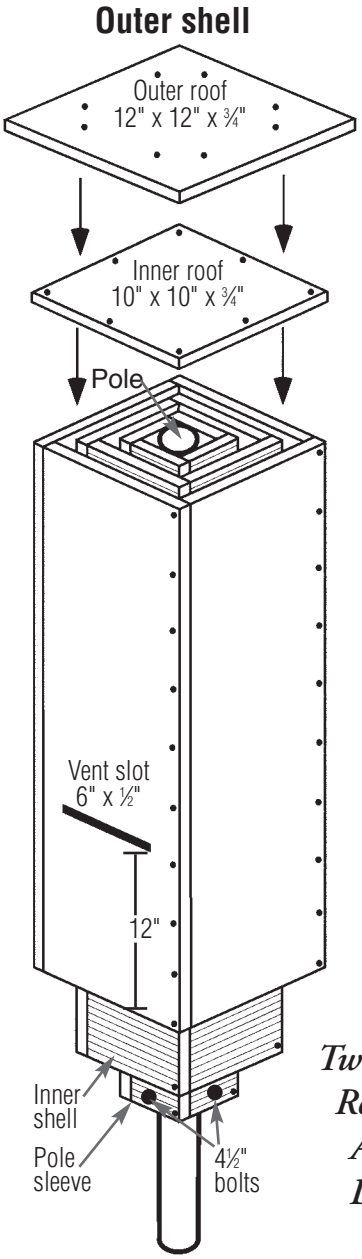
2" diameter (2⅜" outside diameter) steel pole, 20' long
Two 1" x 4" (¾" x 3½" finished) x 8' boards*
Two 1" x 8" (¾" x 7¼" finished) x 8' boards*
Two 1" x 10" (¾" x 9¼" finished) x 6' boards*
24" x 24" x ¾" piece of AC exterior plywood
Box of 100 exterior-grade screws, 1⅝"
Box of 100 exterior-grade screws, 1¼"
16 to 32 exterior-grade screws, 2"
20 to 30 roofing nails, ⅞"
One quart water-based primer, exterior grade
Two quarts flat, water-based stain or paint, exterior grade
Asphalt shingles or dark galvanized metal
One tube paintable latex caulk
Two ¼" x 4½" carriage bolts, washers and nuts

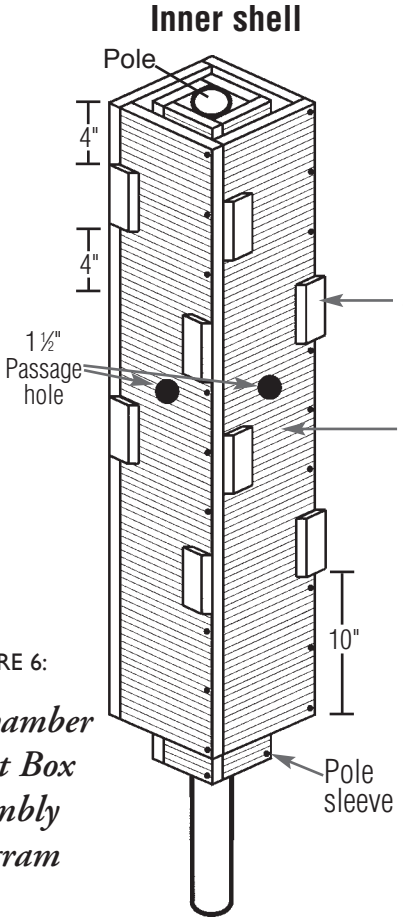
** Western red cedar or poplar preferred*

Recommended tools

Table saw or circular saw
Caulk gun
Hammer
Tape measure
Square
Jigsaw, keyhole saw or router
Sandpaper or sander
Rasp or wood file
Variable-speed reversing drill
1½" hole saw or spade bit
⅛" and ¼" drill bits
Screwdriver bit for drill







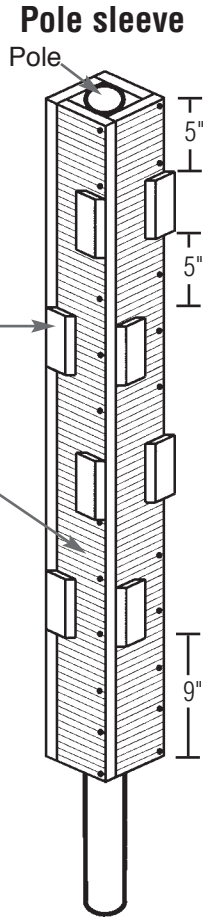


FIGURE 6:

Two-chamber Rocket Box Assembly Diagram

Construction

1. Measure, mark and cut out parts according to Figure 7. Dimensions must be exact for correct fit. Cut out two vent slots and four passage holes as shown.
2. Cut ⅛"-deep horizontal grooves ¼" to ½" apart on one side of all 36" and 45" boards and on both sides of all 42" boards. Sand to remove splinters.
3. Drill two ⅛" holes through each ¾" x 1½" x 4" spacer block to prevent splitting.
4. Assemble four pole sleeve boards into a hollow, square box as shown using 1⅝" screws and caulk. Pre-drill holes to prevent splitting. Countersinking holes may also help.

5. Attach spacer blocks to pole sleeve as shown (four per side) using two 1¼" screws per block. Bottom spacer blocks are 9" up from bottom of pole sleeve. Top spacer blocks are 5" from top. Alternate spacer blocks on left and right sides, 5" apart.
6. Assemble four inner shell boards into a hollow, square box as in step 4.
7. Slide pole sleeve into inner shell until top edges are flush. Bat passage holes will be towards the top. Mark location of spacer blocks. Secure inner shell to pole sleeve with 2" screws through the spacer blocks to ensure no screws protrude into roosting chambers. Pre-drill holes first to avoid splitting spacer blocks (countersinking holes may also help).
8. Attach spacer blocks (4 per side) to inner shell as shown, using two 1¼" screws per block. Bottom spacer blocks are 10" up from the bottom edge of the inner shell. Top spacers are 4" from top. Alternate spacers left and right sides, 4" apart.
9. Assemble four outer-shell boards into a hollow, square box as in step 4. Vent slots are on opposing sides and oriented towards the bottom.
10. Slide finished outer shell over inner shell, so that 6" of inner shell protrudes below outer shell. Mark locations of spacer blocks. Secure outer shell to inner shell as in step 7 (pre-drill holes first). Ensure that no screws protrude into the roosting chambers.
11. Caulking first, attach inner roof to box with 1¼" screws. Carefully drive screws into top edges of shells to prevent screws from entering roosting chambers.
12. Center and attach outer roof to inner roof with 1¼" screws, caulking first.
13. Paint or stain exterior three times (use primer for first coat). Cover roof with shingles or dark galvanized metal.
14. Slide completed rocket box over pole. One inch up from the bottom edge of pole sleeve, drill a ¼" hole all the way through pole and sleeve. Rotate box and pole 90° and drill another ¼" hole, 2 inches from the bottom, through pole and sleeve. Secure box to pole with two 4½" bolts, washers and nuts. Orient vent slots north and south during installation.

Optional modifications to the rocket box

1. For extra mounting height, insert a 4½" bolt and nut about halfway up through pole sleeve after completing step 5.
2. For extra heat-holding capacity, create a compartment in upper half of pole sleeve with a 2½"-square piece of leftover plywood. Fill upper half of sleeve with sand, gravel or dirt, and seal with another piece of plywood flush with top.
3. In warmer climates, a larger outer roof with more overhang can be used for additional shading.

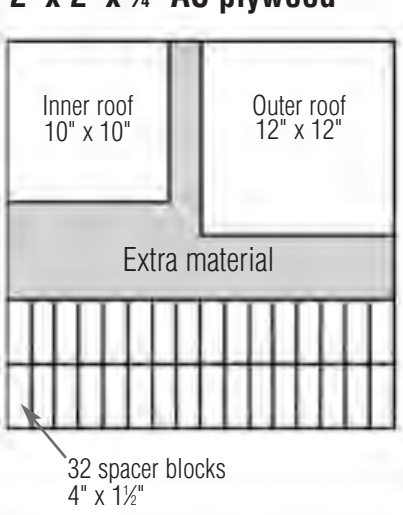
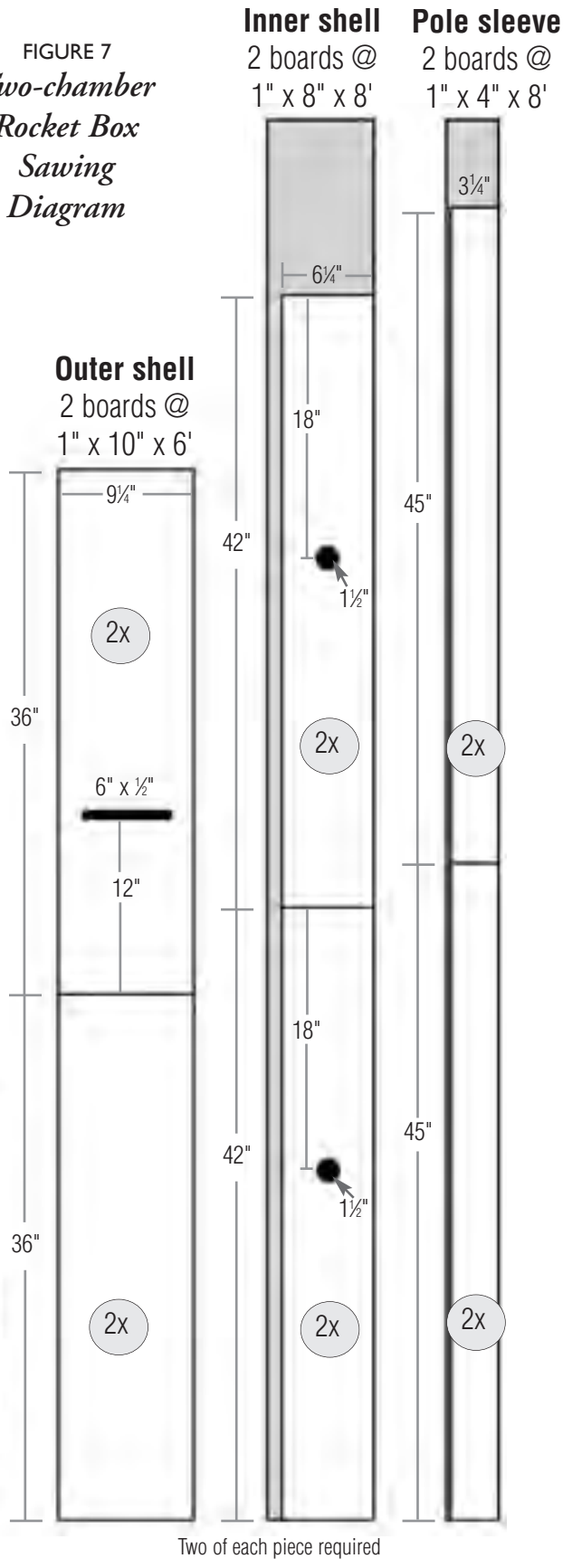


FIGURE 7
Two-chamber Rocket Box Sawing Diagram



Plans from: Tuttle, M. D., M. Kiser, and S. Kiser. 2004. The Bat-House Builder's Handbook: Second Edition. Bat Conservation International, Austin, Texas.

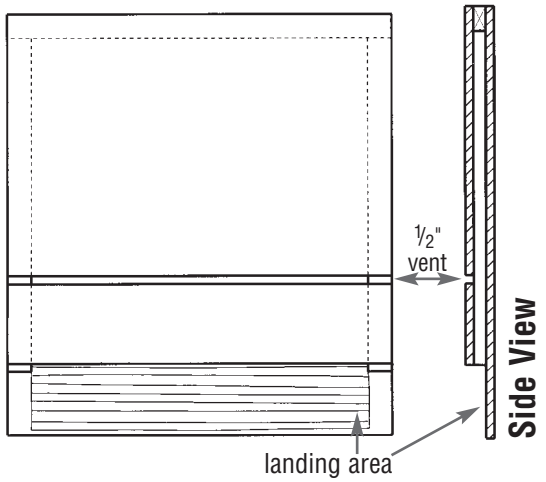
Single-chamber Bat House (wall mounted)

Materials (makes one house)

¼ sheet (2' x 4') ½" AC, BC or T1-11 (outdoor grade) plywood
One piece 1" x 2" (¾" x 1½" finished) x 8' pine (furring strip)
20 to 30 exterior-grade screws, 1"
One pint dark, water-based stain, exterior grade
One pint water-based primer, exterior grade
One quart flat, water-based paint or stain, exterior grade
One tube paintable latex caulk
1" x 4" x 28" board for roof (optional, but highly recommended)
Black asphalt shingles or galvanized metal (optional)
6 to10 roofing nails, ⅞" (if using shingles or metal roofing)

Recommended tools

Table saw or handsaw	Caulking gun
Variable-speed reversing drill	Paintbrushes
Screwdriver bit for drill	Hammer (optional)
Tape measure or yardstick	Tin snips (optional)



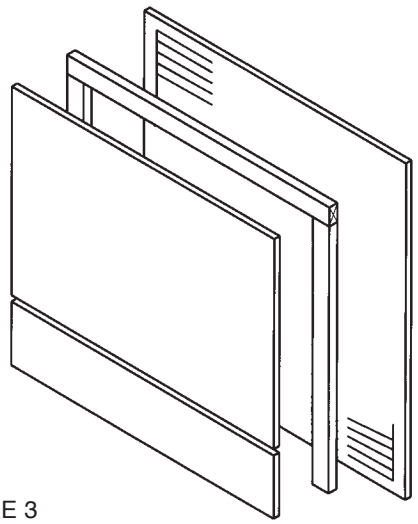


FIGURE 3

Construction

1. Measure and cut plywood into three pieces:
   26½" x 24" 16½" x 24" 5" x 24"
2. Roughen inside of backboard and landing area by cutting horizontal grooves with sharp object or saw. Space grooves ¼" to ½" apart, cutting 1/32" to 1/16" deep.
3. Apply two coats of dark, water-based stain to interior surfaces. Do not use paint, as it will fill grooves.
4. Cut furring strip into one 24" and two 20½" pieces.
5. Attach furring strips to back, caulking first. Start with 24" piece at top. Roost chamber spacing is ¾".
6. Attach front to furring strips, top piece first (caulk first). Leave ½" vent space between top and bottom front pieces.
7. Caulk all outside joints to further seal roost chamber.
8. Attach a 1" x 4" x 28" board to the top as a roof (optional, but highly recommended).
9. Apply three coats of paint or stain to the exterior (use primer for first coat).
10. Cover roof with shingles or galvanized metal (optional).
11. Mount on building (south or east sides usually best).

Optional modifications to the single-chamber bat house

1. Wider bat houses can be built for larger colonies. Be sure to adjust dimensions for back and front pieces and ceiling strip. A ¾" support spacer may be needed in the center of the roosting chamber for bat houses over 24" wide to prevent warping.
2. To make a taller version for additional temperature diversity, use these modifications: From a 2' x 8' piece of plywood, cut three pieces: 51" x 24", 33" x 24" and 12" x 24". Cut two 8' furring strips into one 24" and two 44" pieces. Follow assembly procedure above.
3. Two bat houses can be placed back-to-back, mounted between two poles, to create a three-chamber nursery house. Before assembly, cut a horizontal ¾" slot in the back of each house about 9" from the bottom edge of the back piece to permit movement of bats between houses. Two pieces of wood, 1" x 4" x 4¼", screwed horizontally to each side, will join the two boxes. Leave a ¾" space between the two houses, and roughen the wood surfaces or cover the back of each with plastic mesh (see item 5 below). Do not cover the rear exit slots with mesh. One 1" x 4" x 34" vertical piece, attached to each side over the horizontal pieces, blocks light but allows bats and air to enter. A galvanized metal roof, covering both houses, protects the center roosting area from rain. Eaves should be about 3" in southern areas and about 1½" in the north.
4. Ventilation may not be necessary in cold climates. In this case, the front should be a single piece 23" long. Smaller bat houses like this one will be less successful in cool climates. However, those mounted on buildings maintain thermal stability better and are more likely to attract bats.
5. Durable plastic mesh can be substituted to provide footholds for bats. Attach one 20" x 24½" piece to backboard after staining interior, but prior to assembly. Details on page 11.

Build and Maintain Nesting and Roosting Boxes



Many of Canada's wildlife need trees, especially large ones, that are dying or dead (snags) as safe places to nest in the warmer months and escape poor weather and predators the rest of the year. They are also a key source of food for birds who glean insects along tree trunks and branches.

Where safe, it is best to leave these older trees in your backyard alone. But if it's not possible, or if they were removed before you moved to your home, putting up birdhouses – aka nesting boxes – and roosting boxes can make a big different for bird species that have adapted to these structures.

Tree Cavity Birds in Canada

Tree cavities are formed by either natural decay, an animal or both. Some birds, such as woodpeckers, make their own cavitieswith their strong bills, while others, like owls, nuthatches and chickadees, use these pre-made holes once they are abandoned.

Here's a list of Canadian bird species that have been known to use tree cavities. Many of these birds will use either a bird box and/or a roosting box.



- Eastern Bluebird
- Black-capped Chickadee
- Boreal Chickadee
- White-breasted Nuthatch
- Red-breasted Nuthatch
- Tufted Titmouse
- Pileated Woodpecker
- Downy Woodpecker

- Hairy Woodpecker
- Red-headed Woodpecker
- Northern Flicker
- Red-bellied Woodpecker
- American Kestrel
- Peregrine Falcon
- Merlin
- Barn Owl
- Eastern Screech Owl
- Barred Owl
- Boreal Owl
- Saw-whet Owl
- Northern Hawk Owl
- Pygmy Owl
- Flammulated Owl
- Spotted Owl
- Turkey Vulture
- Great Crested Flycatcher
- Purple Martin
- Tree Swallow
- Chimney Swift
- Vaux's Swift
- House Wren
- Prothonotary Warbler
- Common Goldeneye
- Bufflehead
- Common Merganser
- Hooded Merganser
- Wood Duck

However, according to "Cavity-Nesting Birds of North American Forests" by Scott, Evans, Patton and Stone, the Peregrine Falcon and Merlin no longer had access to big enough cavities with the removal of large trees around the early 1900's and had to adapt to other means of surviving. Some, the western population of Purple Martins have not adapted well to man-made boxes and still need large snags.



Benefits of Putting up Boxes

It is captivating to watch our winged friends building nests, feeding eager mouths and seeing their young take flight. But having cavity nesting birds around our properties is also a huge benefit as they keep insect and rodent populations in check.

It is also satisfying to know that we are helping these important wild neighbours. As more and more people remove the dead or slowly decaying trees from their properties (for various purposes, including firewood, safety, aesthetics and development), there are fewer homes for these important birds.

Removing decaying trees also removes a food source as they forage on insects found on and in dead or dying trees. In fact, experts say that keeping three or four snags (dead or dying trees) per acre of forest is critical for many organisms in that ecosystem, including birds. That's where we can make a real difference!

Some species, like the Eastern Bluebird, once faced serious decline because of the dwindling number of natural cavities available to them, but rebounded because of nesting box programs organized throughout their range.

Where possible, leave dead or dying trees standing. Remove any potentially dangerous branches if near paths, homes or other areas of human activity. If the tree trunk is also a concern (perhaps the top looks weak) consider having a tree company lop the top off to allow the stronger lower portion of the tree to remain standing for several more years. This is especially important for wide trees as larger birds who need bigger homes have less options with fewer mature trees around.

If you can't keep a snag on your property or you want to support these birds, you can put up nesting boxes for the spring and summer and roosting boxes for the rest of the year.



Making Your Own

The dimensions and placement of the nesting box, as well as the size and height of the entrance hole will determine which species will set up house. Check that the species you wish to support lives in your region and that the habitat on your property matches their needs.

Both nesting and roosting boxes benefit from an overhang which prevents rain from going in and makes it harder for predators, like cats and racoons, to reach in. If you are able, cut a groove along the underside of this roof, close to the edge, to channel away any rainwater that could trickle in.

Both boxes should also have a predator guard. You can attach a metal piece fitted around the entrance hole so it can't be chewed wider or, if on a pole, place a baffle below it to prevent animals from climbing up. It's important not to have perches outside the boxes as they make it easier for predators to enter the box.

They will also need a side that can be easily removed or opened for regular cleaning.

When looking to buy or make a nesting or roosting box, keep in mind the main differences between the two kinds of boxes.

MATERIALS

Use woods that resist weathering, such as cedar, pine or redwood. Always avoid pressure-treated lumber as it can be toxic to wildlife. Use lumber at least 2.5 centimetres thick. For roosting boxes, consider using thicker wood to increase the insulation value.

To help the box blend in, use pieces of wood with bark still attached. These slabs are less expensive and can often be found at sawmills and lumber yards.

Consider using screws instead of nails to make it easier to correct mistakes and remove parts in the future if needed. Or use a hinge and latch for even greater access.

It is better not to paint or stain the box. This helps the box blend in, avoiding the attention of predators, and will be healthier for those that use the box. If you do choose to paint, however, follow these tips:

- Use a non-toxic water based paint.
- Paint nesting boxes in the fall for the fumes to dissipate before spring. Paint roosting boxes in the spring, once the coldest days are over.
- Do not paint the inside to prevent paint fumes and flakes from harming young birds.
- Use natural colours that help the box blend in.
- Avoid dark paint colours for nesting boxes, as they can cause the box to hold more heat.

ROOSTING BOXES

- Can have perches inside. They are not necessarily needed as birds have been known to huddle inside but if used, place at different heights and allow sufficient room for moving about.
- Include scuffed sides for gripping.
- Have a low entrance hole so heat rises.
- Do not have ventilation holes in order to contain heat. If your roosting box does have ventilation holes, ensure it is placed on the floor corner and that it is very small.
- Are often larger in size than nesting boxes to accommodate several birds at once.
- Benefit from using thicker wood for added insulation.
- Can be placed in a spot that allows for maximum sunlight, if desired.

DIMENSIONS

These boxes can be any size, as they are known to accommodate varying numbers of birds at one time. You could make them the same size as a nesting box or larger to allow several birds to roost together.

If you have the space, put up a roosting box with a smaller hole (see entrance hole sizes below) and one with a larger hole to attract different species.

CONSTRUCTION

Cut the pieces as specified in the table above, keeping in mind the two side panels should be a bit taller at the back, to allow for a roof that slopes down at the front. (If you are a woodworker or are up for the challenge, you could use two pieces of wood for the roof which slope down at the sides. To do this, you will need to make the front and back pointed at the top to be snugly attached to the roof.)

Whatever box you decide to make, allow extra for the roof to overhang on the front and, if you wish, the sides. If you

are comfortable with woodworking, cut the top of the sides at a slight downward sloping angle and cut the edge of the roof where it meets the backboard to match so it sits snugly.

Drill a hole in the front panel to make an entrance hole using the measurements indicated in the accompanying table (note both the entrance hole diameter and the height of this hole above the floor).

With rough sandpaper, make the inside walls rough enough for young birds to climb out of the box. The higher the entrance hole from the floor, the more help the bird will need. Some species, like ducks, need actual grooves called kerfs.

Attach the pieces with screws or nails. If you choose nails, decide which side you will use to access the inside for cleaning and use screws for that wall, allowing you to undo and reattach each year. You could also use a hinge and latch although raccoons may be able to open it, depending on how loose the latch is.

Drill a few small holes on the sides of the box where you have an overhang to allow hot air to escape. Drill a few small holes (1/4”) in the floor near the walls for moisture drainage. Make the front wall rough on the inside, to help the young climb out as they grow. Some species, such as ducks, will benefit from a few grooves or notches.

Do not attach a platform or perch outside the box. Predators could raid the nest and young birds might venture out of the box too soon.

INSTALLATION

Roosting boxes can be treated very similarly to nesting boxes in terms of placing in a sheltered spot facing away from prevailing winds, being stable even in strong winds, adding protection from predators and located several feet

off the ground. They have different needs in terms of heat, however, as they need the sun's warmth to help survive the colder months, so place on the southern side of a building or tree.

MAINTENANCE

If you think the box is empty, take it down, clean out any droppings and return immediately to the tree. In the spring the box can be cleaned out and disinfected with hot water, as with nesting boxes.

When summer arrives, close the box up or put it away to prevent sparrows and mice from taking up residence.

NESTING BOXES

- Have small ventilation holes near the top to let heat escape.
- Have drainage holes along the bottom to let any moisture drain away.
- Have a roughly textured inside front panel for small birds, and grooves along the inside front panel for larger birds, to climb out once they are old enough.
- Can be placed in a few locations: along a tree trunk to mimic the natural habitat, mounted on a solid metal pole if you are concerned about predators, or mounted on a wooden pole (if you choose a wooden pole, place a baffle – a downward facing cone – just below the box) to prevent predators.
- Should be placed in a spot where it will get shade from nearby trees or building during the hottest part of the day as too much heat can be fatal for young birds. Additionally, face away from prevailing winds.
- Must be well secured so it doesn't move. Even a tiny slant can affect the development of young birds. If it is fixed on a pole, ensure it doesn't sway in the wind.
- May require monitoring for some birds, such as bluebirds. Check out this article for more information.

DIMENSIONS

Below are the measurements for nest boxes of a few Canadian bird species. Keep in mind that the depth (width of the walls) will be less than the height of the walls

and match the dimensions of the floor panel. The roof, if you use one piece of wood and it has an overhang, will be a bit longer than the floor panel.

The floor and roof are attached to the top and bottom edge of the walls, rather than the insides of the walls (which would make the box wider and shorter).

To be most efficient with (buying and) cutting wood, consider copying the method below, adapting the measurements to the species in question.

Species	Entrance hole diameter	Height of hole above floor	Floor panel	Width of wall panels	Height of wall panels	Roof	Height above ground
American Kestrel	7.5 cm (3")	31 cm (12")	25 cm x 25 cm (10" x 10")	25 cm (10″)	40 cm (16")		6-9 m (20-30 ft)
Bufflehead	6 cm (2.5")	30 cm (12")	15 x 15 cm (6" x 6")	15 cm (6″)	37 cm (15")		3 m (10 ft)
Chickadee	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2-5 m (6.5-16 ft)
Downy Woodpecker	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2-3.5 m (6.5-11.5 ft)
Great Crested Flycatcher	5 cm (2")	15 cm (6")	15 cm x 15 cm (6" x 6")	15 cm (6″)	20 cm (8")		3-5 m (10-16 ft)
Hairy Woodpecker	4 cm (1.5")	22-30 cm (8.5-12")	15 cm x 15 cm (6" x 6")	15 cm (6″)	30-35 cm (12-14")		3-5 m (10-16 ft)
House Wren	2.5-3 cm (1-1 1/4")	10-15 cm (4-6")	10 cm x 10 cm (4" x 4")	10 cm (4″)	15-20 cm (6-8")		2-3 m (6.5-10 ft)
Northern Flicker	6 cm (2.5")	35 cm (14")	15 cm x 15 cm (6" x 6")	15 cm (6″)	40 cm (16")		2-5 m (6.5-16 ft)
Nuthatch	3 cm (1 1/4")	15 cm (6")	9 cm x 9 cm (3.5" x 3.5")	9 cm (3.5″)	20 cm (8")		2 m (6.5 ft)

Species	Entrance hole diameter	Height of hole above floor	Floor panel	Width of wall panels	Height of wall panels	Roof	Height above ground
Red-headed Woodpecker	5 cm (2")	25 cm (10")	5 cm x 15 cm (6" x 6")	15 cm (6″)	140 cm (16")		4-9 m (13-30 ft)
Screech Owl	7.5 cm (3")	31 cm (12")	20 cm x 20 cm (8" x 8")	20 cm (8″)	40 cm (16")		4-9 m (13-30 ft)
Wood Duck	7.5 x 10 cm oval (3" x 4")	46 cm (18")	30 cm x 30 cm (12" x 12")	30 cm (12″)	61 cm (24")		2.5-4.5 m (8-15 ft)

CONSTRUCTION

1. Cut one floor panel, one roof panel, two side panels, one back panel and one front panel. If you are comfortable with woodworking, cut the sides at a slight downward sloping angle and cut the edge of the roof (where it meets the backboard) to match so it sits snugly.
2. Cut an entrance hole in the front panel.
3. Nail most of the pieces together, using screws for the removable side that will provide easy access for cleaning.
4. Make several perches out of dowel 0.7 cm or 1 cm in diameter, mounting the perches at varying heights inside the box. (Optional.)
5. Add some wood chips to the floor for added insulation and to help absorb fecal matter. (Optional.)

INSTALLATION

Install the box when the birds you hope to attract return from their migration or, if they remain year round, shortly before nesting time. Putting it up too early can attract species such as the House Sparrow and European Starling which nest early. These introduced species can be aggressive, driving off or killing native species. Alternatively, you can put the boxes up earlier but with a plug in the entrance hole which can be removed when you think the relevant birds are ready to nest. This is especially important in Purple Martin houses.

Mounting nest boxes on metal poles will help prevent predators from accessing the box. Metal T bars are excellent. They should also be placed at a sufficient distance from trees and other structures so that squirrels and cats cannot jump

to the box. An alternative is to use a wooden post and to slip a length of PVC piping around the post to prevent predators from climbing it.

Nest boxes can also be mounted on tree trunks. In this case, cut the back a little longer so it comes above the roof and therefore creates a place to nail to the tree. These spots can leave the nest vulnerable to predators which you can discourage by putting a guard, such as a collar, around the trunk. These tree guards help protect the nest and may also provide a place for some forest-dwelling bat species to roost.

Make sure your box is mounted securely for wind storms. Even subtle movements can affect the development of the young. Also, have the box face away from prevalent winds.

Place in an area that is not sprayed with pesticides as they reduce and contaminate the local insect population.

- Eastern Bluebirds

Place nesting boxes on 1.5 to 1.8 metre poles in quiet open fields, orchards or pastures with some nearby trees for perching. Leave a minimum of about 100 m between boxes. Click here for detailed information. A good idea is to place bluebird boxes in pairs about ten to twenty feet apart. This typically encourages Tree Swallows to take one box and bluebirds the other. These swallows tend to fight off other swallow pairs that are close by but tolerate bluebirds as neighbours.

- Tree Swallows

Situate boxes on 1.5 to 1.8 poles in backyards, front yards, near fields, a river or pond. This species will possibly use boxes that are mounted on the sides of buildings or under eaves. Leave about 15 m between boxes or make sure they are not visible to each other.

- Ducks

Place nest boxes near the shoreline or in a wetland. Use steel poles, dead or live trees to install the boxes 1.2 to 1.8 m above the water or ground. Make kerf cuts

in the wood – grooves that serve as steps and help ducklings to get out of the box.

MAINTENANCE

While there has been the tendency to remove used nests in the fall, some studies suggest that there can be benefits for leaving them. Sometimes birds will choose a clean box while others will choose one with an old nest.

A couple of benefits to keeping an old nest, according to bird expert, David Bird, are that reusing a nest can save a bird time and energy. And for bluebirds, where parasitic wasps actually help these birds by eating harmful blood-sucking blowfly larvae, parasitic wasps will use the old nest to overwinter in until the following year.

Removing nests, however, removes various mites and fleas that could infest adults and their young. It also keeps the height of the current nest lower. This keeps nestlings safer as they are farther away from the entrance hole. It minimizes young birds from accidentally falling out and prevents them from being easy prey for animals reaching in the box.

You may need to be your own citizen scientist and notice from year to year what your birds prefer.

If you choose to clean your nesting box each fall to get rid of parasites, keep in mind that for species like Eastern Bluebirds which typically nest two (sometimes three) times each summer, you might want to clean the nesting box between broods.

When cleaning, it's a good idea to wear a facemask (available at hardware stores and drug stores) to avoid breathing in any potential fungi and parasites. Scrub your box with a stiff brush and bleach. Rinse well with just-boiled water and allow it to air dry thoroughly in the sun.

Thanks to Cliff Bennet for his helpful suggestions with this article.

APPENDIX 6:
Native Plant Salvage Plan

Native Plant Conservation Plan For Lakestone

9678 Benchland Drive, Lake Country

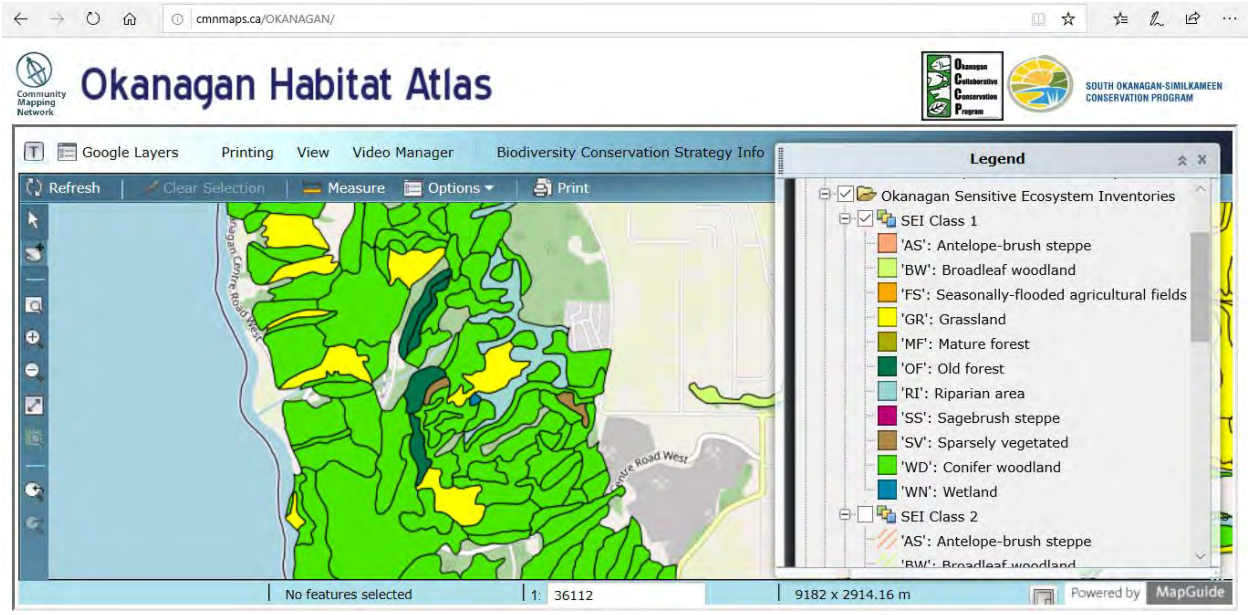
Plan developed by Tanis Gieselman, SeedsCo Community Conservation

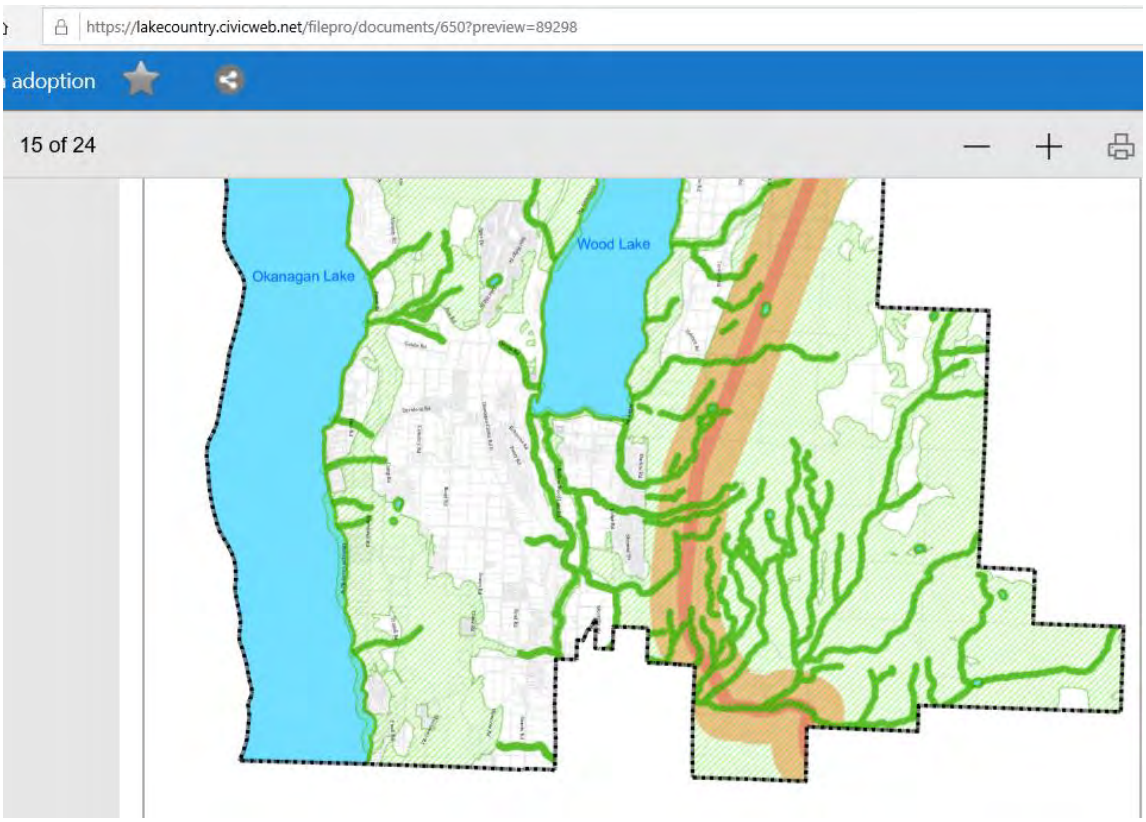
at the request of Ecoscape Environmental Consultants Ltd.

Project Overview

This development is situated in habitat of high value ESAs, so planning to mitigate, restore, and compensate for the destruction of habitat is essential for meeting Federal, Provincial, and local government objectives to:

- Prevent the loss of habitat for rare and threatened species (in Environmentally Sensitive Areas).
- Prevent the loss of green spaces, which reduces flood risk and improves climate resilience.
- Keep remaining habitat well connected to support species migration. For example, there is a network of small riparian corridors and remaining habitat that for a last remaining East-West connection across the valley, connecting Okanagan Lake to the upland Regional Corridor outlined on District of Lake Country OCP Map 15 (Natural Environment Development Permit Area).





SeedsCo Community Conservation – Bringing Conservation to the Construction Zone

- Communities in the Okanagan are all nestled amongst endangered grassland and wetland ecosystems, which are important ecological networks of habitat and migration corridors used by local species.
- Protected areas are the best way to do habitat conservation, but not everything can be set aside. Few systems are currently in place for conservation in developing areas. Meanwhile, native seed resources for reclaiming land that has been developed are limited, especially for large projects.
- Development projects can take an important opportunity to maximize biodiversity conservation by supporting salvaging of native plant species from developing areas, and using these collections to re-plant the landscape post-development.
- SeedsCo Community Conservation has worked over the past seven years to develop strategies for seed salvaging and conservation in partnership with large development projects such as The Ponds, Wilden, and CedarCreek Estate Winery.
- Collections of native plants and seeds are salvaged from each site before it is developed. 10% of the collections are offered for use in restoration or landscaping at the developed site after construction. The remainder of the collections are archived for long-term conservation, and sold to support conservation operations and education programs.

- Seeds salvaged thus far have been distributed back into the community through community partnerships like the Kelowna Nectar Trail, Seedy Saturday and other community events, the Okanagan College Aboriginal Education Department, and the RDCO Parks Volunteer Program. Seeds have also been shared with local native plant nurseries, international botanical gardens, and have been used for restoration initiatives at the En'Owkin Centre, and in Bertram Creek Regional Park.

Pre-development Salvage Collection

- A salvage team visits the proposed development site each week of the growing season. A species list and map of the site is recorded initially. Each subsequent week, several species are chosen for salvage. Species are prioritized for collection according to when their seeds are ripe, and which areas are to be imminently developed.
- Some plant species are also collected by transplanting whole plants to a safe location for propagation, especially for areas where development will occur before a season of seeds can be collected.
- Teams need 8 hours per week for every 2 ha of proposed development area to salvage. The proposed development has an estimated total of 50 ha that will need to be surveyed for salvage, which could be achieved for 10 ha each year over 5 years.

During Development

- Use observation data from pre-salvage collection to identify on a fine scale, and tag important wildlife trees, At Risk plant and animal populations, wetlands, and other important features that are of a high priority to avoid disturbing or for relocation.
- Take whole plants and cuttings from the native vegetation as it is being removed from the development sites. Plants can be potted and grown on site for use in residential and restoration plantings post development.
- If large areas of native plants are desired for landscaping post-development, plants can be pre-ordered, and seeds from previous collections can be grown off-site, to be ready for planting at completion.

Post-development

- 10% of seeds and plants salvaged from the site are provided back to the source for re-planting after development for participating in the conservation partnership.
- 30%-50% of collections are archived for long-term conservation.
- The remaining collections are sold to support the archiving of conservation collections, and for research and other educational initiatives.
- We encourage native species be planted in restoration areas, parks, public greenspaces, street meridians, and private landscaping, and can provide guidance on selection of appropriate species for various applications.

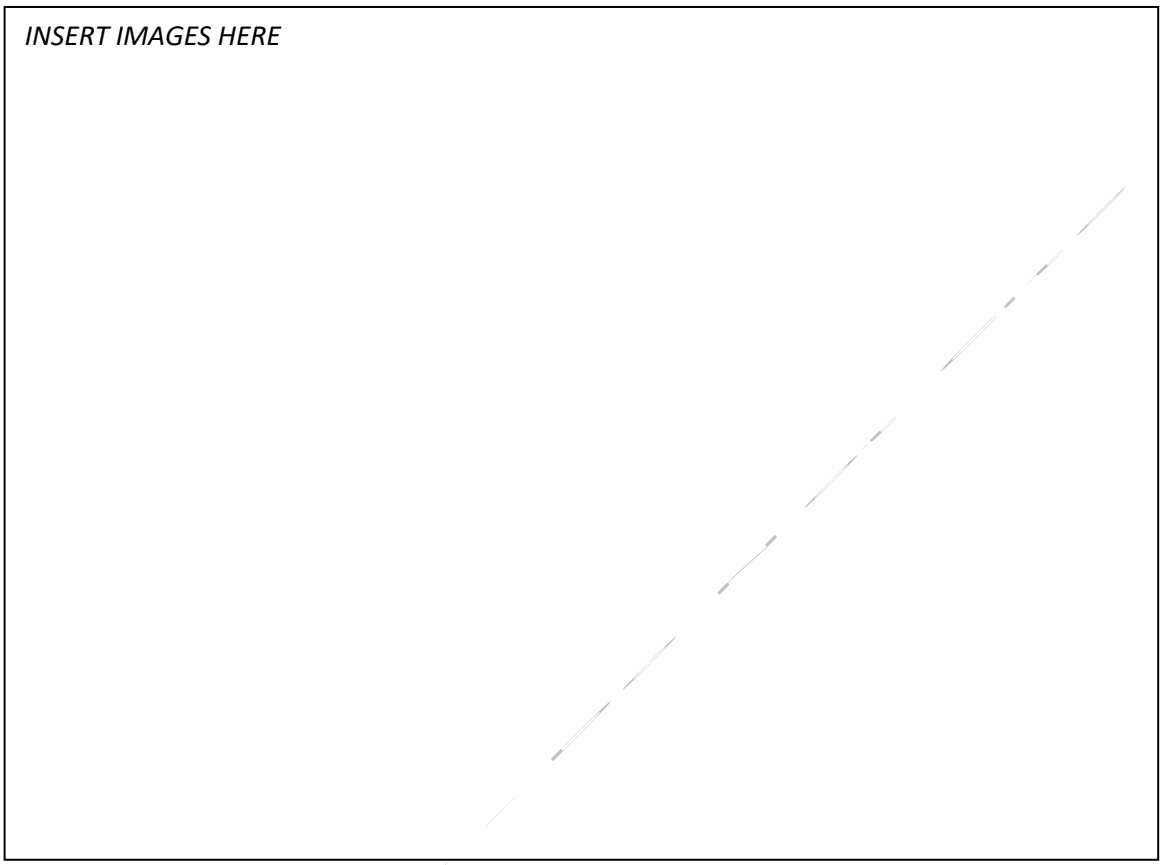
Benefits of Salvaging Native Species

Salvaging native seeds from developing areas enhances the supply of native plants for local projects, and supports biodiversity by maintaining grassland habitat throughout the Okanagan Valley. Okanagan grassland plants are adapted to the harsh Okanagan climate, so they require little additional care or water once they are established, and are ideal for water-efficient urban landscaping. Many of these plants are also essential for supporting local species like bees and other wild pollinators, and are in high demand for conservation and restoration initiatives. Native plant species support wild pollinators throughout the season, in between the limited times when our cherry and apple orchards are blooming, and some wild pollinators even require a particular species of native plant for their survival. Native grasslands support our cattle industry, and provide important winter range for mule deer and bighorn sheep, and even though grasslands cover less than 1% of BC, they support over 30% of our rare and endangered species! The Okanagan is an important biodiversity hotspot, where the arid grasslands of the south meet the northern forests and create a unique and rich community of life that is threatened by intense development pressure. We have already lost 50-75% of our major grassland types, and over 80% of historical wetlands in the Okanagan to development (see Lea, 2007. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=52470). Including native species in all landscaping can help local species survive as developed areas expand around them.



APPENDIX 7:
Guidelines for Amphibian and Reptile Conservation

DRAFT
Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia



DRAFT 5 – Jan. 25, 2019

TABLE OF CONTENTS

Acknowledgements 6
1.0 INTRODUCTION 7
1.1 Background 7
1.2 Purpose 7
1.3 British Columbia Legislative Context 7
Species at Risk Act, 2002 8
1.4 Document Scope and Audience 8
1.5 Document Outline 9
2.0 WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA 11
2.1 Mechanisms of How Roads Can Impact Herpetofauna Populations 12
2.1.1 Habitat Loss 12
2.1.2 Barriers to Movement 13
2.1.3 Road Mortality 14
2.1.4 Attraction to Roadside Habitat 15
2.2 Long-term Impacts of Roads to Populations 16
2.3 Impacts of an Expanding Road Network and Increased Traffic in the Future 18
2.4.1 Road Surface Maintenance 18
2.4.2 Drainage Maintenance 21
2.4.3 Vegetation Maintenance on Roadsides 21
3.0 SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY 21
3.1 Step 1: Identify the assessment area 24
3.1.1 Identify and map species up to 3 km away from your project footprint boundary 25
3.1.2. Identify and map habitat in your project area 26
3.1.3 Inventory species and habitats in your project area 27
3.2 Step 2: Identify the Impacts - Risk Assessment 27
3.3 Step 3: Avoid 29
3.4 Step 4: Minimize and restore on site using BMPs and expert advice 31
4.0 GUIDANCE FOR MITIGATION PLANNING AND DESIGN 31
Where the results of the risk assessment conducted as part of the Screening Tool indicate a “high-risk” road project, a mitigation plan is required. A mitigation plan would also be useful for “medium-risk” projects where mitigation is deemed suitable. 31
4.1 Background information for Developing a Mitigation Plan 31
4.2 Designing crossing structures 32
4.2.1 Bridges and Elevated Roads 33

4.2.2 Tunnels 35
4.2.2.1 Tunnel Design 35
4.2.2.2 Types of Tunnels for Amphibians and Reptiles 38
4.2.2.3 Number of Tunnels, Location, and Spacing 43
4.2.2.4 Retrofitting Existing Drainage Culverts 45
4.2.3 Wildlife Overpasses 45
4.2.4 Fencing for Reptile and Amphibian Crossings 47
4.2.4.1 Fence Design 47
4.2.4.2 Fence Length and Placement 51
4.2.4.3 Fence Maintenance 53
4.2.5 Recommendations by Species Group 53
4.3 Additional Planning and Design Mitigation Measures 61
4.3.1 Influencing Driver Behaviour 61
4.3.2 Influencing Wildlife Movement 64
5.0 GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES 66
5.1 Timing of Construction Activities 66
5.2 Mitigation Measures for Construction Activities 67
6.0 GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES 68
6.1 Assessing and Prioritizing Application of Mitigation Guidelines During Road Maintenance Activities 68
6.2 Road Surface Maintenance Guidelines 69
6.2 Drainage Maintenance Guidelines 69
6.3 Roadside Vegetation and Wildlife Fence Maintenance Guidelines 70
7.0 MONITORING 71
7.1 Compliance Monitoring 71
7.2 Maintenance Monitoring 71
7.3 Effectiveness Monitoring 72
7.3.1 Developing an Effectiveness Monitoring Plan & Study Design 73
7.3.2 Sampling Protocols and Techniques for Effectiveness Monitoring 75
7.3.2.1 Road Surveys 76
7.3.2.2 Monitoring Crossing Structures and Fencing 79
7.3.2.3 Monitoring Population Trends 81
7.3.2.4. Population Viability Modelling 82
7.4 Communication Needs for Adaptive Management 83
8 REFERENCES 84
9.0 APPENDICES 114
Appendix A – Amphibian and Reptile Species, their status (federally SARA listed species are highlighted in bold), and the TRANS region(s) where they occur. (current to June 2018; please check SARA registry and BC Species and Ecosystem Explorer for updates) 114

APPENDIX B – Impacts of Roads on Amphibians and Reptiles (federally listed species are highlighted in bold) 116
APPENDIX C – General Habitat Associations of Amphibians and Reptiles in BC 122
APPENDIX D – Migration, Dispersal, and Movement Distances of Amphibians and Reptiles in BC (federally listed species are highlighted in bold) 124
APPENDIX E – Examples of mitigation projects to reduce road impacts on amphibians and reptiles in BC 130
Appendix F – Instructions for Navigating iMapBC 135

List of Tables and Figures

Figure 1. Effects of roads on amphibians and reptiles. Red arrows indicate animal movements and other arrows show direction of influence of labelled effects. (Based on impacts outlined in Andrews et al. 2008, Beebee 2013, Langen et al. 2015, Marsh and Jaeger 2015.) 12

Figure 2. Flowchart summarizing the use of the Screening Tool and the development of a mitigation plan for road projects. 23

Figure 3. Relative level of risk posed by a road project for amphibians and reptiles based on likelihood of harm and severity of harm. 29

Table 1. The general active/sensitive periods for amphibians and reptiles in BC. *Note:* The timing of life history phases is species- and region-specific, varies annually, and must be confirmed with a QP. 30

Figure 4. Box, arch, and round tunnels buried into the ground and providing an interior height of at least 0.5 m are recommended for ease of movement of amphibians and reptiles under roadways. Interior width will vary with the tunnel design and species (Section 4.3.5). 35

Figure 5. Road crossing locations of adult Red-Legged Frogs (blue dots) and Western Toads (red dots) in spring adjacent to a breeding site near Duncan, BC. Adult movements were more random and widely dispersed than the relatively narrow corridors used by dispersing Western Toad juveniles (pink arrows) in summer after emergence from the breeding site. 44

Figure 6. Design of fencing to exclude amphibians from roadways and/or guide them towards tunnels. 49

Table 2. Fence material options and considerations. See 4.2.5 for species group recommendations. 49

Table 3. Recommended above-ground heights and below-ground depths for fencing for each species group. 50

Figure 7. Fence ends should curve back, by a minimum of 200 cm, towards the shoulder side of the road to deter animals that are moving along the fence from continuing onto the road and, ideally, redirect them back towards the crossing structure. 51

Figure 8. Fencing placement in relation to crossing entryways. Fencing should be continuous between multiple, adjacent crossing structures to increase the “capture” area of migrating individuals. 53

Figure 10. Overview and key elements for planning a rigorous study design that will assess the effectiveness of road mitigation for amphibians and reptiles. 73

Figure 11. Relative level of effort required to collect data to meet different monitoring objectives, including where the monitoring takes place and example sampling techniques used for each. 76

Table 5. Advantages and disadvantages of techniques used to monitor road crossing structures. 80

Acknowledgements

This document was based on *Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario* (Ontario MNRF 2016); we would like to thank the authors for giving us permission to extract portions of text verbatim and images for use in this document. The primary penholders on this document were Elke Wind, Barb Beasley, and Mike Sarell, who prepared the first draft and addressed subsequent reviews of this document with input from B.C. Ministry of Environment and Climate Change Strategy. We would like to acknowledge the contributions of the participants of the 2018 Herpetofauna and Roads Workshop, held the 21st of September in Kamloops, BC, who added pertinent examples, insights, and information that greatly improved this guidance document. We are particularly grateful to the participants that took the time to submit written comments: Steve Beja, David Clough, Jakob Dulisse, Christine Lion, Alison Peatt, Robyn Reudink, David Seburn, and Stephanie Winton.

Kristiina Ovaska and Purnima Govindarajulu were the primary reviewers and editors of this document. Other reviewers include Kendra Morgan, Orville Dyer, Robin Reudink, Jamie Leatham, Manjit Kerr-Upal, and Jemma Green.

1.0 INTRODUCTION

1.1 Background

Amphibians and reptiles are the most at risk species assemblages in British Columbia, with more than 50% of species in each group listed provincially and/or federally as species of conservation concern. Road mortality is identified as a significant threat to amphibians and reptiles, and mitigating this threat is identified as a priority action in the recovery planning documents for most of these species. To address this issue, the first "Herpetofauna and Roads Workshop" was held in Nanaimo in 2011. This workshop brought together qualified professionals (QPs) from within and outside government, academics, and conservation biologists to learn about road mortality issues, share unpublished research, and work together toward more effective solutions.

One of the most significant outcomes of this meeting was the creation of the BC Herpetofauna and Roads Working Group, a network for exchanging ideas. In the years since that first meeting in 2011, some members of the BC Herpetofauna and Roads Working Group and others conducted substantial new research, both in mitigation project design and in effectiveness evaluation. However, the results are not widely available and standard guidance is still lacking. This guidance document fills that need and is based on a similar document produced by the Government of Ontario in 2016 (Ontario MNRF 2016). This document is updated with BC-specific information and the most recent literature.

1.2 Purpose

The purpose of *Guidelines for Amphibian and Reptile Conservation during Road Building and Management Activities in British Columbia* (hereafter referred to as Guidelines) is to provide road authorities, and the qualified professionals advising them, with a comprehensive knowledge base to avoid, minimize, and mitigate road impacts on amphibians and reptiles in BC. Road authorities include all levels of government, industry, and private landowners who build, manage, and maintain roads in BC. The information in this document follows the mitigation hierarchy set out in the Government of British Columbia's ***Procedures for Mitigating Impacts on Environmental Values*** and provides information for mitigating impacts arising from road building and upgrading, as well as from maintenance activities on existing roads.

1.3 British Columbia Legislative Context

The information and procedures described in this document do not create new legal requirements or supersede any statute. However, they are intended to serve as a decision support tool to inform the implementation of existing legislation and regulatory requirements improve awareness and understanding of the best available science, and allow for flexible, well informed, and balanced solutions. Some legislation that might have implications for road building and maintenance activities and their impact on herpetofauna is listed below.

Provincial Legislation

Wildlife Act, 1996

In BC, all native wildlife, including amphibians and reptiles, are protected under the BC *Wildlife Act*. Under the Act it is an offence to kill, harm, collect, transport, or trade in native wildlife species. An exemption permit may be issued when all avenues to avoid impacts to wildlife have been examined and deemed not feasible.

Forest and Range Practices Act, 2002

The *Forest and Range Practices Act* provides for management of forest and range practices on Provincial Crown lands for the habitat of species at risk identified in the *Identified Wildlife Management Strategy* (see Appendix A for amphibians and reptiles listed as Identified Wildlife). Part of the protection for these species includes limited or no road building within designated Wildlife Habitat Areas. For a list of approved Wildlife Habitat Areas, visit: http://www.env.gov.B.C..ca/wld/frpa/iwms/wha.html.

In addition to these existing laws, the Government of B.C. is in the process of drafting BC-specific Species at Risk legislation. Requirements under this act will be updated in this document once they become available.

Federal Legislation

Species at Risk Act, 2002

The *Species at Risk Act* provides the legislative framework for the protection of species at risk in Canada. The purposes of the *Species at Risk Act* are to prevent wildlife species in Canada from disappearing; to provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity; and to manage species of special concern to prevent them from becoming endangered or threatened. The Act provides for the development of recovery and management planning documents for species listed under the Act. These documents prioritize recovery and threat mitigation actions, including the identification of Critical Habitat—defined by the Act as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or action plan for the species"—and the listing of activities likely to result in the destruction of Critical Habitat. For example, Table 3 of the *Recovery Strategy for the Western Rattlesnake (*Crotalus oreganus*), the Great Basin Gophersnake (*Pituophis catenifer deserticola*) and the Desert Nightsnake (*Hypsiglena chlorophaea*) in Canada 2017* lists road building and road maintenance as activities with the potential to result in destruction of critical habitat. This Guidelines document, along with recovery planning documents and others, provide guidance on preventing and mitigating the impacts of roads.

What is Mitigation?

The ***Procedures for Mitigating Impacts on Environmental Values*** (Environmental Mitigation Policy; EMP) defines a "mitigation measure" as a tangible conservation action taken to avoid, minimize, restore on-site, or offset impacts on environmental values and associated components, resulting from a project or activity.

[*From:* Version 1.0, May 27, 2014]

"There is no universally accepted mitigation design that is effective for every socio-economic roadway situation or wildlife species. The effectiveness of mitigation depends on the level of commitment and dedication of all stakeholders."
(Colley et al. 2017.)

The location of approved Critical Habitats for species at risk that occur in BC can be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en.

1.4 Document Scope and Audience

Preventing the impacts of roads on amphibians and reptiles is a science that continues to evolve as new solutions are implemented and tested. As such, it is not possible at this time to provide specific or directive best management practices that can be applied universally across diverse road projects. Instead, this document offers guidelines for developing site-specific mitigation based on current peer-reviewed and grey literature (e.g., websites and conference proceedings), government documents,

academic theses, and questionnaire-based surveys of experts in road ecology and other areas of relevance (e.g., engineering, species biology). When knowledge gaps are identified, the recommendations include a range of options based on the best available science and expert opinion, as well as interpretation based on species-specific needs and life-history traits.

The intended audience of this guidance document is primarily the qualified professionals who advise the road authorities that build and maintain roads in BC, to support professional reliance and adherence to the precautionary principle. This document is equally relevant to government staff reviewing development applications and providing advice to the statutory decision-makers. Finally, this document will also be useful for academics interested in assessing the effectiveness of, and improving, mitigation measures, and addressing knowledge gaps in current road ecology as it pertains to amphibians and reptiles.

This document presents current information, as of the date of publication. It is intended to be updated as new information becomes available. The members of the BC Herpetofauna and Roads Working Group will be the community of practice that prioritizes and guides the development and updating of these Guidelines going forward.

1.5 Document Outline

Much of the information in this document is subject to ongoing research and is evolving rapidly. It is strongly recommended that the services of a QP with experience in the geographical region, and with the species of concern and the mitigation techniques required, are engaged to ensure that the most biologically sound and cost-effective solutions are developed and considered early in the project planning cycle. Citations and links for further information are provided throughout the document to enable QPs to access the latest developments, updates, and data from previous and ongoing projects.

This document is organized into the following sections:

Section 1 (INTRODUCTION) provides information on the purpose of the document in relation to regulations associated with the protection of amphibian and reptile species in BC.

Section 2 (WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA) provides background information on the diverse and complex impacts of roads on amphibians and reptiles that go beyond simple road mortality. Recent information on these more subtle and indirect effects provides the background against which to assess the need for, and development of, road mitigation measures.

Section 3 (SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY) provides step-by-step guidance for assessing whether mitigation is needed as a result of anticipated effects of a project on amphibians, reptiles, or their habitats.

Section 4 (GUIDANCE FOR MITIGATION PLANNING AND DESIGN) describes how to develop a mitigation plan for new and existing roads taking into account landscape-level considerations for habitat protection and connectivity. It provides details on road designs to reduce impacts, amphibian and reptile crossing structures and fencing systems. Options for influencing driver and wildlife behaviour to reduce impacts are also discussed.

Section 5 (GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES) provides considerations for reducing impacts from road construction including timing construction activities to avoid construction-related

impacts, and considerations regarding the use of temporary measures to minimize impacts during construction.

Section 6 (GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES) describes how various maintenance activities can affect amphibians, reptiles, and their habitats and outlines mitigation strategies to reduce those potential impacts.

Section 7 (MONITORING) highlights the importance of filling knowledge gaps related to the effectiveness of mitigation measures for reducing road impacts on amphibians and reptiles. Monitoring requirements for compliance, maintenance, and evaluating the effects of mitigation on population viability are described. Study design and monitoring techniques for measuring crossing structure and fencing effectiveness to assist in adaptive management of these structures are discussed.

REFERENCES, PERSONAL COMMUNICATIONS and APPENDICES summarize resources and provide more detailed information about the status, geographic location, home range, and dispersal distance of amphibian and reptile species in BC, the road impact assessments for these species, and examples of amphibian and reptile crossing structures implemented across BC.

2.0 WHY MITIGATION IS NECESSARY: IMPACTS OF ROADS ON HERPETOFAUNA

Roads are a critical part of BC's transportation infrastructure, underpinning a strong and vibrant provincial economy. In 2018, BC had approximately 719,000 km of roads (Environmental Reporting B.C. 2018). The majority of these roads (92%) are unpaved industrial (forestry, mining, etc.) roads and the remainder are paved highways and municipal and local roads. Decisions affecting road construction and maintenace need to consider many important factors, including public safety, cost, and timing. In recognition that the importance of roads needs to be balanced againt their known impacts on wildlife, there is a growing field of study focused on mitigating the potential ecological impacts of road networks (Forman et al. 2003, Coffin 2007). While paved roads amount to only a fraction of the total road network in BC, they may have a disproportional impact on herpetofauna because they are associated with higher traffic volumes, and are often wide with multiple lanes, which increase the risk of road mortality (Jochimsen et al 2004).

Reptiles and amphibians are particularly vulnerable to roads because of their need to move between different habitats for their various life-history requirements. Frogs, salamanders, and turtles migrate regularly between aquatic and terrestrial habitats as part of their annual life cycle. Roads often intersect their travel routes, as roads are commonly built along valley bottoms and follow the shorelines of water bodies. Most large snakes undertake long-distance seasonal movements, which brings them in contact with the roads that crisscross their home range. Hobbs (2013) calculated that almost half (49%) of the 368 confirmed Western Rattlesnake dens in BC's arid interior were within 1 km of a road.

Amphibians and Reptiles are Particularly Vulnerable to Roads

The threats to herpetofauna extends beyond BC and Canada:

- Globally, a higher proportion of amphibian and reptile species are declining compared to mammals or birds. Within BC, 67% of native reptile and 55% of the native amphibian species are at risk.
- Roads are a greater threat to amphibians and reptiles than for other vertebrates.
- Some roads are assessed in the highest threat category in provincial and federal recovery documents.

(References: IUCN 2010, Rytwinski and Fahrig 2012, COSEWIC 2013, COSEWIC 2015a, BC Species and Ecosystems Explorer 2018, see Appendix A and B)

Roads can result in the following impacts on amphibians and reptiles (Fig. 1):

- Habitat loss
- Barriers to movement leading to habitat fragmentation and isolation of populations
- Road mortality of individuals hit by vehicles
- Habitat pollution from runoff resulting in reduced fitness or increased mortality
- Increased predation
- Habitat degradation resulting in reduced survival and reproductive success
- Attraction to poor-quality roadside habitats

These impacts can lead to reduction of body condition of animals, a reduction of genetic diversity as populations become fragmented, and ultimately, population declines and potential extirpation. Individual and population-level responses can occur more rapidly when impacts combine to produce a **cumulative effect** (see Section 2.3, Box 1).

An understanding the various ways in which roads can impact herpetofauna is essential for planning avoidance and mitigation measures for future projects. In this section, examples of past projects from

B.C. provide context and lessons learned, including what has worked and what has not worked. Drawing attention to both the positive and negative aspects of past projects helps to reveal how impacts were assessed and solutions implemented, where solutions were either too costly and/or logistically not feasible, and where adjustments are needed in the future.

Photo x. Roads are cited as the most significant threat to Western Rattlesnake populations (COSEWIC 2015a).

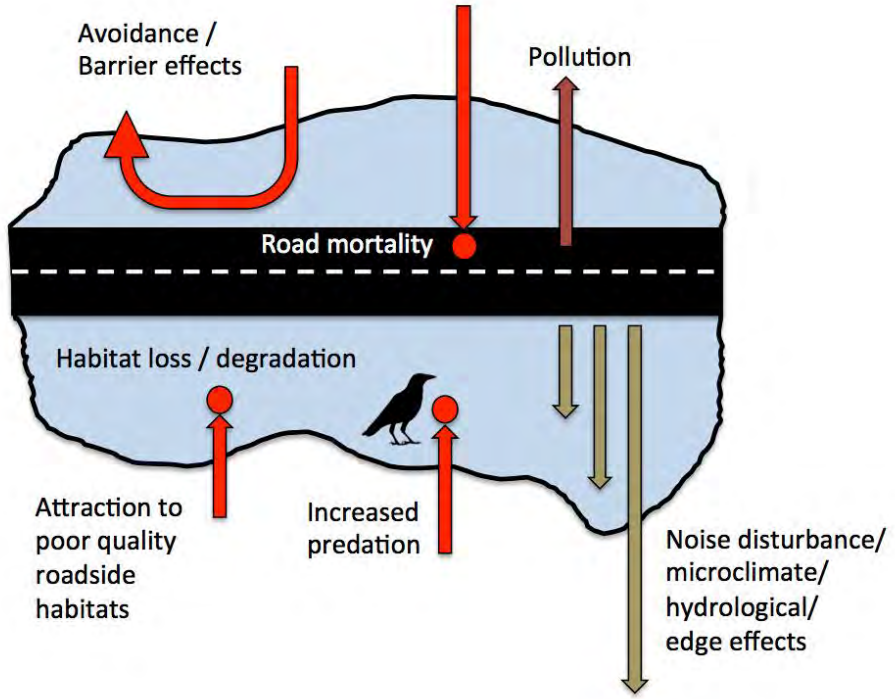


Figure 1. Effects of roads on amphibians and reptiles. Red arrows indicate animal movements and other arrows show direction of influence of labelled effects. (Based on impacts outlined in Andrews et al. 2008, Beebee 2013, Langen et al. 2015, Marsh and Jaeger 2015.)

2.1 Mechanisms of How Roads Can Impact Herpetofauna Populations

2.1.1 Habitat Loss

The construction and widening of roads may remove habitat that is important to amphibians and reptiles (Beebee 2013, Marsh and Jaeger 2015). The footprint of a road itself may destroy breeding sites, foraging areas, hydration sites, overwintering hibernacula, and migratory/dispersal routes. Habitat along the side of the road and/or downstream may also be lost or severely degraded by contaminants from the road, compacted soil, altered hydrologic regimes, sedimentation, human garbage and disturbance, edge effects such as increased sun and wind exposure, altered plant and animal communities, and increased exotic invasive species (Langen et al. 2015). The width of the habitat area impacted by a road, known as the "road-effect-zone," may be many times the road's actual width (Forman and Alexander 1998, Jochimsen 2004).

Two recent road projects highlight the impacts that roads can have on amphibian and reptile habitat loss, and the challenge of avoiding and mitigating those impacts. The Highway 99 upgrades from Horseshoe Bay to Whistler, completed in preparation for the 2010 Winter Olympics to accommodate increased traffic volumes, resulted in a 1.9-km highway realignment through a wetland complex at Pinecrest. Several wetlands used by Northern Red-legged Frogs (*Rana aurora*) and other species were partially or completely filled, and a permeable retaining wall at the wetland-highway interface increased drainage that led to further wetland habitat loss (Malt 2012) (Figure x). The project implemented a number of mitigation measures, but the effectiveness of these mitigation measures is uncertain and the subject of continued research. Another example is the 2017 highway expansion near Williams Lake that inadvertently exposed a garter snake den at a time when the snakes were in the den. The den was destroyed during construction, leading to an emergency salvage of hibernating snakes (Steciw 2018). A replacement den was constructed; however, the effectiveness of this mitigation measure remains uncertain as follow-up effectiveness monitoring has not been completed.

2.1.2 Barriers to Movement

Roads disrupt normal movement patterns of amphibians and reptiles. Paved and gravel road surfaces and mowed right-of-ways have different microclimates and provide less protective cover from predators compared to the surrounding landscape (Langen et al. 2015). Amphibians have permeable skin, which makes them vulnerable to desiccation (drying out) while on paved roads, which rapidly lose surface moisture to evaporation. During dry weather, many amphibian species rarely cross roads, even though they continue to move through moist, vegetated habitats (Ervin et al. 2001, Gravel et al. 2012). Some snake species avoid crossing roads because the open space exposes them to predators (Shine et al. 2004, Andrews and Gibbons 2005, Kingsbury 2011). In some situations, roads include steep roadside verges, concrete barrier structures, and curbs that physically prevent some amphibian and reptile species from crossing (e.g., curbs on a road at Waterton Lakes National Park Reserve obstructed movements of Long-toed Salamanders (*Ambystoma macrodactylum*), B. Johnston pers. comm.). In addition, collision with vehicles causes road mortality (see Section 2.3), which alters the abundance of animals moving across the landscape. When animals avoid or are prevented from crossing roads, their habitats can become fragmented into isolated patches. This can have detrimental impacts on individuals, populations, species, and ecosystems (see Box below) (Hocking and Babbitt 2014, Cosgrove et al. 2018).

Consequences of Roads as Barriers to Movement at Various Scales

- **Restricted home range and resource access** on a daily or seasonal basis can result in poor health and reduced survival and reproductive output, which can ultimately lead to population decline.
- **Impediments to dispersal affect demographics** because they make it more difficult both for declining populations to be rescued via immigration and for unoccupied patches to be recolonized. Limited dispersal can also increase competition among individuals that would otherwise live further apart spread out to find resources.
- **Population isolation** over several generations results in low genetic diversity and higher risk of extinction (e.g., Timber Rattlesnakes (*Crotalus horridus*) in hibernacula that were isolated by roads had lower genetic diversity that resulted in morphological abnormalities, low survivorship, and greater susceptibility to disease compared to non-isolated populations).
- **Blocked or restricted flow of energy and nutrients** may affect food webs within and across ecosystems (e.g., the high number of amphibians moving from land to water to lay their eggs can result in substantial energy subsidies to ponds).

(References: Regester et al. 2006, Marsh et al. 2008, Clark et al. 2010, Clark et al. 2011, Rouse et al. 2011, Robson and Blouin-Demers 2013, Hocking and Babbitt 2014, Cosgrove et al. 2018)

2.1.3 Road Mortality

Amphibians and reptiles are forced to cross roads when they move between seasonal breeding, foraging, and overwintering habitats. Road mortality is primarily a function of traffic volume, regardless of road surface (paved or unpaved), road width, traffic speed, or other road characteristics. Road-killed amphibians tend to be concentrated on roads near wetlands, usually during warm, rainy weather, as adults make seasonal migrations to and from breeding wetlands over late winter and spring, and as metamorphosed juveniles emerge and disperse over the summer and fall. On the coast, where temperatures are mild, the active period for amphibians can extend from as early as February to as late as November (e.g., Beasley 2006, Wind 2014); the active period is shorter in other parts of the province (e.g., Crosby 2014; see Table 1). Hatchling turtles are killed as they disperse from nests in spring (beginning in March) and adult female turtles are killed in summer (June to July) when they leave the water and seek terrestrial nesting sites (Engelsoft et al. 2011, Killburn et al. 2011). Snake road mortality mainly occurs near dens and gullies during the active period (April to October); road mortality is especially high during summer and fall (July to September), when snakes are breeding and returning to hibernacula (Pickard et al. 2009, Winton 2017).

When herpetofauna cross roads, they are extremely vulnerable to being run-over by vehicles for a variety of reasons:

- Most species cannot recognize and avoid the threat of oncoming vehicles (Bouchard et al. 2009).
- Many species are too small for drivers to see and avoid, especially amphibians, which are active at night (Beckmann and Shine 2012, B. Beasley, pers. obs.).

- Turtles, salamanders, and some snakes move very slowly and may immobilize (i.e. "freeze") in response to passing vehicles, increasing their likelihood of being killed (Aresco 2005, Mazzerolle et al. 2005, Andrews and Gibbons 2005). For example, Gophersnakes use slower rectilinear movement (versus fast sinusoidal movement) in open areas such as roads, possibly to avoid detection by avian predators (M. Sarell, pers. obs).
- Amphibians will linger on roads after rains in order to readily absorb water through their more permeable ventral skin.
- Snakes and toads can be attracted to paved roads for thermoregulation, lingering on the warm surfaces in order to raise their body temperature, thereby increasing the time they are at risk of being run over (Waye and Shewchuk 2002, Wind 2018).
- Some drivers deliberately run over reptiles. Ashley et al. (2007) reported that 2.7% of motorists in their study in Long Point, Ontario intentionally hit snakes and other reptiles on the road. Drivers have been observed deliberately targeting snakes in B.C. as well (M. Sarell, pers. obs.).

Species that move shorter distances or move less frequently are less prone to road mortality (Carr and Fahrig 2001). There are several species in B.C. that are infrequently found dead on roads (see Appendix B). Terrestrial-breeding salamanders, tailed frogs, lizards, and some small snakes, including Sharp-tailed Snake (*Contia tenuis*), have small home ranges and are therefore less likely to encounter roads unless roads bisect their prime habitats. Unfortunately, the few individuals that are killed on roads are potentially dispersing to other populations, and are therefore especially important for maintaining genetic diversity across populations.

2.1.4 Attraction to Roadside Habitat

Roads and roadside habitats often attract amphibians and reptiles to their detriment. For example, turtles nest in gravel substrates on road shoulders (Evelyn 2018); frogs and salamanders breed in warm, shallow water in roadside ditches and stormwater ponds (Ostergaard et al. 2008, Karraker and Gibbs 2011); some snakes and toads bask on roadsides for thermoregulation (Waye and Sewchuk 2002, Andrews et al. 2008, Crosby 2014, Wind 2018); Great Basin Spadefoots in B.C.'s arid interior have been observed hydrating themselves in puddles that form on roads after rain (P. Govindarajulu, pers. obs.); Western Toads have been observed on roads eating earthworms, which can be numerous on rainy nights (J. Dulisse, pers. obs.); and frogs are known to be attracted to road surfaces with streetlights where insect prey are abundant (Perry et al. 2008, Davies et al. 2012). Some species may also use roads as travel corridors.

Roadside habitats may be of poor quality in many ways:

- Increased exposure to traffic increases chances of mortality from vehicles and maintenance equipment (e.g., mowing).
- Contaminants from the road, such as de-icing salts and dust control agents, accumulate in roadside ponds and lower the survival of eggs and larvae of some species (Sanzo and Hecnar 2006, Karraker 2008, Collins and Russell 2008).
- Roadside ponds and ditches may have short hydroperiods that leave egg masses and larvae desiccated when water recedes (Ostergaard et al. 2008).
- Traffic noise can disrupt choruses of breeding frogs (Nelson et al. 2017).
- Artificial light may interfere with navigational cues and the visual capabilities of some species (Perry et al. 2008).

Studies show considerable variation in the quality of roadside ponds; some potentially provide source habitat while others act as sink habitats or ecological traps (McCarthy and Lathrop 2011, Le Viol et al. 2012, Gallagher et al. 2014). Source habitat produces a large enough number of juveniles to that survive and increase adult populations, while sink habitats and ecological traps attract breeding adults but do not produce sufficient juveniles to contribute to overall population stability or increase. Researchers suggest that roadside stormwater ponds may provide source habitat, especially in areas where natural wetlands are scarce, but caution that further study and management is needed to prevent them from becoming traps (Le Viol et al. 2012). For example, Karraker and Gibbs (2011) found that Spotted Salamander (*Ambystoma maculatum*) egg masses were smaller near roads than away from roads. Additionally, they found that road mortality shifted breeding populations toward smaller, younger individuals with lower reproductive capacity.

2.2 Long-term Impacts of Roads to Populations

Populations of amphibians and reptiles have been known to decline as a result of road mortality and population isolation (Aresco 2005, Eigenbrod et al. 2008a, Fahrig and Rytwinski 2009). Such declines usually take years to detect (Marsh and Jaeger 2015). Aquatic breeding amphibian species typically experience large annual fluctuations in population size, so long-term data collection over at least ten years is needed to detect a trend (Pechmann et al. 1991). Similarly, it can take time to see a cumulative effect where annual mortality of reptiles is low (Pike et al. 2008). Findlay and Bourdages (2000) detected road-related losses in amphibians and reptiles in Ontario decades after roads were built.

Modelling can be used to forecast the effects of road mortality on populations. Models require information about the probability of survival and reproduction, and the average number of offspring produced (i.e., fecundity) in a population that experiences road mortality. This information is used to calculate whether the population size will change over time.

Examples of Population Models that Estimate the Impacts of Road Mortality

- Northern Red-legged Frogs (*Rana aurora*) along Highway 99 at Pinecrest, B.C., experienced a high rate of mortality because the highway bisected important wetland habitats. A population model predicted a high probability of local extinction within 40 years given the observed rate of 16-28% road mortality per year (Malt 2012).
- A model was used to assess the effects of road mortality on Blotched Tiger Salamanders (*Ambystoma mavortium*) at White Lake, BC, based on 240 road killed juveniles in 2013 and an estimate that 7200 young were produced in 1997. The model indicated that the population would be able to sustain the annual loss of juveniles. However, the road mortality of only a few breeding females when population numbers were low, could quickly lead to a population decline (Southern Interior Reptile and Amphibian Working Group 2016; Dyer 2018).
- Row et al. (2007) modeled the effects of roads on Black Ratsnakes (*Elaphe obsoleta*) in Ontario and predicted that the probability of extinction of the population would rise from 7.3% to 99% over 500 years (based on only 0.026 deaths per crossing), illustrating the long-term effects of sustained, low rates of road mortality on a species with low reproductive output (fecundity).
- Winton (2018) used detailed population viability analysis (PVA) paired with refined road mortality estimates to evaluate the persistence of a Western Rattlesnake (*Crotalus oreganus*) population threatened by road mortality at White Lake, BC. Overall, an estimated 6.6% of the population was killed on the road annually and the PVA indicated that although the population was likely to persist for the next 100 years, it would be in continual decline as a result of road mortality. Any increases in road mortality rates resulted in increased probability of extinction.

Modelling can be used to forecast the effects of road mortality on populations. Models require information about the probability of survival and reproduction, and the average number of offspring produced (i.e., fecundity) in a population that experiences road mortality. This information is used to calculate how the population size will change over time based on different levels of mortality of various life-stages on the road. Models show that population declines vary among species and is based on the species behaviour or life-history traits that increase exposure to traffic, the proportion and life-stage of the population that encounters traffic, traffic volumes, and the ability of the population to sustain high rates of mortality (Marsh and Jaeger 2015).

Species behavioural traits that increase exposure to traffic include:

- frequent long-distance movements (i.e., most individuals in the population make daily movements, migrate, and/or disperse, versus being sedentary or territorial);
- attraction to habitats on or near roads; and
- slow road-crossing speed.

Road and landscape conditions that result in high road and traffic encounter rates include:

- high road density within home ranges;
- roads (low/moderate/high traffic volume) that intersect migratory or dispersal paths;
- roads (low/moderate/high traffic volume) that are immediately adjacent to important habitats (e.g., dens or breeding ponds); and
- consistently high volumes of traffic.

Traits of species most vulnerable to ongoing or high rates of mortality include:

- low fecundity and long generation times (long life spans and late sexual maturity), as among turtles and snakes;
- small population sizes, such as naturally/currently rare or endangered species (e.g., Sharp-tailed Snakes and Nightsnakes);
- populations that fluctuate and experience periods of low population numbers (e.g., tiger salamanders during long-term drought);
- sex-specific behaviour or life-history traits that cause adult females to be particularly vulnerable to road mortality (e.g., females may migrate longer distances than males)—the loss of reproductive females is more significant for population persistence than the loss of males or juveniles (Photo x);
- isolated populations; and
- populations within which reduced competition for resources does not cause a rebound in population size (i.e., road kill is not like a “sustainable harvest” that is compensated by higher survival and / or reproductive rates among the survivors, or by immigration).

Photo x. Traffic kills female Western Pond Turtles more than males because females make overland movements to nesting areas.

2.3 Impacts of an Expanding Road Network and Increased Traffic in the Future

Between 2000 and 2005, the amount of paved and unpaved roads in B.C. increased by 23%, from an estimated 570,000 km to 702,574 km (Austin et al. 2008). Road expansion has been low since then, and was estimated at 719,000 km in 2018 (Environmental Reporting B.C. 2018). As human populations grow, and as development and resource extraction continues, there will be further increases in traffic volume and pressure for road expansions and repair. B.C.'s population increased by 56% from 1986 to 2015 (B.C. Environmental Indicators), and it is expected to grow to nearly 6 million people by 2031 (Austin et al. 2008). These population projections are important to consider because even if there are no new roads constructed, traffic volumes on existing roads may increase with increasing population density and therefore increase road impacts on amphibians and reptiles.

> ***What is a Cumulative Effect?***
> The Government of British Columbia defines cumulative effect as "Changes to environmental [or other] values caused by the combined effect of past, present and potential future human activities and natural processes." The legacy and ongoing impacts of existing roads combine with the impacts of new road construction and present and future road maintenance to produce cumulative effects that amplify detrimental changes to herpetofauna population health and biodiversity in BC. Therefore, it is important to assess and manage cumulative effects when mitigating the impacts of road management activities on herpetofauna.
>
> (Reference: Government of B.C. 2016)

Herpetofauna in BC are likely to be differentially impacted by paved and unpaved roads; however, there are no known studies to quantify the differences. Paved and unpaved roads may present similar levels of habitat loss and degradation, barriers to movement, and attraction of amphibians and reptiles to poor roadside habitats. Nevertheless, road mortality for many species is likely to be higher on paved, multi-lane highways than smaller paved and unpaved roads because the number of animals killed increases with traffic volume for most species (Fahrig et al. 1995, Mazzerolle et al. 2004, Gibbs and Shriver 2002, Jochimsen 2004). In the case of forestry roads and other unpaved resource roads, effects may be temporary, as these roads may be decommissioned to reduce their long-term impacts.

2.4 Impact of Ongoing Road Maintenance Activities

In addition to the construction of new roads and upgrades to existing roads, roads need to be maintained in order for them to be safe and accessible. The cumulative impacts of mandatory road maintenance activities on herpetofauna can be significant because they are continuous in nature and occur across the entire road network. A number of road maintenance activities can have direct (e.g., mortality) or indirect (e.g., habitat loss/degradation) impacts on amphibians and reptiles. Ongoing road maintenance activities may disproportionately impact amphibians and turtles, which are often found breeding in habitats adjacent to roads.

2.4.1 Road Surface Maintenance

Various chemicals are used to suppress dust and stabilize the base of the road surface. The chemicals commonly used for this purpose are calcium chloride and magnesium chloride, although in some cases water or water mixed with oil or other agents can be used (B.C. MOTI 2019, USDA n.d.). The larvae of some aquatic-breeding amphibians experience

> ***Road placement within the surrounding landscape is one of the most important factors determining the severity of road impacts on amphibians and reptiles.***
>
> (Andrews et al. 2008)

reduced survivorship when exposed to these chloride-based chemicals (Dougherty and Smith 2006, Harless et al. 2011). The effect of these chemicals on reptiles is not well understood but impacts may occur for species that spend a significant amount of time in the water (e.g., turtles).

The objective of snow removal and ice control practices are to remove winter accumulations from roadside, overhead, and pedestrian-accessed infrastructure, and to restore traction. Anti-icing, de-icing, and/or pre-wetting materials are used for this purpose. Inputs of melt water carrying these chloride-based chemicals contaminate roadside aquatic habitat with sand, salt, and chemicals; amphibian larvae that are exposed experience reduced survivorship (Dougherty and Smith 2006, Collins and Russell 2009, Harless et al. 2011). Disposal of accumulated snow into roadside aquatic habitats used by amphibians for breeding may cause delayed breeding due to cold water temperatures. Temporary wildlife fencing can also be crushed by snow plows or damaged under the weight of snow piles.

Chloride Contamination from Dust Control and Road De-Icers (extracted from Copan 2016)

Canada applies 5 million tonnes of road salts annually (Environment Canada 2012). Chlorides are commonly used in de-icing agents due to their low price and abundance. Of these, sodium chloride (NaCl) is the most frequently used. Some chlorides, such as magnesium chloride flakes (MgCl), are used for both road de-icing and dust control.

Ecologists consider the application of chlorides to roads to be one of the leading anthropogenic factors affecting amphibians in northern climates (Environment Canada 2001, Environment Canada 2012). Amphibian species that breed early in the year are subject to the highest toxicity levels of road de-icers because their breeding season coincides with ice and snow melt (Collins and Russell 2009, Helmreich et al. 2010). In addition to direct impacts, the use of chlorides along roadways could affect the distribution of amphibians within the landscape. For example, Karraker et al. (2008) found that Spotted Salamander and Wood Frog egg mass density declined significantly with proximity to roads, with increased salinity having a small but detectable negative influence on egg mass density.

Environment Canada (2012) released a Code of Practice in response to concerns over road de-icers. The code seeks to regulate the use of salt-based de-icers, as well as to promote the use of "green" alternatives, such as urea, formates, and acetates, that are considered more environmentally friendly than the road salts currently used (Environment Canada 2012). However, some of these alternatives also have issues or limitations (e.g., some cannot be applied at low temperatures and/or have corrosive effects on concrete and metals, etc.). Calcium-magnesium acetate (CMA) is of interest as an alternative de-icer because it has relatively low toxicity and is non-corrosive. However, it depletes oxygen levels in aquatic systems as it breaks down, which can be harmful to aquatic life, such as developing amphibians. Also, it is considered to be less effective and requires more frequent applications (approximately 1.2-1.6 times more) when applied alone to achieve the same results as sodium chloride (Manning and Crowder 1989, Transportation Research Board 1991). Its primary use currently is to supplement salt-based de-icers (Fay and Shi 2012).

Copan (2016) compared acute toxicities of a traditional road de-icing chloride agent (NaCl) to a non-chloride alternative (CMA). She found that acute exposure to ecologically relevant levels of NaCl was detrimental to the survival of Wood Frog tadpoles. The 96 hour LC50 values for tadpoles (the concentration that causes tadpole mortality after 96 hours of exposure) ranged from 85.77 mg/L to 1406.96 mg/L depending on the tadpole's site of origin and developmental stage. This response is concerning, given that Environment Canada (2001) reported higher chloride concentrations for ponds within 50 metres of roadsides, with many exceeding 4000 mg/L. In comparison, the 96 hour LC50 values for CMA toxicity was 2588.45 mg/L for Wood Frog tadpoles in aerated tanks, and 465.17 mg/L in non-aerated tanks. These values fall outside the typical 10-100 mg/L range of CMA found within roadside ponds and wetlands (Horner 1988, Transportation Research Board 1991); however, direct sampling of road runoff has been known to yield concentrations as high as 5000 mg/L (Horner, 1988; Transportation Research Board, 1991).

INSERT IMAGE OF DUST CONTROL APPLICATION BESIDE WETLAND HABITAT

Roads are cleaned periodically to remove debris such as pieces of tire, discarded auto parts, and other debris. Disposal of this debris on the side of the road could contribute to water contamination, destroy habitat structures, or affect the structural integrity of mitigation structures such as guiding fences for crossing structures.

2.4.2 Drainage Maintenance

The objective of drainage maintenance is to provide effective drainage on and along road surfaces for driver safety and to protect roads and supporting infrastructure from erosion. Maintenance work in and along ditches containing water, and removal of obstructions such as beaver dams, may strand eggs and impact larval amphibians. Direct impacts may come from machinery use, while indirect impacts may relate to changes in hydrology, such as a drop in water levels that strands eggs or larvae. Amphibians can be inadvertently captured in the spoil during roadside ditch cleanout work where standing water occurs.

Shore, bank, and watercourse maintenance is carried out to prevent scour and erosion damage to roadways at shores and banks of watercourses. Debris and potential obstructions that threaten to damage highways, which may be a considerable distance upstream or downstream, are removed. This could inadvertently affect amphibians if the obstructions had created pooled water ideal for amphibian breeding. Removal of these obstructions when amphibian eggs and larvae are present could result in stranding if the removal of obstructions results in water draining, or the animals being washed away if removal of the obstruction results in high flow volumes. In some cases, rip-rap is installed to prevent water flow over road surfaces or to stabilize the shoreline. Depending on the size of the rip-rap boulders, these installations could act as barriers to movement of amphibians and turtles.

2.4.3 Vegetation Maintenance on Roadsides

The objective of vegetation control is to improve visibility for road users and facilitate drainage. This relatively exposed, open habitat with shorter vegetation may attract certain amphibian and reptile species, inadvertently putting them at risk of predation and road mortality. Vegetation maintenance activities, such as mowing, can lead to direct mortality of amphibians and reptiles occupying the shoulder environment, especially during periods of migration. In addition, if mowers and other machinery are not properly cleaned between sites, it could result in invasive plants and diseases agents (e.g., *Batrachochytrium dendrobatidis*, ranavirus) being introduced to new habitats or wetlands, causing degradation of habitat for amphibians and reptiles. In some cases, herbicides may need to be used to control vegetative growth. Some of these herbicides are known to be hazardous to amphibians and reptiles.

Wildlife fencing, including fencing to direct amphibians and reptiles towards a safe crossing structure, has been installed along some stretches of highways and other paved roads in BC. The mowers and weed snippers used for vegetation control can damage these fences by inadvertently slashing them, creating gaps in the fencing. Amphibians and reptiles can escape through these gaps and end up on the road surface, where they are again at risk of road mortality.

3.0 SCREENING TOOL – ASSESSING PROJECT-SPECIFIC LEVEL WITHIN THE MITIGATION HEIRARCHY

The Government of British Columbia's ***Procedures for Mitigating Impacts on Environmental Values*** (2014) establishes the mitigation hierarchy to guide development and application of measures to mitigate impacts on environmental values and associated components. The levels of the mitigation

hierarchy are: (1) Avoid, (2) minimize, (3) restore on site, and (4) off-set. Although set out as a hierarchy with the expectation that all feasible measures at one level are considered before moving to the next, in practice, the levels within the mitigation hierarchy will often be considered as a whole. The feasibility of measures at each step of the hierarchy should be considered iteratively to reach the most cost-effective solution to achieve maximum ecological benefit.

This screening tool enables the gathering of information and assessment of the first three levels of the mitigation hierarchy. The screening process may be used as a decision support tool that makes the process by which the final decision was made transparent and defendable. **The expectation is that the screening tool will be used primarily by the QPs advising proponents on the project**, to gather and evaluate the scientific information necessary to provide the rationale for the required mitigation level for amphibians and reptiles in the project area. The screening tool may also help QPs communicate the necessity of mitigation measures for herpetofauna in the project area to road engineers and planners. The screening tool can be applied for one-time projects, such as road construction and expansion, as well as for regular road maintenance activities.

The Screening Tool and Mitigation Planning process are outlined in Figure 2. The results generated from the Screening Tool will guide proponents and their QPs to activity-specific guidelines in sections 4, 5, and 6.

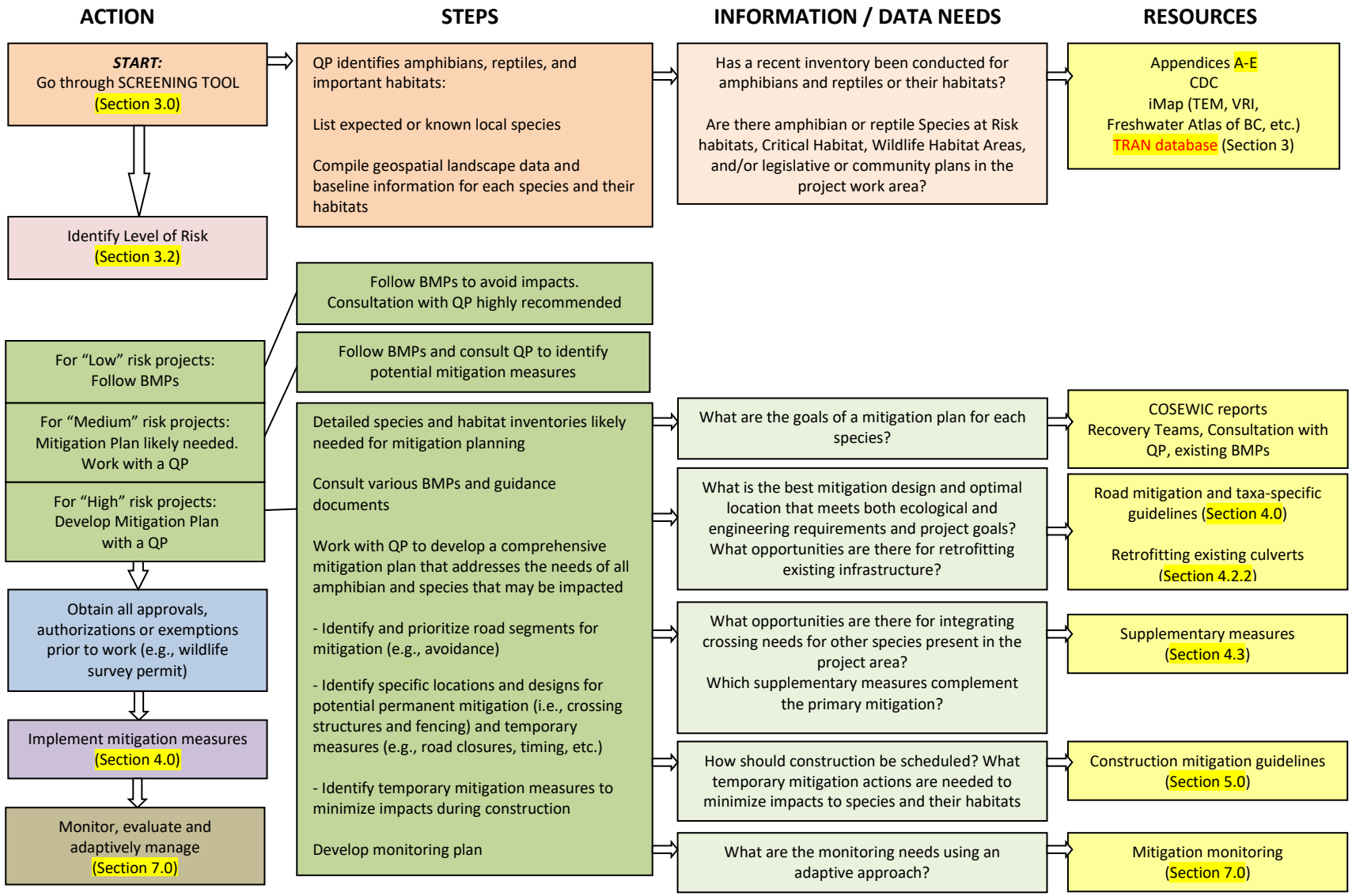


Figure 2. Flowchart summarizing the use of the Screening Tool and the development of a mitigation plan for road projects.

3.1 Step 1: Identify the assessment area

To identify whether amphibians and reptiles may be impacted by a project, it is necessary to identify the boundaries of the assessment area. This area needs to include the ***project footprint*** (physical works required; construction area) as well as the ***area of influence*** of the project on the target species (e.g., important habitats such as dens or breeding sites, movement corridors, and movement distances of amphibians and reptiles). Consideration of the impacts on amphibians and reptiles at local and landscape levels is a vital component of effective mitigation planning for transportation projects (Semlitsch 2008). Animals move within habitats to access resources (local scale), and move between habitats during migration (e.g., to breeding or overwintering habitat) and dispersal (landscape scale).

BC's amphibian and reptile species vary in their home range size and dispersal distances (Appendix D). Examples of highly mobile species in BC include Western Toads, which have been tracked dispersing over 7 km in less than 24 hours during spring migration on Vancouver Island (Davis, unpubl. data cited in COSEWIC 2012d), and Western Rattlesnakes, which have been tracked moving over 3.5 km between summer foraging areas and overwintering dens (Gomez et al. 2015). Western Painted Turtles have been recorded travelling a straight-line distance of 2 km in the Lower Mainland, traversing four sloughs and ending at a small wetland (Kilburn and Mitchell 2011). It is important to consider road placement early in the planning stages of all new developments, so that they can be placed where they pose the least risk of road mortality and isolation of habitat.

Identification of the area of influence is not as straightforward as for the project footprint. In order to determine the area of influence of the project on amphibians and reptiles, first identify the local species and important habitats that may occur within 3 km of the project footprint (or further, when highly mobile species are recorded in the area). This value is based on recorded movement distances of amphibians and reptiles away from dens, breeding sites, and hibernacula in BC or the Pacific Northwest (see Appendix D). For road maintenance activities, the area of influence will be the area directly impacted by the action (e.g., road surface and shoulders, roadside mowing swath) and also the adjacent area that might be indirectly impacted by that action (e.g., roadside ditches and wetlands that may be impacted by runoff of dust control and de-icing chemicals, herbicides, or sediment, or whose hydrology may be affected by drainage maintenance activities).

3.1.1 Identify and map species up to 3 km away from your project footprint boundary

A. Using Appendix A, identify which species are likely to occur within the project footprint. Include confirmed or potential non-native species in order to factor them into the salvage/management plan (i.e., where details of humane euthanasia of American Bullfrogs, Green Frogs, and Pond Slider turtles may be needed).

B. Further refine your species list by consulting the government databases listed below to identify known and potential amphibian and reptile occurrences and important habitats in the project area. Refer to section 3.1.3, below, for project areas where few to no species records are included in government databases.

iMapBC

1) Go to https://maps.gov.bc.ca/ess/hm/imap4m/
2) Select the tab titled "Data Sources"
3) Click "Add Provincial Layers"
4) Select "Fish Wildlife and Plant Species", under which you should search within the following data sources:
    - BC Frogwatch Amphibians (Select all species in your region, based on Appendix A)
    - BC Frogwatch Reptiles
    - BC Frogwatch Turtles
    - Species and Ecosystems at Risk – Publicly Available Occurrences – Conservation Data Centre (includes publicly available data and masked secured data – see below)
    - Wildlife Species Inventory – Incidental Observation Points – Nonsensitive
        - WSI- IO – Reptiles and Amphibians – Nonsensitive
    - Wildlife Species Inventory – Survey Observation Points – Nonsensitive
        - WSI- IO – Reptiles and Amphibians – Nonsensitive
    - Telemetry Observation Points – Nonsensitive
        - WSI- TO – Gopher Snake - Nonsensitive

Note: Shapefiles can be requested from iMapBC (e.g., for use in ArcMap).

Data-sensitive species and ecosystems

Occurrence data are not made publicly available for elements that are considered "sensitive" (e.g., species at risk, den sites, hibernacula), and are masked (buffered) in the iMapBC and CDC sites (i.e., presented as a polygon). This is to protect species from persecution or harm, for proprietary reasons, or to protect government interests. However, secured records are released on a need-to-know basis if a project location overlaps a secured element occurrence and the details of the element occurrence are relevant to decision making. If the species of interest is included in the list of Species and Ecosystems Susceptible to Persecution or Harm, or if the mapping exercise above reveals the occurrence of masked secured data in your area of assessment, contact the Conservation Data Centre or Species Information Database (sometimes referred to as the Wildlife Species Inventory) using the information below; include your reasons for requiring the data, details related to project/activities, and the precise area of interest:

- All Wildlife (including Species at Risk and WHA): SPI_Mail@gov.bc.ca
- Species and Ecosystems at Risk: cdcdata@gov.bc.ca/250-356-0928

An online training module must be completed, and a Confidentiality and Non-Reproduction Agreement signed and submitted by all personnel that will have access to the data before secure data can be released. For more information on this process, consult the Species and Ecosystems Secure Data and Information Procedures.

Example of How to Further Refine Your Species List:
Appendix A provides a species list for each region in the province. Additional information may be gleaned from Biogeoclimatic Zones (BEC zones) and elevations within 3 km of the project area. Species accounts can help determine if the project is likely within the habitat range for the initial species list from Appendix A. For example, looking at the snake species listed in Appendix A for Region 3, if the road project is situated in the Montane Spruce between 1100-1400 m elevation, species account information states that some snake species are possible but less likely and that the project is likely above any hibernacula. In that scenario, you are likely only dealing with possible summer habitat for snakes.

3.1.2. Identify and map habitat in your project area

Use Appendix C and the government databases listed below to identify and map important habitats for the amphibian and reptile species in your region/project area, such as breeding and hibernation sites, and corridors that connect important habitats (e.g., streams connecting forest patches, forests and meadows connected to wetlands, etc.; see Section 4.1.1). In BC, important habitats for amphibians and reptiles include, but are not limited to:

- Old/mature forest stands and patches (e.g., terrestrial salamanders)
- Grasslands/shrub-steppe (e.g., snakes, tiger salamanders, spadefoots)
- Streams and creeks and associated riparian areas (e.g., tailed frogs, giant salamanders)
- Rock outcrops (e.g., snakes, lizards)
- Talus slopes (e.g., snakes, lizards)
- Small, ephemeral (temporary) ponds and surrounding upland areas (e.g., aquatic-breeding amphibians)
- Wetlands and lakes and associated riparian areas (e.g., turtles, aquatic-breeding amphibians)

Habitat databases and other habitat resources:

1) **iMapBC** (See Appendix F for instructions):
    - **Critical Habitat** for Federally-Listed Species at Risk – Posted;
      For the most up-to-date information, mapped **Critical Habitat** (proposed and approved) for federal species at risk that occur in BC can also be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en
    - **Wildlife Habitat Areas** – Approved, Proposed, and FRPA
    - **Terrestrial Ecosystem Mapping** (TEM)
    - **Vegetation Resources Inventory** (VRI)
    - **BC Freshwater Atlas**

2) Government of Canada **Species at Risk Public Registry** has links to up-to-date **Status Reports and Recovery Strategies**, including a description of critical habitat.
3) **BC Species and Ecosystem Explorer**:
    - Provides reports and detailed information on the annual habitats utilized by each species in BC.
4) **B.C. Species at Risk Recovery Planning** documents
5) Existing **models** for amphibians and reptiles, for example:
    - Okanagan (using TEM) - Warman et al. 1998 (updated version available)
    - Merritt Forest District (using VRI) - completed by Keystone for the Nicola Valley Innovative Forestry Society (2008)

    For more information, visit https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-habitats/wildlife-habitat-mapping or contact:
    Calvin Tolkamp
    Ecosystem Information Section (ECOINFO)
    Phone: 778-698-4018
    Email: Calvin.Tolkamp@gov.bc.ca

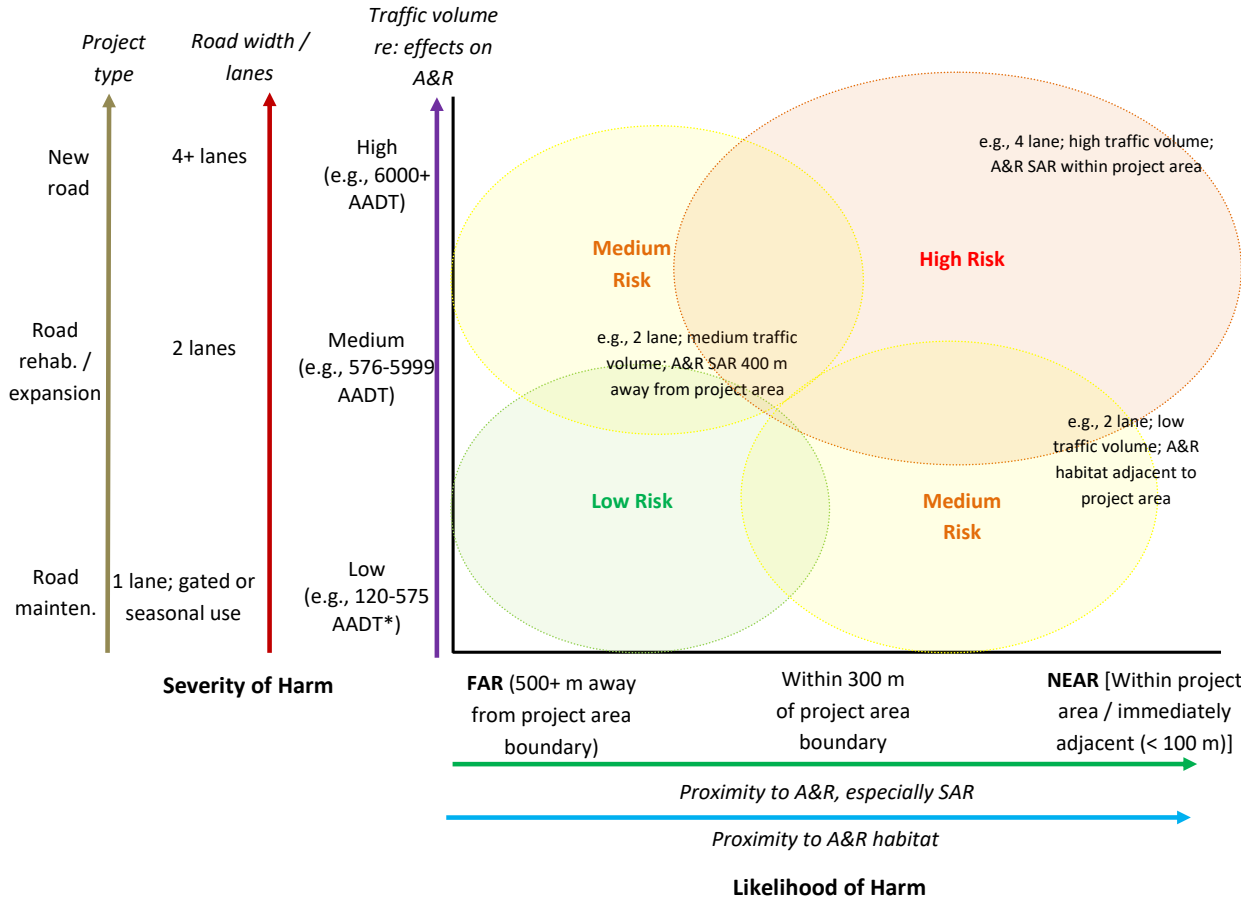
Provincial databases of amphibian and reptile occurrences provide a critical first step for assessing potential impacts. Unfortunately, for most herpetofauna species, existing data is rarely adequate to develop effective mitigation. It may be necessary for additional baseline data to be obtained by a qualified professional biologist (QP) to meet provincial and federal environmental mitigation standards.

3.1.3 Inventory species and habitats in your project area

Do not consider the lack of records for a certain species as evidence that it is not present. If there is no information in the databases listed above, a field inventory by a qualified professional biologist (a QP with previous experience working with the species of interest) is necessary to confirm whether amphibian or reptile species or their habitats are present. This is especially if the project area is located within the range and habitat of amphibian and reptile species at risk for which roads have been identified as a threat in assessment and recovery documents. A field inventory may not be necessary if recent and appropriate surveys indicate no amphibian or reptile species have been detected in the area. "Recent" is suggested to be within the past five years and is based on average lifespan of many herpetofauna. An "appropriate" survey is defined as one that follows provincial inventory guidelines (e.g., Resources Information Standards Committee (RISC) standards) in terms of the appropriate survey season(s), sampling techniques, and level of effort for the expected species in the area (Appendix A). Surveys conducted within the project footprint and area of influence would be the most appropriate based on average home ranges and dispersal distances of herpetofauna.

3.2 Step 2: Identify the Impacts - Risk Assessment

For the purposes of this document, **risk** is defined as exposure to harm. The level of risk that a road project poses to amphibians and reptiles is influenced by two main components: (1) *likelihood of harm*, determined by the proximity of the project/road to amphibian and reptile species (especially species at risk), and/or their habitats; and (2) *severity of harm*, which considers short-term (determined by factors such as timing and duration of construction; e.g., road maintenance) and long-term (determined by factors such as road width/number of lanes and traffic volume; e.g., new road construction) impacts. Severity of harm for amphibians and reptiles in relation to roads is influenced by:



- **Project type:** Some projects result in habitat loss or degradation in addition to risk of collision/mortality (e.g. new road construction).
- **Road width**: Wider roads expose crossing individuals to greater risk compared to narrower roads and may be a movement barrier for some species; potential traffic volume increases with the number of lanes.
- **Traffic volume**: Traffic volume can affect the density of local frog and toad populations, especially when amphibian and reptile migration/active periods coincide with peak traffic times daily or seasonally (e.g., in spring, summer, and / or after sunset).

Figure 3 provides an understanding of the many factors that act together to determine the relative level of risk that a project poses to local amphibian and reptile populations.

Traffic Volume/Intensity

Traffic volume is considered the most significant risk factor for wildlife along roads (Charry and Jones 2009). Fahrig et al. (1995) found fewer live and dead frogs and toads (anurans), a higher proportion of dead anurans, and reduced anuran density (as measured by breeding chorus intensity) with increasing traffic intensity along two 2-lane roads near Ottawa, Ontario. Estimates of the potential effect of traffic volume on amphibians and reptiles should consider differences on both a daily and seasonal basis, as most amphibians and reptiles are most active in spring and summer and at night.

* AADT = Average Annual Daily Traffic; based on data compiled by Charry and Jones 2009 relating traffic volume to impacts on amphibians and reptiles. Note: Estimates of traffic volumes in spring and summer would be more accurate in terms of their impacts on amphibians and reptiles.

Figure 3. Relative level of risk posed by a road project for amphibians and reptiles based on likelihood of harm and severity of harm.

It should be noted that the need for action is not determined by risk of the project alone but also by vulnerability of the affected species/population, which may be increased by cumulative effects of other road management activities, other human activities (e.g., resource extraction, development), and natural processes (e.g., disease). Endangered species/populations might trigger mitigation measures even from low-risk projects, while mitigation may be minimal for medium-risk projects when species/populations are stable. The mitigation effort required must be judged at a project-specific level taking both risk and species vulnerability into consideration.

ACTIONS associated with relative level of risk:

- **High Risk – Mitigation is necessary**
    1. Conduct further species and habitat inventories, if necessary, at a fine scale (e.g., field surveys) to determine exactly where mitigation is required.
    2. Consult BMPs for guidance: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/best-management-practices.
    3. Develop mitigation and follow-up monitoring plans in consultation with a QP with appropriate species and local experience.
        - Provincial guidelines for mitigation planning can be found at: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/policy-legislation/environmental-mitigation-policy.
- **Medium Risk – Some mitigation is likely necessary**
    - Consult BMPs and, if necessary, additional experts and QPs to identify need and extent of potential mitigation measures.
- **Low Risk – Minimal mitigation required**
    - Consult BMPs and, if necessary, additional experts and QPs to avoid and/or reduce impacts.

3.3 Step 3: Avoid

Regardless of the assessed risk, due to the sensitivity of herpetofauna to roads, avoidance is the most effective mitigation approach and should always be considered. Information and assessments from Step 1 and 2 can be used to follow the provincial guidelines for mitigation planning, with avoidance being the first step in the mitigation hierarchy.

The most effective conservation strategy for protecting wildlife, including amphibians, reptiles, and their habitats, is to avoid impacts. Impacts can be avoided either spatially or temporally or by using both strategies. Spatial avoidance includes not working in important habitats and travel

Avoidance Challenges

Although measures can be taken to avoid important terrestrial habitats, such as known or potential hibernacula/dens, the locations of these important habitats are largely unknown. As such, project managers should be aware that construction or maintenance work that involves removing or disturbing ground cover (e.g., large downed wood, stump, or rock removal), could uncover hibernating amphibians and reptiles (e.g., snake dens). See guidelines below for actions required under this scenario.

corridors. Temporal avoidance includes conducting work during periods when the animals are less vulnerable (e.g., not clustered at den sites or breeding ponds). Avoidance is often more feasible when amphibians and reptiles are considered early in the planning process (see Section 3.0).

For new road projects, overlay the proposed road location with the spatial data on species occurrences and habitats collected in Step 1. Where possible, alter the alignment to avoid known occurrence records and important habitat features, such as wetlands, rock outcrops, and talus slopes. Ideally, allow a buffer of at least 300 m from these important habitat features. Spatial avoidance may be much more challenging for road improvement projects, such as road widening, creation of medians, and installation of shoulder barriers. In these cases, temporal avoidance may be considered during the project. Road improvement projects may offer a valuable opportunity to retrofit mitigation measures where significant amphibian and reptile migration and dispersal routes have been identified (e.g., where occupied breeding sites or dens occur near the road alignment).

When possible, road maintenance and rehabilitation activities, such as culvert or bridge improvements/replacements/removals, repaving, ditch cleaning, and other maintenance activities, should be avoided at times of the year when herpetofauna are clustered at important habitat features (e.g., when reptiles are at hibernation sites or when amphibians are congregated at breeding ponds; Table 1). When impacts are unavoidable, appropriate mitigation measures should be incorporated into the project design.

Table 1. The general active/sensitive periods for amphibians and reptiles in BC. *Note:* The timing of life history phases is species- and region-specific, varies annually, and must be confirmed with a QP.

Amphibian & Reptile Group	**Breeding / Active Period (Sensitive)**	**Migratory / Active Period (Sensitive)**	**Relatively Inactive Period (Hibernation, summer inactivity)**
Terrestrial Salamanders	Spring and Fall (e.g., Feb–June; Sept –Nov)	Not applicable	Winter; Summer (on land/subsurface) (e.g., Dec–Jan; Jun–Aug)
Pond-breeding Amphibians	Later winter/spring (e.g., Jan–May on the south coast; Apr–June in the interior and north)	(1) Late winter/Spring and Fall (e.g., Oct–June on the south coast; Mar–May in the interior and north) (2) Late summer/Fall (metamorphs disperse; e.g., June–Sept, or later in interior)	Fall/Winter (some on land/subsurface, some underwater) (e.g., Nov–Jan on the south coast; Oct–Mar in the interior and north)
Stream-breeding Amphibians	Summer (e.g., June)	N/A	Fall/Winter (in water and riparian areas)

			(e.g., Oct–Feb)
Turtles	Spring–Summer (females nesting) (e.g., May–July)	Spring–Fall (e.g., March–Oct)	Fall/Winter (underwater) (e.g., Oct–Feb)
Snakes and Lizards	Summer (July)	Spring, Summer, and Fall (e.g., Apr–Oct)	Fall/Winter (on land/subsurface) (e.g., Oct–Mar)

3.4 Step 4: Minimize and restore on site using BMPs and expert advice

If the project cannot avoid all impacts to amphibians and reptiles or their habitats, seek expert advice to develop a mitigation plan and implement the guidelines below for minimizing impacts, restoring habitat on-site, and where necessary, offsetting. Where complete mitigation cannot be implemented (i.e., avoid, minimize, restore on-site), offsetting is recommended by the B.C. Environmental Mitigation Procedures (B.C. MOE 2014). This may include the restoration or creation of habitat outside of the project area, such as wetland or den construction in an area occupied by a species at risk. Additional monitoring and adaptive management requirements may be included in project-specific plans.

In addition to the guidelines below, the B.C. Environmental Mitigation Procedures, the Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia, and the Best Management Practices for Amphibian and Reptile Salvages in British Columbia provide a good foundation for developing a mitigation plan.

4.0 GUIDANCE FOR MITIGATION PLANNING AND DESIGN

Where the results of the risk assessment conducted as part of the Screening Tool indicate “high-risk” or “medium-risk” then planning for mitigation measures becomes necessary. A fully developed mitigation plan is necessary in the case of “high-risk” projects to design and monitor effective measures to reduce impact on amphibians and reptiles. While a fully developed mitigation plan may not be essential for “medium-risk” projects, assessing opportunities for reducing the impact on amphibians and reptiles is recommended.

4.1 Background information for Developing a Mitigation Plan

The data compiled from the Screening Tool (Section 3.0), in combination with data collected during field inventory work (if applicable), will support the development of an effective mitigation plan, the steps of which are outlined in Figure 2. These data can be compiled into a geographic information system (GIS) that can be overlaid with georeferenced project layers. The following considerations and resources support project planning:

- Consider the local (daily or within-season) and landscape (from season to season between habitats) movement patterns of the species identified to be potentially present in the project area and map these potential movement corridors.
- Consider a multi-species perspective to ensure that a strategy for an individual species does not create unintended negative impacts on other amphibians and reptiles or other wildlife species.
- In the case of larger road projects, the duration of the environmental assessment (EA) process can last for multiple years, especially if there are time lapses between the preliminary assessment, detail design, and construction. This provides opportunities for inventories and

other data collection within the project study area that can better inform mitigation planning and provide important data for post implementation effectiveness monitoring (Before-After-Control-Impact (BACI) design).

- Other useful data that may be available to support project planning include existing and future road network and other infrastructure, such as existing barriers (e.g., median and shoulder barriers) and passageways (e.g., culverts), and adjacent railroads and local or private roads.
- Identifying and considering existing and future land use, status, and ownership may also prove useful while designing a mitigation plan. For example, the condition and ownership of land adjacent to a project may provide opportunities for maintaining connectivity and protective buffers. Most Official Community Plans map environmentally sensitive areas and areas for development at a regional scale. Provincial and Regional Parks, ecological reserves, Wildlife Management Areas, Wildlife Habitat Areas, and other areas designated for conservation are mapped at a provincial scale (see Section 3.0, Step 1 for details).
- Effective communication is also important, from the planning to the implementation phase of mitigation measures. It is important for all individuals involved in construction and maintenance projects, including road crews, to be made aware of the mitigation measures to be implemented for the project (e.g., the need for additional, dry culverts with fencing; the need for fences to be buried properly, without gaps that allow animals to move through to the road). Communicating and coordinating with other jurisdictions (e.g., municipalities and conservation authorities) that own or manage adjacent infrastructure and land is also important.

4.2 Designing crossing structures

Specifically-designed crossing structures (e.g., elevated roads, under- and overpasses) with fencing are often the most effective mitigation strategies to reduce road mortality and enhance habitat connectivity (Dodd et al. 2004, Aresco 2005, Cunnington et al. 2014, Baxter-Gilbert et al. 2015, Rytwinski et al. 2016). This section provides a summary of current knowledge of best crossing structure and fence designs that allow amphibians and reptiles to move between habitats bisected by roads, with an emphasis on BC. Different species preferentially use different types of crossing structures and we are still learning about the requirements of many of BC's species. This document provides the minimum and/or an acceptable range of recommended design specifications (e.g., height, length, and width for crossing tunnels and fencing) based on the best available information. Illustrations, relevant examples, photos, references, and caveats are provided throughout.

It is important to weigh the potential detrimental effects of installing crossing structures and fencing against the benefits. Channelling animals through narrow crossing structures could increase predation pressure (Little et al. 2002) and the transfer of disease. Restricting movements across the landscape with fences could slow the escape of animals from wildfire, introduce invasive plants by disturbing soil, and alter ecological processes that rely on open dispersal (e.g., pollination, decomposition, germination, etc.). Furthermore, any individuals or species that will not use crossing structures are effectively blocked by fencing. Very little research has been done to test these effects. For example, Little et al. (2002) found no studies that specifically examined predation rates in or near crossing structures compared to areas further away; there was only scant anecdotal evidence of predation events at some wildlife passages. Without the science to guide us, careful consideration is needed to decide whether mitigation crossing structures and fencing can be installed in ways that would have minimal detrimental effects that are outweighed by the benefits.

Elevated roads and bridges most effectively mitigate the impacts of roads on amphibians and reptiles for a variety of reasons (see Section 4.3.1). The next best option is to install a series of discrete crossing structures or underpasses, hereafter referred to as tunnels (see Section 4.3.2). Tunnels with associated fencing are the most common form of mitigation and have been applied broadly across BC. Wildlife overpasses that are used to connect habitats for larger wildlife species, such as deer, caribou, and bears, may also be used by amphibians and reptiles (Grift et al. 2009). Certain features that accommodate amphibians and reptiles must be incorporated into wildlife overpasses in places where this kind of multi-species approach is deemed appropriate (see Section 4.3.3).

Crossing structures alone are not sufficient for mitigating road impacts (Schmidt and Zumbach 2008, Rytwinski et al. 2016); they must be used in conjunction with fencing (see Section 4.3.4), which is essential for two purposes: guiding animals to the entranceways of crossing structures and preventing animals from accessing the road surface where they risk being killed. Fencing designs, in combination with crossing structures, must be tailored specifically to the terrain at mitigation sites and to the behaviour and movements of target species (see Section 4.2.5).

The majority of amphibians and reptiles do not naturally want to move through crossing structures. Specific designs and fences are needed to guide (encourage) them to move through these structures.

Installation of crossing structures and fencing during new road construction provides the greatest opportunity for creating functional passages because roads can often be designed to accommodate the recommended sizes of crossing structures (i.e., engineers can plan for appropriate grades and amounts of fill). Road improvement and rehabilitation projects are more challenging because the existing road profile often constrains what can be done. Despite these constraints, there are numerous examples in BC of the addition of new crossing structures to existing roads during upgrades (Appendix E). There are also examples of retrofitting of existing drainage structures to facilitate wildlife passage (see Section 4.2.2).

4.2.1 Bridges and Elevated Roads

Rivers and valley bottoms form natural movement corridors for amphibians, reptiles, and other wildlife. The best solution when a road cannot avoid crossing a river or wetland, or avoid following a shoreline for a long distance, is to install a bridge or elevated road with an appropriate span distance to allow free water flow and maintain the continuity of the natural shoreline habitat (Beben 2016). These larger structures make it possible for various species to move freely under the road and access resources without being constrained to narrow crossing structures. Bridges and elevated roads are particularly important on wider roads (e.g., more than two lanes) because animals are more reluctant to move through long, narrow tunnels than to move under more open bridges of the same length (e.g., turtles; Yorks et al. 2011).

A variety of frog, lizard, snake, and turtle species have been shown to cross under bridges (Smith 2003). Design details vary, but the width of the bridge crossing should be wider than the width of the stream at high water to allow dry passage for terrestrial animals along its banks (Lesbarreres and Fahrig 2012). Planting herbaceous vegetation and shrubs that extend from the edge of the road to beneath the bridge, or adding other cover objects, will provide safety cover. It is important to install ramps that allow animals to cross over abutments if they extend from the shoulder to the riverbank, otherwise they form barriers for animal movement (Figure x).

Bridges and Elevated Roads	
Description • Larger multi-span bridges, arches, viaducts, and elevated roads.	
Advantages • Maximizes connectivity of migratory routes along creeks, shorelines, and throughout wetland habitats • Maintains ecological and physical properties and processes • Allows for the integration of terrestrial pathways at creek and river crossings	
Disadvantages • Expensive compared to smaller crossing structures.	
Application	• Deck on piles or columns
Engineering Considerations	• Engineering measurements and road design will determine best options for bridge or elevated road
Maintenance Considerations	• Natural substrate and cover objects must be maintained

Example Bridges and Elevated Roads	
Photo of bridge structure with connected guiding fences – Highway 4 Lost Shoe Bridge	Photo of elevated road over wetland
Photo x.	Photo x.

4.2.2 Tunnels

In this document, the term tunnel is used to distinguish crossing structures intended for amphibian and reptile use from culverts, which are designed to transport water under the road. Box tunnels, arch tunnels, and round tunnels (Fig. 4) buried into the ground are the primary recommended tunnel types because they provide a natural, relatively flat or horizontal (versus rounded) crossing substrate, and sufficient air, light, and clearance for hopping amphibians (frogs and toads). If the edge between the ground and lateral wall is concave rather than a 90° angle, amphibians will attempt to climb the walls and are less likely to move through the tunnel (Schmidt and Zumbach 2008). The interior height of tunnels retrofitted to existing roads will be constrained by the depth of the ditch relative to the road height, but the minimum interior height should be at least 0.5 m. The interior width will vary with the tunnel design and species (see below and Section 4.3.5). The tunnel should be as wide as possible within the constraints of the materials used to fit the road bed. Longer tunnels (i.e., under more road lanes) will need to be wider and higher to maintain ambient light and temperature throughout the span of the tunnel.

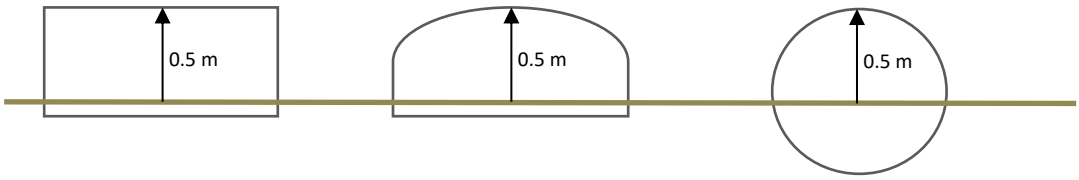


Figure 4. Box, arch, and round tunnels buried into the ground and providing an interior height of at least 0.5 m are recommended for ease of movement of amphibians and reptiles under roadways. Interior width will vary with the tunnel design and species (Section 4.3.5).

4.2.2.1 Tunnel Design

Tunnels need to have particular moisture, temperature, and light conditions to be readily used by amphibians and reptiles (Andrews et al. 2008). In general, tunnels should have an interior width as wide as possible and an overall length as short as possible to allow airflow and keep temperatures inside similar to those outside of the tunnel (Woltz et al. 2008, Yorks et al. 2011). For example, Smith (2003) observed that amphibians and reptiles in Florida used tunnels more often if they were at least 1.5 m wide and 0.6 m high internally, compared to smaller tunnels. In addition to suitable temperatures, amphibians prefer tunnels with high moisture levels due to the permeable nature of their skin and their vulnerability to water loss. Some species tend to avoid structures that are too dark. Design elements can be used to create suitable microclimates in and near crossing structures (e.g., the use of natural substrates, inclusion of cover objects). For example, artificial (e.g., fluorescent lighting) and ambient lighting inside a culvert has been shown to encourage tunnel use by turtles (Yorks et al. 2011) and speed up movements through tunnels by an eastern species of salamander (Jackson 1996). However, artificial light may alter the vision of frogs and have other detrimental impacts (Perry et al. 2008).

General tunnel design recommendations to facilitate amphibian and reptile use (for tunnels < 3 m inner width) are outlined below based on the literature and expert opinion. Specific requirements for individual species or taxonomic groups are summarized in Section 4.3.5.

Design Specifications

- Tunnels should be as open (internally wide and tall) as possible to maximize air flow and ambient light inside the tunnel.
    - Suitable microclimate and light conditions may be achieved by designing tunnels with larger (typically wider) openings, using two structures connected with fencing when a median is present (Photo x), or with an open-top or partial open-top tunnel (Photos x and x).
- At locations where tunnels will be relatively long (e.g., under roads wider than two lanes), consider the following:
    - A bridge or large underpass (> 3 m inner width)
    - Elevating the road (especially when new highway alignments will bisect critical habitat for species at risk)
    - A wildlife overpass
    - Separate, shorter tunnels under each of the opposing traffic lanes with an open median between. Ensure the two tunnels are connected with appropriate fencing in the median. Head walls may help prevent animals from climbing over or around the entrances of each tunnel (Photo x).
- On divided highways, crossing structures should never end in the centre median (Photo x) unless they are connected to other structures with fencing.
- When possible, include "skylights" or fenced gaps at medians and shoulders. Skylighted/grated tunnels can be used along roads that receive snow (e.g., they have been successfully used in Waterton Lakes National Park in Alberta, and in Killbear Provincial Park and the Long Point Causeway in Ontario).
- Where existing culverts are being replaced, increase the size of tunnels to at least minimum design specifications, and use the tunnel type guidelines summarized in Section 4.2.2.2; incorporate specific recommendations for each applicable species or taxonomic group (refer to Section 4.2.5).
- For all species, tunnel entryways should be flush with the terrain.

Microhabitat and Cover

To encourage use by amphibians and reptiles, all terrestrial crossings should have a natural substrate on the tunnel floor that consists of soil, sand, branches and other natural materials (Photos x and x). The use of local, moisture-holding soil (i.e., soil with high organic matter content, such as wood and humus, often referred to as "overburden") in crossing structures is widely recommended for amphibians (e.g., Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013). For example, Woltz et al. (2008) observed that fewer frogs crossed through tunnels containing bare concrete or PVC compared to natural substrate. Substrate selection should be informed by the following considerations:

- Soils should be from the local area to maintain the composition of the local soil microfauna and avoid introducing invasive species.
- Soils that consist of large stones should be avoided because these typically have lower moisture-holding capacity.
- Sediment baffles (e.g., open plate) may be used to "hold" natural substrate in place if water flows through the tunnel (Photo x).
- Cover objects (flat rocks and/or woody debris) should be placed throughout larger tunnels to provide security cover and shelter from predators. These cover objects should not block sightlines or impede individuals from crossing straight through the tunnel.

- Sufficient cover objects (e.g., one relatively large boulder/log or 2-3 cobbles/pieces of wood per 10 m) should be present near the entrances of all terrestrial crossing structures to provide shelter and safety cover.
- Retain as much natural vegetation at the entranceways as possible during construction; where needed, additional planting should occur after construction.

Other Design Considerations

- The amount of desired water within the tunnel will vary across the province depending on local species and conditions. Some species will utilize tunnels containing water (e.g., turtles) while others will not (e.g., lizards). It may be desirable to allow rainwater to enter tunnels in drier interior locations where precipitation is rare/low compared to wetter coastal environments where precipitation can be heavy and lead to frequently flooded tunnels. Where it is deemed suitable to have some water in wildlife tunnels (e.g., designed for aquatic amphibians or turtles), the water should be standing or have low flow rates. Except for tailed frogs and giant salamanders, few amphibian and no reptile species will move through tunnels filled with fast-flowing water. Wildlife tunnels should never be fully submerged (e.g., Caverhill et. al. 2011, Photo x), as amphibians and reptiles require access to surface oxygen.
- Terrestrial tunnels should be as level as possible for the entire length of the structure so that any water that enters the tunnel will move through at a low flow rate. One exception to this is tunnels with grated tops, which can fill with water; these tunnels should be installed with a slight slope to allow for drainage and natural cleaning of the tunnel. The slope of tunnels with grated tops can follow the natural contour of the land or be highest in the middle and slope downwards towards either end to make it level with the ground at both entrances of the tunnel.
- Tunnel entrance bottoms (including the soil level inside the tunnel) should be at ground level so animals do not need to “step up” or “step down” to enter the structure (Photo x).
- At terrestrial tunnels, most runoff water should be diverted away from the entrances with drainage ditches or sloped excavation (Photo x). However, it is important to allow some rainwater to enter the tunnel to keep soils moist for amphibians (Malt 2012, B. Beasley pers. obs.).
- If they are large enough, culverts intended for drainage and tunnels with water flow can be made suitable as crossing structures for some species by creating a bench that allows dry passage through the tunnel. The bench can be integrated into the culvert or tunnel design (e.g., attached to the side wall), but it must be situated above the high water mark and connected (extended) to dry ground at both tunnel entryways to be effective (Photo x).
- When arch tunnels are used at road-stream crossings, terrestrial corridors should be retained along the stream riparian zone by using wider tunnels that extend beyond the high water mark (Photo x). This design can better accommodate seasonal high water and flooding events (Lesbarrères and Fahrig 2012).
- When dealing with multi-species issues and variable site conditions, a mixed array of tunnel types and sizes should be provided. Structural diversity of tunnels can provide an experimental setting to test species-specific crossing preferences (see Section 7).
- Many crossing structures become ineffective over time due to lack of maintenance (Iuell et al. 2003). Regular maintenance is required for long-term effectiveness of all tunnels to ensure that the microhabitat is intact, passageways are clear of debris, and that suitable substrate remains. Maintenance needs to be factored in to the original design and budget of mitigation structures.

4.2.2.2 Types of Tunnels for Amphibians and Reptiles

<table>
<tr><th colspan="2">Box Tunnel</th></tr>
<tr><td colspan="2">Description
Traditionally used for drainage, concrete box culverts can be modified specifically to serve as tunnels for amphibian and reptile passage.
Tunnels up to 3 m wide or high are typically made from precast concrete.
The maximum recommended tunnel length is 25 m (i.e., to fit under a 4-lane road) because amphibians and reptiles are reluctant to use longer structures.
Variations include open-top or open-grate, open-bottom, and variations of these.</td></tr>
<tr><td>Open-top</td><td>Achieved with slots or grooves along the top or open-grate, set upon two concrete footings.
Allows for internal moisture, light, and temperature conditions more similar to ambient conditions.
Possible concerns with influx of road debris, pollutants, or traffic noise.
Installation at a downward incline from middle of road to edge of road to allow for drainage and natural cleaning of the tunnel.
The use of larger tunnel entryways in small tunnels facilitates maintenance.</td></tr>
<tr><td>Open-bottom</td><td>Three-sided structures.
Allows natural topography and substrate conditions to be retained (e.g., streambed or grass floor).</td></tr>
<tr><td colspan="2">Advantages
Lower road cover requirements for concrete box tunnels compared to arches or round metal tunnels allows them to be set higher in the roadbed.
Provide more cross-sectional area, or openness, than round or elliptical tunnels of the same width. The amount of light and airflow (microhabitat conditions) in a smaller-sized open-top tunnel may be equivalent to that of wider/taller tunnels that are enclosed.
Straight (vertical) walls are easy for animals to follow continuously from straight-walled fencing, and they may be perceived by target species to provide increased openness.</td></tr>
<tr><td colspan="2">Disadvantages
Interior opening is smaller, darker and potentially colder compared to passages under bridges and elevated roads.</td></tr>
<tr><td>Application</td><td>Open-top grate tunnels have previously been used on low-use roads or roads in protected areas (e.g., cattleguards; M. Sarell pers. comm.).
The tunnel floor should be buried and covered with natural substrate and cover objects.
An open-top in the road shoulder and a closed-top along the road pavement may be more suitable for high volume roads.
For divided highways with two structures that end in the median, tunnels should be connected with a fence.
Headwalls may be used at the entrance to shorten the length of the structure or to create a seamless join to a concrete guide wall.</td></tr>
<tr><td>Engineering Considerations</td><td>Open-top tunnels must be at grade with the road surface.
Road must be constructed with a vertical road profile that will allow for the height of the tunnel and adequate cover for structural stability. The necessary elevational relief will vary depending on the size of box tunnel and</td></tr>
</table>

Box Tunnel	
	road loading requirements. For a concrete box culvert with a vertical opening of 0.5 m, there will need to be at least 1 m between the elevation at the surface of the road and the elevation at the bottom of the ditch or where animals enter the tunnel. • Design variations may require special design drawings if not prefabricated.
Maintenance Considerations	• Natural substrate and cover objects must be maintained. • Open-top tunnels may have to be periodically flushed with water (e.g., with a fire hose) to clean build-up of road pollutants. • Smaller tunnels will be more difficult to keep clear of debris. • Larger structures allow better maintenance accessibility while having relatively minor cost increases relative to the cost of the road project. • Open-top tunnels are thought to interfere with snow removal; however, this has not been the case in tunnel installations in cold countries (Langton 2014). • The top of the tunnel wears away at the same rate as the road surface (see review in Langton 2014).

Examples of Applications of Box Tunnels	
Photo 1. Precast concrete box tunnel filled with material (like the one at Ryder Lake) (photo taken from side of road).	Photo 2. Open-top tunnel with a grate near road shoulder (photo taken from above from side of road).
Photo 3. Open-top tunnel with a manhole grate at centre of road (photo taken from above road).	Photo 4. Interior of tunnel with manhole grate at centre of road.
Photo 5. Open-top tunnel with slots at Waterton Lakes National Park (manufactured by ACO Systems Ltd.) (photo taken from above road).	Photo 6. Interior of open-top tunnel with slots for light and air flow.
Photo 7. Open-bottom concrete box tunnel with natural substrate continuous with outside substrates (shown from above at roadside).	Photo 8. Open-bottom and open-top tunnel with grate set on two concrete footings (shown from above at roadside) allows natural substrate to be retained.

Photo 9. Adding soil to bottom of concrete box culvert along Highway 4 near Uclulet (Photo: B. Beasley).	Photo 10. Cover objects placed on soils in bottom of concrete box tunnel (Photo: B. Beasley).
Photo 11. Box tunnels meeting in the median should be connected with fencing (Photo: Kari Gunson).	Photo 12. Box tunnel with headwalls connected to guiding fences at entrance.

Arch or Round Tunnel	
Description • Made of concrete, corrugated steel, aluminum, or plastic. • Arch tunnels have open bottoms and are recommended for tunnel widths greater than or equal to 1.5 m in diameter (common widths: 1.8 m, 2.4 m, and 3.0 m). • It is also possible to make the shape of an arched tunnel by compressing a round pipe. • The maximum recommended tunnel length is 25 m because amphibians and reptiles are reluctant to use longer structures. • Recommended sizes for arch tunnels are slightly larger than box tunnels to compensate for the loss of openness as a result of tunnel shape.	
Open-top	• Slotted open-top or vertical skylight risers along the length of the tunnel to provide natural light.
Open-bottom	• Achieved by using arch tunnel, or by placing sufficient natural substrates into bottom of round tunnels to increase the floor width (at least 2 m in diameter).
Advantages • Round tunnels work well in aquatic conditions for turtles and semi-aquatic snakes. • Increasing the width of the tunnel allows for the retention of terrestrial corridors alongside the stream or creek bed.	
Disadvantages • Interior space is smaller, darker and potentially colder compared to passages under bridges and elevated roads. • Higher road cover requirements for arches or round metal tunnels requires them to be set lower in the roadbed. • Provide less cross-sectional area or openness than box tunnels of the same width. • Rounded vertical walls are not as easy for animals to follow continuously from straight-walled fencing.	
Application	• Arch structure may be preassembled and dropped in place or assembled at site. • Corrugated steel arch or concrete side slabs are placed on footings.
Engineering Considerations	• Footings are required for arch tunnels. • In terrestrial conditions, round tunnels should be filled with local soil and

	debris to create a level crossing surface for amphibians and reptiles. The recommended tunnel substrate depth depends on tunnel diameter—0.1 to 0.2 m can be adequate as long as it raises the height of the bottom to a level that will not be flooded. The minimum diameter of a round tunnel is 2 m to compensate for the internal height lost with the addition of substrate material. • Buried tunnels may be more suitable when tall footings are required.
Maintenance Considerations	• Natural substrate and cover objects should be maintained. • Larger structures allow better maintenance accessibility while having relatively minor cost increases relative to the cost of the road project.

Examples of Applications of Arch/Round Tunnels	
Photo 13. Arched tunnel with natural stream crossing.	Photo 14. Aluminum arch culvert on metal footings.
Photo 15. Pipe culvert with slotted top installed for Timber Rattlesnakes in Illinois, U.S.	Photo 16. Zoom-in of open-top pipe culvert at road for Timber Rattlesnakes in Illinois, U.S.
Photo 17. Corrugated metal culvert crossing Highway 97.	Photo 18. Very large corrugated metal culvert crossing Sea to Sky Highway at Pinecrest.

4.2.2.3 Number of Tunnels, Location, and Spacing

The following considerations are outlined to assist with site selection for the optimal placement and number of crossing structures:

Location

In general, crossing structures should be placed where the road bisects habitat used by the target species (e.g., aquatic features and wetlands), where the road is between important, adjacent seasonal habitats used by a species (e.g., aquatic breeding habitat and upland overwintering habitat), and where the road bisects a movement corridor (e.g., natural linear pathway, such as a riparian area, hedgerow, or gully). Tunnels and fencing are best located where movement paths cross existing and proposed roads, as determined from field surveys or spatial analyses (see examples in Gunson et al. 2012, Persello et al. 2011, Beasley 2013, Grods and Garner 2018, Neilson 2018). Field surveys over at least one year are likely needed to account for different species and seasonal differences. Examples of predictable movements include annual spring migrations of adult amphibians between upland forests and breeding ponds (e.g., Wind 2014), snake migrations to and from overwintering hibernacula (e.g., Winton 2017, Fortney et al. 2013), and female turtle terrestrial nesting migrations and inter-wetland movements (e.g., Evelyn 2018). Road mortality hotspots, or areas where the highest number of animals are killed, are often used to guide placement of crossings (reinforcing the need for comprehensive pre-construction wildlife surveys). For rare or long-lived species with low reproductive rates, any location with a road-killed individual may reflect a location that requires long-term mitigation, as even small numbers killed on the road each year may be unsustainable.

In cases where past road mortality has reduced populations, road kill numbers may be low even at sites with high traffic volume.

Priority should still be given to high-traffic locations where habitats are near and straddling the road. These sites are particularly important locations for recovering depressed populations.

Exact locations for crossing structures depend on the terrain at the specific site:

- Crossing structures should be integrated with the natural landscape. Gullies and ravines are often used as movement corridors and are ideal positions for placing crossings under roads if there is sufficient elevation relief for installing a structure of appropriate height.
- Vertical alignment and location should be based on water level. For example, terrestrial tunnels should be placed in the roadbed just above the high water mark defined by the maximum water level in the ditch during stormy periods.
- Hydraulic and engineering information should be used to predict the amount of water that will flow through the tunnel at its proposed location during migration and dispersal seasons. This can then be used to decide whether the proposed location is appropriate for the target species. Refer to taxonomic-specific recommendations for aquatic and terrestrial crossing types in Section 4.2.5, in addition to site-specific conditions measured in the field.
- Modify existing or planned man-made features (e.g., ditches, retaining walls) that can act as barriers to amphibians and reptiles moving along the right-of-way (parallel to) or towards (perpendicular to) roads, so that they do not block animals from accessing crossing structures (Gartner Lee and Ecoplans 2009).

Number and Spacing

The number of crossing structures and spacing between them will depend on the length of the section of road that animals interact with (preferably measured with road encounter data, see Section 7.2.1) and the distances that individuals of the species are willing to move along guiding fences to where they will encounter crossings. For example, Long-toed Salamanders moved an average of 29 m along fences monitored in Waterton Lake National Park (Pagnucco et al. 2012). Crossing structures that are not encountered will not be used. On this basis, Schmidt and Zumbach (2008) recommend that tunnels for amphibians be spaced no more than 50 m apart along the core road encounter length, but this distance will vary by species. In BC, distances of up to 250 m between tunnels have been used for some snake species in some areas, although ideal distance may be no more than 150 m apart within high road-encounter zones (M. Sarell, pers. comm.).

- Appendices C and D provide a general summary of movement distances, home range areas, and habitat used by each species, but more detailed species- and site-specific information gathered at mitigation locations should be used to inform the number and spacing of tunnels.
- When roads bisect large expanses of continuous habitat (e.g., forest), several small, evenly distributed crossing structures will increase connectivity more than a single, large crossing structure (Karlson et al. 2017).

The young of some species (e.g., Western Toads) and species in some locations of BC (e.g., dry interior habitats) may move en masse to or from important habitats (e.g., during infrequent rain events). On the coast, amphibians and reptiles typically move away from breeding sites or hibernacula individually and randomly in space and time to access resources in ways that reduce competition and predation (e.g., Fig. 5). In this latter scenario, providing several crossing structures instead of a single structure will better maintain natural distribution patterns.



Figure 5. Road crossing locations of adult Red-Legged Frogs (blue dots) and Western Toads (red dots) in spring adjacent to a breeding site near Duncan, BC. Adult movements were more random and widely dispersed than the relatively narrow corridors used by dispersing Western Toad juveniles (pink arrows) in summer after emergence from the breeding site.

4.2.2.4 Retrofitting Existing Drainage Culverts

Some species of amphibians and reptiles use culverts that have historically conveyed water under roads (e.g., Caverhill et al. 2011). Road improvement and rehabilitation projects provide opportunities to retrofit or enhance existing drainage culverts to facilitate use by these animals. In some cases, existing drainage culverts may already be located and designed correctly for use by the target species and may only require guide fencing to facilitate crossing use and reduce road mortality (Caverhill et al. 2011, Beasley 2012; see section 4.2.4 and Photo X). Existing culverts need to be carefully evaluated for their potential as passages for the intended species before directional fencing is installed. If culverts become frequently inundated with water, some amphibians and reptiles may not be able to swim through them. Retrofitting water-carrying culverts with shelves (benches) attached to the inside of the walls, above the high water line, can make them viable passageways (Photo X).

Photo X. Existing culvert retrofitted with fencing

Photo X. Existing culvert retrofitted with shelf/bench

4.2.3 Wildlife Overpasses

Overpasses are primarily designed for larger animals, such as large carnivores and ungulates, but they can serve as both passageways and intermediate habitats for amphibians and reptiles (Jackson and Griffin 2000, Grift et al. 2009). Wildlife overpasses are sometimes referred to as "green bridges" because they are typically planted with vegetation to form a continuation of the natural landscape. Modifications for amphibians and reptiles include cover objects and ponds for hydration (e.g., in the Netherlands: Grift et al. 2009; see photos x and y). The advantages of overpasses are that they are less confining, quieter, maintain ambient conditions of rainfall, temperature, and light, and serve as passageways for large and small wildlife (Glista et al. 2009). The main drawback is their expense.

Wildlife Overpass	
• A large, multi-species crossing structure that is not usually prefabricated or precast. • Integrated as a multi-species strategy for both large and small animals. • Design includes a bridge deck that spans the road. • Requires a natural landscape planting strategy and drainage system on top of the structure. • The slope of approach ramps should be minimized for greatest visibility. • Overpass width varies from 20 m to > 70 m.	
Application	• Large structures provide greater opportunity to provide cover objects, such as flat rocks, vegetated mounds composed of branches and logs and covered with sod, or rock piles (Photos x and x). • Design enhancements for amphibians and semi-aquatic reptiles include small ponds as "stepping-stones" along the length of the structure. Natural or artificial substrate may be used to retain pond water or rainfall (van der Grift et al. 2003; Figure y). • For multi-use structures, wildlife and human use should be separated or human use should be mitigated. For example, the Rt. Hon. Herb Gray

Wildlife Overpass	
	Parkway in Ontario has incorporated a crossing structure for Butler's Gartersnake and Eastern Foxsnake into the multi-use trail system to minimize disturbance impacts from recreational trail users. • Multi-species fencing designs should be used. For example, the fencing along the Highway 69 overpass in Ontario combines ¼ inch mesh with a 2.4 m-high large animal mesh fence (Photo x).
Engineering Considerations	• Overpass decks can integrate natural footings, such as rock cliffs (Photo x).
Maintenance Considerations	• Maintenance checks for initial establishment of vegetation on overpass structures are required. • Irrigation for pools and vegetation may be required.

Examples of Wildlife Overpasses	
Photo 19. A 30 m-wide overpass installed near Sudbury on Highway 69 in Ontario (view from above).	Photo 20. Brush piles on top of an overpass on Highway 69 in Ontario.
Photo 21. Rock cliff footings on overpass on Highway 69 (view from road).	Photo 22. Multi-species fencing guiding animals to overpass.

4.2.4 Fencing for Reptile and Amphibian Crossings

Crossing structures are not likely to be used by amphibians and reptiles unless they incorporate fencing (Cunnington et al. 2014, Rytwinski et al. 2016). However, careful consideration must be given to the potential detrimental impacts of fencing on non-target species and the ecosystem (see Section 4.3). If the potential benefits to the target species outweigh negative impacts, then fences can be installed balancing benefits to target species against maintaining landscape connectivity for other species. Primarily, limit use to mortality hotspots and between key habitats. Fence lengths will depend, in part, on the species, terrain, and number and spacing of crossing structures. Care must be taken to avoid leaving fencing and crossing structure gaps at amphibian and reptile movement hotspots, as these gaps may have the adverse effect of funneling animals onto the road (e.g., Baxter-Gilbert et al 2015).

Fencing serves two purposes: 1) directing animals towards structure entrances and 2) providing a barrier to exclude animals from the road (e.g., Wilson and Topham 2009). Fencing can be used with crossing structures or as a stand-alone measure to prevent mortality along roads where connectivity is not a concern (e.g., when suitable habitat is adjacent to, but not bisected by the road, or where animals are unlikely to cross successfully due to high traffic volumes; Jackson et al. 2015).

The following recommendations are divided into fencing design, placement, and maintenance considerations and are generally applicable to all amphibians and reptiles. Species-specific details are provided in Section 4.3.5.

4.2.4.1 Fence Design

These recommendations focus on designing and installing high-quality, gap-free fencing, which may have higher initial costs but will be less expensive in the long run, compared to the ongoing maintenance required for lower-quality fencing. A number of projects have experimented with fencing effectiveness for amphibians and reptiles (e.g., Beasley, unpubl. data, Crosby 2014, Dulisse et al. 2018, Langen 2011, Smith and Noss 2011), and new, cost-effective designs are continually being engineered and tested.

Fencing should have a solid, durable framework (stakes, posts, and sheeting) to provide an effective barrier for the target species and to withstand the weight and impact from snow removal. General considerations for fence design are as follows (see Figure 6 for further illustration):

- *Posts:*
    - Steel posts will not break with snow load.
    - Posts that are closer together (e.g., spaced 2-3 m apart) will prevent both fence sag and collapse during severe weather events and snow removal.
    - Stakes or posts should be placed along the road-facing side of the fence to deter climbing and should be buried at least 30 cm into the ground to prevent burrowing.
- *Materials:*
    - The choice between recommended fencing materials listed in Table 2 depends on the target species.
    - Use materials that allow drainage through or beneath the fence at wet sites to avoid pooling at or near a crossing structure (Smith and Noss 2011, Photo x).
    - Use opaque fence materials, especially where snakes or turtles occur.
        - Recent studies on the effects of hardware cloth fences on snakes (Eye et al. 2018) and chain link fencing on tortoises (Peaden et al. 2017) have shown that these animals will repeatedly attempt to get through the fence if they can see

the other side, causing injury or death. In contrast, turtles were found to move more quickly along fences that were opaque (Yorks et al. 2011).

- Fence material should not be flammable in areas that experience frequent wildfires.
- Mesh should not be used as fencing material. Several species of amphibians can climb plastic ¼" mesh fences (Beasley, unpubl. data) and some small snakes can pass through or get stuck in ¼" mesh (Photo x; Smith and Noss 2011, S. Marks, pers. comm.).

- *Fence Depth and Height:*
  - The fence should be buried to a minimum depth of 10 cm, with a fold 10-20 cm wide to create a lip that is directed away from the road (Fig. 6). This is to deter animals from digging under the fence and to reduce the risk of the fence material being pulled out of the ground when bumped.
  - If fences have the potential to be inundated by spring runoff, the fence height should be at least 0.5 m higher than the high water level in spring to prevent animals from jumping or climbing over it.
  - When more than one species is targeted for mitigation, fence height should be the tallest height recommended for all target species (Table 3). The use of an overhanging lip along the top of the fence can allow for the fence to be shorter (see next point).
  - The fence should include an overhanging lip along the top (Fig. 6). This lip should extend 6 cm outwards, away from the road (horizontally), and then 4 cm downwards (vertically).
- *Additional Considerations:*
  - Backfill or ramps installed every 3 to 5 m on the road side of the fence can help trapped animals escape to the safe (shoulder) side of the fence (e.g., Highway 4 wildlife fence, Lost Lake toad fence manufactured by ACO Systems Ltd.; Photo x).
  - Fence ends should be curved or installed in a 90° "U" design to direct amphibians and reptiles away from the road (Fig. 7). This curved section should be a minimum of 200 cm long, though longer is better (D. Seburn, pers. comm.).

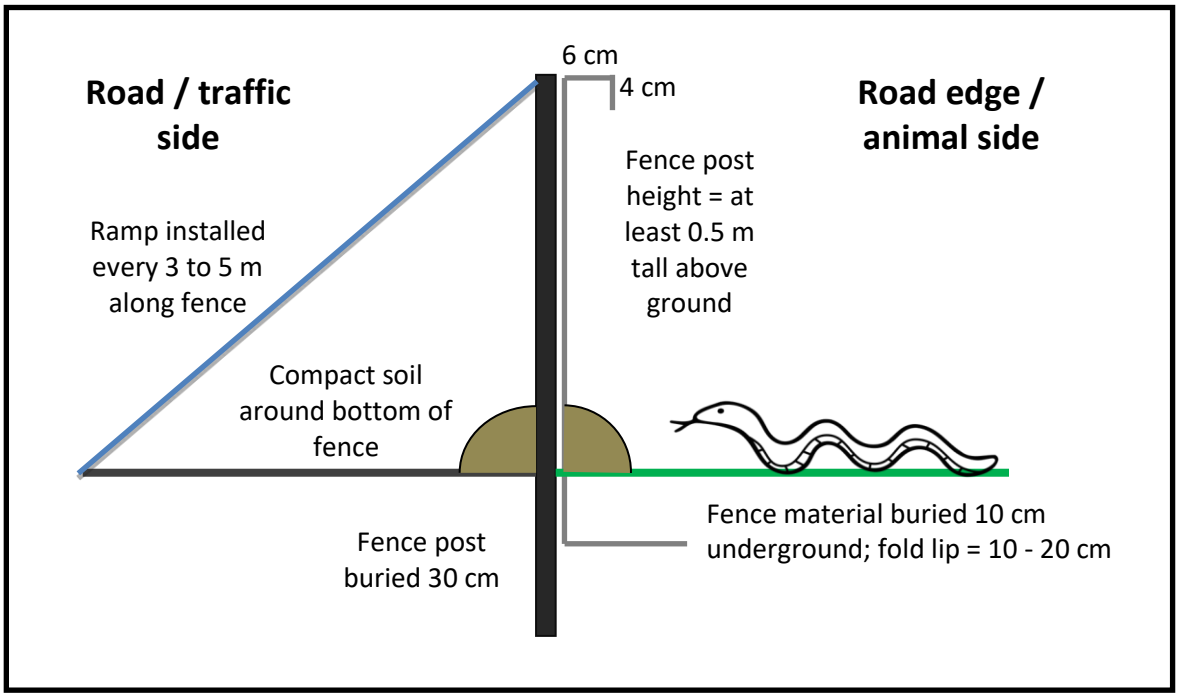


Figure 6. Design of fencing to exclude amphibians from roadways and/or guide them towards tunnels.

Table 2. Fence material options and considerations. See 4.2.5 for species group recommendations.

Material	Use	Recommended?
Hardware cloth or rigid plastic mesh	Durable fence material that allows drainage	Only if drainage is required. Not for turtles or snakes.
Chain link fencing	Standard chain link used for large animals (e.g., 2.5 m high wildlife exclusion fencing with 4" mesh); does not work for many amphibians and reptiles, as individuals can pass through the large mesh holes	Only if additional fencing material, such as heavy-duty plastic fencing, is attached at the base for amphibians and reptiles (Photo x)
Metal (e.g., sheeting)	Durable fence material	Yes
Vinyl	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Wood	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Concrete	Durable fence material	Yes

Heavy duty UV-resistant polymer fencing designed for wildlife	Durable fence material	Yes, except not where wildfires are common, i.e., areas in the Interior where fires are expected at ≤10-year intervals
Light duty geotextile (Photo x)	Temporary fence material (lifespan up to 1 year)	Not for long-term use
Heavy duty geotextile fence	Temporary fence material (2-3 years)	Not for long-term use
Wood lath snow fencing	Temporary fence material (< 3 years)	Not for long-term use
Nylon mesh fencing or erosion materials	Should not be used, as snakes and other species can become entangled and die in this material	No

Photo X. Amphibian and reptile fencing attached to the bottom of large animal chain link fencing.

Photo X. Light duty geotextile fencing—not recommended for long-term use.

Photo X. Waterton Lakes National Park's plastic fencing before & after the 2017 fire, and replacement metal fencing.

Photo X. Use materials that allow drainage under the fence.

Photo x. ¼" mesh fencing being climbed by a frog.

Photo x. The bottom fold of the fence should be 10-20 cm wide and buried 10 cm below ground.

Table 3. Recommended above-ground heights and below-ground depths for fencing for each species group.

Species Group	Recommended depth of buried fence, excluding bottom lip (10 - 20 cm; see Fig. 6)	Recommended height of fence, excluding top lip (6 cm + 4 cm; see Fig. 6)
Turtles	10 - 20 cm	60 cm
Frogs and Toads	10 - 20 cm	50 cm
Snakes	10 - 20 cm	100 cm
Lizards	10 - 20 cm	unknown
Salamanders	10 - 20 cm	30 cm

Photo x. Backfill or a ramp on road side of fence.

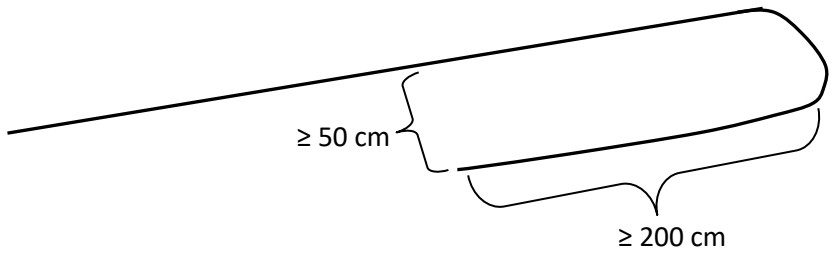


Figure 7. Fence ends should curve back, by a minimum of 200 cm, towards the shoulder side of the road to deter animals that are moving along the fence from continuing onto the road and, ideally, redirect them back towards the crossing structure.

4.2.4.2 Fence Length and Placement

Fence length depends on the species' movement abilities as well as the interface of the surrounding habitat with the road. Spatial analyses of where species are found can help determine how much fencing is required and where it should be placed (Gunson and Teixeira 2015). However, when roads bisect continuous expanses of habitat, fencing is often required along the entire stretch of road to prevent mortality. The following should be considered when evaluating fence and crossing structure placement:

- Data collected from inventory work, road surveys, expert opinion, and other sources should be used to understand species presence, habitat use, and movements in relation to the road (see Appendices A-D).
- Maximum movement distances of the target species along fences should be used to inform fencing length. For example, salamanders generally will not move distances greater than 50 m along fences (Schmidt and Zumbach 2008), while frogs, turtles, and snakes may move much farther (see Appendix D). Some species will move considerable distances along the fence and access the road at the fence ends; this can only be avoided if the fence is longer than the distances that the species will move, or if the fencing is extended back away from the road at each end (see Fig. 7 above).
- Solid rock areas should be avoided when possible; if rocky areas cannot be avoided, dirt or mortar can be used to hold the fence in place and infill irregularities in the rock surface to create a seal (Photo x).
- Wherever possible, the fence should direct wildlife, without impediment, towards the crossings.
- To be effective in guiding animals, fencing must connect to the tunnel entrances smoothly and without gaps. Connections should follow a 'V' pattern (Fig. 8a) or span between multiple crossing structures in a 'W' pattern (Fig. 8b) to funnel animals. Many factors, such as land ownership, terrain, limitations of the fencing material, road maintenance requirements, ditch

drainage, etc., must be included in the design. Where wildlife fencing is constrained by road right-of-ways and existing fencing, a 'W' pattern may not be possible; in these cases, 'V' patterns should be used in proximity to the crossings to funnel animals.

- Effective fencing requires regular, planned maintenance (see Section 4.3.4.3 below).

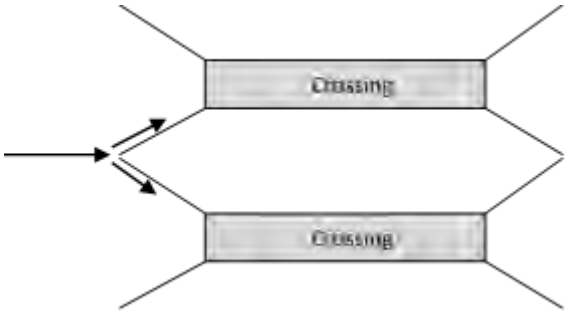
Right-of-way considerations:

- Fencing should be placed as far as possible from the road edge to minimize impacts from snow removal, mowing, or other roadside maintenance practices.
- Fencing cannot interfere with road interchanges or driveway access.
- Fencing cannot interfere with ditch drainage or any watercourse flows that intersect the road.
- Permissions and permits must be obtained from the road authority.
- When the fence extends beyond the right-of-way, permission must be obtained from property owners.

Photo X. Dirt or gravel keeping fence in place along rocky areas.



a. "V" formation of fencing is used to guide amphibians and reptiles towards a crossing structure.



b. "W" formation of fencing is used to guide amphibians and reptiles towards multiple crossing structures.

Figure 8. Fencing placement in relation to crossing entryways. Fencing should be continuous between multiple, adjacent crossing structures to increase the "capture" area of migrating individuals.

4.2.4.3 Fence Maintenance

All fencing requires routine checks and maintenance which should be planned and budgeted for (see Section 7.2). The frequency of maintenance checks and repairs will vary with the durability of the fence and the rate of vegetation growth and mammal activity along it. After snowmelt, a thorough survey and immediate fence repairs are essential before amphibians and reptiles emerge from hibernation. The following are recommended considerations for fence maintenance:

- Regular maintenance is required to clear vegetation and debris from all fences. Woody vegetation, leaves, thick grasses, and other debris that pile up along the fence may provide a "ladder," or puncture the fence, allowing animals to access the road. Clearing of vegetation and debris also helps to reduce fuel loads to protect fencing materials that may be flammable.
- Fences should be marked with tall posts and flagging tape to alert maintenance crews to their presence, especially where mowing and snow removal will occur.
- Routine fence surveys should be done using a checklist approach to identify where repairs are required, including the location and description of any damage (see Section 7.2). The survey checklist should include monitoring for potential carcasses along the fence and on the road during the active season (Table 1) to ensure that the fence materials and design are effective (not allowing animals onto the road) and not negatively affecting any local amphibian and reptile species (e.g., entangled snakes).
- Repair crews need to fix the fence in a timely manner (e.g., before and during the active season) to minimize fence breaches by amphibians and reptiles.
- Amphibian and/or reptile carcasses on the fence or adjacent road may be an indication of a failure of fence design, signalling a need for immediate fence repairs, modification or replacement.

Fence Maintenance Checklist:

Prior to the active season

- ☐ Fence is standing (has not collapsed)
- ☐ Fence links to the crossing structure with no gaps
- ☐ Fence is vegetation free
- ☐ No holes or gaps in or under the fence

During the active season

- ☐ No carcasses along fence
- ☐ No carcasses along the road

4.2.5 Recommendations by Species Group

In addition to the general design considerations for reptiles and amphibians that are outlined above, the following are specific recommendations that are unique to each group. The following recommendations are based on species that have been observed using tunnels. It is unknown how effective the specifications below are to other reptile and amphibian species, or for overpasses, in BC. This underscores the importance of conducting effectiveness monitoring for mitigation projects (Section 7.0).

In general, tunnel design recommendations are made with the assumption that as tunnels get longer, an increase in width is more important than an increase in height in order to maintain suitable climatic conditions (see Box 1).

SPECIFICATIONS FOR TURTLES

Type of structure and minimum size based on tunnel length

Tunnel Length	Box Tunnel (w x h)	Arch Tunnel (w x h)	Round Tunnel (diameter)	Other Structure Recommended
15 m	1.5 m x 1.0 m	1.8 m x 0.9 m	1.5 m	
15-25 m	1.8 m x 1.0 m	2.0 m x 1.0 m	1.8 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Terrestrial and aquatic structures are suitable for most turtle species.
- Open and closed-top tunnels have been used by turtles; however, open-top tunnels may increase crossing success.
- Do not install rip-rap at entranceways, along footings, or leading into the crossing structure.
- Concrete fabric can assist in allowing turtles to climb into or out of culverts that have steep hills.
- A minimum of 150 m (Appendix D) of fencing (60 cm high, buried 10-20 cm into ground; Table 3) on either side of the crossing structure is recommended to funnel turtles to entranceways and keep them off the road/highway.
- Fencing should be opaque.
- Substrate type may not be as important in terrestrial tunnels for turtles as with other amphibians and reptiles.

Rationale

Use of culverts has been documented for Western Painted Turtles in BC. For example, after a couple of years and several design modifications, turtles were observed going through a large culvert installed under Highway 97 where the road was expanded to four lanes, south of Williams Lake (Bings and Steciw 2018).

Several studies have demonstrated relatively high use of large (> 1.5 m width) crossing structures by species of turtles outside of BC:

- The Port of Portland Authority built turtle culverts for Western Painted Turtles, which, although not scientifically studied, appear to work (Kintsch and Cramer 2011).
- In Ontario, a drainage culvert 1.8 m in diameter that was approximately half-full of water (Caverhill et al. 2011) was used regularly by Blanding's Turtles and was also used by Snapping Turtles.
- Multiple Spotted Turtles were confirmed to cross through a tunnel 1.8 m x 1.8 m (Kaye et al. 2005).
- Aresco (2005) documented over 200 turtle crossings through a 3.5 m-diameter drainage culvert.
- Wood Turtles continued to use a stream that passed through a culvert that was 3 m in

diameter and 26 m long (Parren 2013).

Caverhill et al. (2011) found that turtles will cross through tunnels 25 m long, although crossing success may be lower as length increases (Yorks et al. 2011).

In a simulated tunnel experiment, more turtles crossed through a tunnel that let in at least 75% ambient light through the top (Yorks et al. 2011).

Turtles have used closed-top tunnels (e.g., Dodd et al. 2004, Aresco 2005, Kaye et al. 2005, Caverhill et al. 2011) and Wood Turtles (Photo 54) and Snapping Turtles (Whitelock 2014) have crossed through open-top tunnels in Ontario.

Blanding's and Spotted Turtles have been documented to cross through tunnels with natural substrates (e.g., Kaye et al. 2005, Caverhill et al. 2011), but in a simulated crossing structure experiment, Painted and Snapping Turtles did not demonstrate a substrate preference (Woltz et al. 2008).

Photo x. Turtle in terrestrial tunnel.	Photo x. Turtle in aquatic tunnel.

SPECIFICATIONS FOR SNAKES AND LIZARDS				
Type of structure and minimum size based on tunnel length				
Tunnel Length	**Box Tunnel (w x h)**	**Arch Tunnel (w x h)**	**Round Tunnel (diameter)**	**Other Structure Recommended**
15 m	1.0 m x 1.0 m	1.5 m x 0.75 m	1.0 m	
15-25 m	1.5 m x 1.0 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Open and closed-top tunnels have been used by snakes. Open-top tunnels may increase crossing success for some snake species while allowing others to access road surfaces through the opening.
- Depending on the tunnel material and shape, lizards may be able to access the road surface through open-top tunnels.
- Aquatic tunnels are not recommended for some BC snakes and all BC lizards. Existing culverts with intermittent flows are likely to be used by snakes and should be considered during project design.
- Do not install rip-rap at crossing entranceways.
- A minimum of 250 m of fencing (1 m high, buried 10-20 cm into ground; Table 3) is required on either side of the crossing structure (Appendix D) to funnel snakes to entranceways and keep them off the road/highway.
- Fence height and length are unknown for lizards.
- Fences should be opaque and the tops and bottoms should be folded over as per Figure 6.
-).

Rationale

Note: BC-specific data are not available. These recommendations are adapted from the *Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario* (2016) and other publications and reports from outside the province.

Snakes (e.g., Taylor and Goldingay 2003, Laidig and Golden 2004, Roberts 2010, Eads 2013) and lizards (e.g., Taylor and Goldingay 2003, Painter and Ingraldi 2007, Arizona Game and Fish 2010) have used a variety of crossing structures under roads. However, compared to other taxa, there is less certainty about crossing structure design preferences for these species.

Snakes have crossed through tunnels as small as 0.25 m in diameter (Roberts 2010), but tunnels 1.0 m in diameter had a greater crossing success than smaller tunnels for the Eastern Gartersnake and Eastern Ribbonsnake in an experiment by Eads (2013).

Both closed-top (Taylor and Goldingay 2003, Laidig and Golden 2004, Roberts 2010, Eads 2013) and open-top (Pagnucco et al. 2011, Colley et al. 2017) crossing structures have been used by snakes.

Wandering Garter Snakes in Waterton Lakes National Park, Alberta, moved through open-top tunnels manufactured by ACO Systems Ltd. that have interior dimensions of 0.50 m wide x 0.33 m high (Pagnucco et al. 2011).

Open-bottom box tunnels with cross-sectional dimensions of 1.0 x 1.0 m in Killbear Provincial Park, Ontario, were used by many (11) Massasaugas and 2 Eastern Foxsnakes in 2014 (Colley et al. 2017).

Timber Rattlesnakes have crossed through concrete-bottom structures (Laidig and Golden 2004), but

natural substrate or habitat conditions may enhance use (Laidig and Golden 2004).	
Photo # Snake in terrestrial tunnel.	Photo # Snake fencing.

SPECIFICATIONS FOR SALAMANDERS				
Type of structure and minimum size based on tunnel length				
Tunnel Length	**Box Tunnel (w x h)**	**Arch Tunnel (w x h)**	**Round Tunnel (diameter)**	**Other Structure Recommended**
15 m	1.8 m x 0.5 m	1.5 m x 0.75 m	0.6 m	
15-25 m	1.5 m x 1.0 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road

Additional Design Considerations

- Salamanders prefer tunnels with high moisture content and even small pools of standing water, but the tunnel should not be flooded with water.
- Open- or closed-top tunnels can be effective. Open-top tunnels allow more light into the tunnel and possibly greater moisture levels, the latter being important in longer tunnels. The use of open-top tunnels may allow the dimensions to be smaller than those listed above (see below).
- Open-top tunnels may result in higher levels of road salt and other pollutants in the tunnel. However, these may be washed away with storm events.
- Soils and leaf litter substrates should be used as opposed to larger gravel or stone substrates.
- Multiple tunnels should be used where migration paths cross roads towards aquatic breeding sites. Tunnels for salamanders should not be more than 30 m apart (e.g., Pagnucco et al. 2012).
- Fencing must be buried at least 10 cm into the ground to prevent salamanders from burrowing beneath it, and the height should be at least 30 cm (Table 3).
- Fencing should have an overhanging lip to prevent salamanders from climbing over (Figure 6).

Rationale

Northwestern Salamanders will swim through tunnels with slow-moving water (B. Beasley, unpubl. data).

Both closed-top (Patrick et al. 2010, Beasley 2013, Bain 2014) and open-top (Jackson and Tyning 1989, Allaback and Laabs 2002, Pagnucco et al. 2012) crossing structures have been used by *Ambystoma* spp. (mole salamanders).

Box culverts with local, damp soil conditions are recommended for amphibians (see Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013).

In general, tunnels for amphibians are recommended to be at least 1 m x 1 m in size (Schmidt and Zumbach 2008). Some salamanders may pass through smaller tunnels (e.g., Long-toed and Barred Tiger Salamanders moved through open-top tunnels manufactured by ACO Systems Ltd. that had interior dimensions of 0.50 m x 0.33 m (Pagnucco et al. 2011), and *Ambystoma* sp. salamanders have crossed through round tunnels as small as 0.25 m in diameter and 0.2 m wide (Bain 2014)); however, salamanders demonstrate hesitancy to enter small tunnels (Jackson 1996) and the percentage of salamanders that successfully cross through may be low (e.g., Allaback and Laabs 2002, Pagnucco et al. 2012). Larger tunnels are required to ensure sufficient space for natural substrate and cover

objects.

Salamanders will cross through tunnels with or without natural substrate, but Woltz et al. (2008) found that fewer individuals cross through bare concrete tunnels than tunnels with natural substrate. Furthermore, natural soil substrate will retain moisture longer, lessening the risk of salamanders dehydrating or not entering structures.

Photo x. Salamander in culvert.	Photo x. Salamander climbing fence.

SPECIFICATIONS FOR FROGS AND TOADS

Type of structure and minimum size based on tunnel length

Tunnel Length	Box Tunnel (w x h)	Arch Tunnel (w x h)	Round Tunnel (diameter)	Other Structure Recommended
15 m	1.8 m x 0.5 m	1.5 m x 0.75 m	0.6 m	
15-25 m	2.0 m x 0.5 m	1.8 m x 0.90 m	1.5 m	
>25 m	*Not recommended*	*Not recommended*	*Not recommended*	Bridge/elevated road/overpass

Additional Design Considerations

- Frogs and toads prefer tunnels with high moisture content and even small pools of standing water, but the tunnel should not be flooded with water.
- Open- or closed-top tunnels may be used. Open-top tunnels will allow moisture and air flow in the tunnel, especially along long tunnels.
- Open-top tunnels may result in higher levels of road salt and other pollutants in the tunnel. However, these may be washed away with storm events.
- Soils and leaf litter substrates should be used as opposed to larger gravel or stone substrates.
- Fencing should be at least 50 cm high to prevent ranid frogs from jumping over it, and buried 10-20 cm below ground to prevent frogs and toads from burrowing underneath (Table 3).
- Fencing should not be made of ¼" plastic mesh because ranid frogs and toads will attempt to climb it rather than follow it to tunnel entranceways (B. Beasley, unpubl. data, P. Govindarajulu, pers. comm.).
- Fencing should have an overhanging lip to prevent frogs and toads from climbing over it (Figure 6).

Rationale

Frogs and toads have used a wide variety of crossing structures under roads (reviewed in Schmidt and Zumbach 2008, Puky et al. 2013).

Wide crossing surfaces with local, moist soil are recommended for amphibians (e.g., Jackson 2003, Smith 2003, Schmidt and Zumbach 2008, Amphibian and Reptile Conservation 2009, Beasley 2013).

Northern Red-legged Frogs were reluctant to enter tunnels with dry soil (Malt 2011) but readily enter tunnels with moist substrates (Beasley 2013).

Although toads have been documented using tunnels < 1.0 m wide (e.g., Lesbarrères et al. 2004, Pagnucco et al. 2012, Ottburg and van der Grift 2013, Puky et al. 2013, Wind 2014), larger tunnels tend to be more effective (e.g., Puky et al. 2013) and are easier to maintain. Very high toad crossing rates have been documented at tunnels 1.8 m wide (Biolinx Environmental Research & Nicola Naturalist Society 2013, 2014). Newly metamorphosed toadlets, which disperse en masse, move more readily through tunnels—even narrower ones—compared to adult toads (E. Wind, unpubl. data).

Guidelines for road crossing structures in England have been developed for the Common Toad (*Bufo bufo*). These guidelines recommend a rectangular crossing structure at least 1.0 m x 0.75 m (w x h) for tunnels up to 20 m long and 1.5 m x 1.0 m (w x h) for longer tunnels (Amphibian and Reptile Conservation 2009).

Both closed-top (Biolinx 2013, Puky et al. 2013, Wind 2014) and open-top (Pagnucco et al. 2012, Ottburg and van der Grift 2013) crossing structures have been used successfully by other toad species.

Photo x. Frog in culvert.	Photo x. Frog climbing fence.

4.3 Additional Planning and Design Mitigation Measures

Supplementary mitigation measures, such as installing signage or instituting reduced speed zones at fence ends, may be used with crossing structures and fencing to increase their effectiveness. In addition, supplementary measures may be used as temporary measures during construction, prior to road upgrade and rehabilitation projects, or on existing roads where there would otherwise be no mitigation. The effectiveness of some of these strategies at reducing road mortality and improving connectivity is difficult to measure and largely unknown. Therefore, implementation of these measures should proceed with caution using monitoring and an adaptive management approach.

This section classifies measures as either those that influence driver behaviour or those that influence wildlife movement, as defined by Huijser et al. (2007). The following list of measures is not exhaustive, but instead summarizes what has been used elsewhere, with specific consideration of how each strategy may be applied to amphibians and reptiles.

4.3.1 Influencing Driver Behaviour

Temporary road closures are an effective mitigation tool where there is local support. Other strategies that may influence driver behaviour are presented below. These techniques are attractive because they are often relatively inexpensive to implement. However, they rarely result in a significant reduction in road mortality. This is in part because many reptiles and amphibians are small and difficult to see or avoid. The success of these strategies is further limited by driver attitudes and behaviour; for example, Ashley et al. (2007) found that approximately 2.7% of drivers intentionally ran over reptiles.

The strategies outlined in this section have relatively low effectiveness when used in isolation, so several approaches should be used concurrently whenever possible. For example, a good strategy may include a reduced speed limit, traffic calming measures to reinforce the low speed limit, high quality signage to warn drivers, and a public education program to help drivers understand the measures that have been put in place.

Seasonal road closures offer an effective mechanism for reducing road mortality by eliminating vehicles from a road. Although this is a very effective solution, such closures are typically only feasible for a few days or weeks per year and they must be timed precisely to coincide with amphibian and reptile migrations. This method is particularly applicable at problem areas while more permanent measures are still under consideration or awaiting approval (see Case Study # 1 below). This method is most easily implemented in protected areas, on low volume roads where access to residences or businesses is minimal, or on roads where alternate access (i.e., a detour) exists. This type of strategy requires buy-in from both the road authority and the community using the roads. A public relations campaign is a useful tool to inform and gather support from local residents. This strategy has a relatively low cost.

CASE STUDY #1 – Road closure for the endangered Northern Leopard Frog

The Rocky Mountain population of Northern Leopard Frog (*Lithobates pipiens*) that occurs in BC and is considered endangered and is genetically distinct from leopard frog populations found elsewhere in Canada. Only one natural population of this species remains in BC, in the Creston Valley Wildlife Management Area (CVWMA). Monitoring since 2009 has shown that frogs are killed along the Duck Lake Dyke Road in the CVWMA during seasonal migrations. In fall of 2016 and 2017, a seasonal, voluntary road closure was put in place and patterns of vehicle use and frog migration and mortality were monitored nightly. Signage was used for the duration of the voluntary closures, and educational outreach (social media posts, newspaper articles, radio interviews, and an open house/information session) was provided. Researchers found that the voluntary road closure was ineffective because vehicles continued to use the road and frog mortality was observed both years. In October 2017, the species' Recovery Team submitted a regulation change proposal under the *Wildlife Act* to enact a legal seasonal closure to motorized vehicles, which was approved in 2018. The motorized vehicle closure is in now in effect annually during the spring (March 15 – April 30) and fall (August 15 – October 15) migrations.

INSERT PHOTOS – from Lindsay Anderson and Kat McGlynn

Reduced speed zones allow drivers more time to react to an animal on the road, making them more likely to safely avoid a collision. They have been implemented in Banff National Park to reduce collisions with larger wildlife, such as Grizzly bears (Banff National Park, unpublished data 2011-2014). This methodology is best suited for amphibians and reptiles on low-traffic volume roads or roads in protected areas and where more visible species, such as larger snakes and turtles, are the issue. Speed limits may be reduced seasonally and/or at specified times of day. A reduced speed zone is typically combined with a public awareness strategy and signage to educate motorists about the need to minimize road mortality for amphibians and reptiles. Enforcement or traffic calming mechanisms (see below) are usually necessary for the effective implementation of lower speed limits. This strategy can have a high cost due to the need for regular enforcement.

Traffic calming refers to the installation of road features designed to decrease vehicle speeds without interfering with the flow of traffic. As with reduced speed zones, this methodology is best suited for amphibians and reptiles on low-traffic volume roads and where more visible species are the concern. Some traffic-calming methods, such as speed bumps (Photo X), traffic circles, and raised medians, can only be implemented on low-speed roads. Other methods, such as narrow lane widths and rumble strip patches, may be used on moderate- or high-speed roads. In some cases, speed bumps may interfere with snow removal. However, installations can be used seasonally. This strategy has low to moderate costs depending on the measure used.

Photo X. The use of speed bumps as a traffic calming measure where amphibians and reptiles occur on roadways.

Signage is a low-cost, widespread method of roadside messaging that is relatively easy to implement but has low effectiveness (Photo x). The key objective for signs is to instill awareness so motorists can avoid hitting wildlife. Effectiveness may be improved with a well thought out strategy that discourages driver habituation and includes the following criteria (see Gunson and Schueler 2012, Kintsch et al. 2015):

- local education (e.g., public and school presentations, media articles, etc.);
- seasonal placement of signs with text indicating when target animals are likely crossing;
- enhancement of signs with flags, flashing lights, or unique art work (Pojar et al. 1975, Hardy et al. 2006);
- use of science and data to inform effective placement;
- limiting the use of signs to roads with moderate–high traffic volume to deter sign theft;
- strategic placement of signs, such as the ends of exclusion fencing; and
- use of signs as temporary measures and markers in advance of more permanent mitigation measures (Ontario Ministry of Transportation 2012).

As with all measures in this section, the effectiveness of signage can also be increased by combining it with other measures (e.g., reduced speeds, traffic calming). Benefits of signage for amphibians and reptiles include driver awareness of wildlife on the road and, when used with a public awareness and education campaign, greater understanding of the importance of conservation efforts (see example in Joyce and Mahoney 2001). In Ontario, signage has commonly been used on municipal and provincial park roads, and more recently on provincial roads (Ontario Ministry of Transportation 2012.

Photo x. Example of signage used to make drivers aware of amphibians and reptiles on roadways.

Public awareness and education campaigns are designed to inform drivers about wildlife and roads issues and how they can help minimize or avoid wildlife collisions. For amphibians and reptiles, public awareness campaigns typically target local communities near known high-risk road mortality locations (see Case Study #2 below).

While it is difficult to draw a direct correlation between heightened driver awareness and a decrease in road mortality, this strategy has the potential to improve effectiveness and public acceptance of other mitigation efforts, such as signage, reduced speed zones, or traffic calming measures. The cost of conducting a locally-based public awareness campaign is comparable to that of the other strategies discussed. However, a regional, coordinated, long-term strategy (i.e., similar to the well-known Drinking and Driving Campaign) would entail greater funding and a long-term commitment.

CASE STUDY #2 – Annual Toadfest generates awareness of road mortality

Toadfest is a free, family event held at Summit Lake Provincial Park each year. It is organized by the Fish & Wildlife Compensation Program (FWCP) to raise awareness about Western Toads (*Anaxyrus boreas*) and road mortality. An annual media release lets locals know when the event will take place based on the development rate and movement patterns of the toad tadpoles in Summit Lake. Participants learn about the toad's natural history, life cycle, and habitat needs. Toadlets migrate from Summit Lake to upland habitat in the summer, encountering roads along the way. Toadfest participants help carry toadlets across the road (see table below). The event draws hundreds of visitors each year and is used as a model for other eco-fests. It has also prompted the addition of a second toad crossing tunnel in the area. Toadfest is supported by the Fish and Wildlife Compensation Program, B.C. Parks, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, the Columbia Basin Trust, and the Ministry of Transportation and Infrastructure.

Summary of Toadfest results, 2010-2014 (taken from Dulisse 2015).

	2011	2012	2013	2014	2015
Estimated number of volunteer participants	400	500	500	400-500	300
Estimated total number of toadlets moved	5000*	14,753	13,253	6,853	391

* The number of toadlets moved each year does not reflect population numbers, but rather the relative number of toadlets that were moving at the time of the educational event, the date of which was scheduled early in the season. In some years, the event was held earlier or later than the peak in toadlet migration.

INSERT PHOTOS – asked Irene Manley

4.3.2 Influencing Wildlife Movement

Ramped curbs and escape gaps are used along roads (typically local, municipal roads) to replace vertical curbs that are too high for amphibians and reptiles to climb over. A good example is in Waterton Lakes National Park, where right-angle curbs were replaced with sloped curbs to allow Long-toed Salamanders to successfully escape the road (Photo x). Additionally, escape gaps can be used where the structures meet the road. Escape gaps work well along high-volume roads where continuous sections of precast concrete barriers divide opposing lanes of traffic and animals that enter the right-of-way cannot cross the road. For example, an unexpected mass migration of Western Toad metamorphs emerged onto Highway 19 on Vancouver Island in the summer of 2007 (Fyfe and Wind 2008). In addition to a bucket brigade salvage operation (see Assisted migration below), sections of precast concrete barriers were replaced with those with scuppers (i.e., gaps underneath) to allow toadlets that got onto the highway to get off the road (Photo X). This strategy has a relatively low cost.

Photo x. Right angle curbs used for Long-toed Salamanders in Waterton Lakes National Park, Alberta.

Photo x. Scuppers under precast concrete barriers for toadlets.

Assisted migration can be used where a concentrated amphibian migration crosses a defined stretch of road. Temporary traps (typically drift fencing and buckets) may be used to prevent animals from crossing the road. The captured animals are then collected and moved across the road by volunteers. Alternatively, volunteers can survey the road during peak times and move any animals that are encountered. This strategy requires a handling permit from the provincial government, is labour-intensive, relies on having local volunteers to monitor traps during a migration event, requires safety precautions for the volunteers, and poses some risks to the amphibians (e.g., disease transmission, stress, etc.). However, if timed and coordinated effectively, facilitated migrations can be an effective, temporary measure to help reduce road mortality for amphibians (Photo x; see Case Study #2 of how this technique can also be used for educational purposes).

Photo x. A volunteer assists amphibians across the road.

Habitat creation can be used to reduce the need for individuals to access habitat close to the road or cross the road to access habitat on the other side. Since reptiles and amphibians often show high fidelity to specific habitats and many individuals will continue using historical habitat features, a population-level transition to the new habitat can take decades. Consequently, roadside barrier fencing is still necessary alongside habitat creation to prevent dispersing animals from accessing the road. The costs, feasibility, and effectiveness of creating new habitat are variable and will be site- and species-specific (B.C. MFLNRO 2004).

New habitat creation may include wetlands as breeding sites for amphibians (e.g., Merrow 2007), artificial nesting sites for turtles (see Case Study #3 below; Clarke and Gruenig 2002, Paterson et al. 2013), or gestation/basking sites (Rouse 2005, Parent and Black 2006) and hibernacula (Willson 2005) for snakes. General recommendations for habitat creation, based on the Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014), are as follows:

- A thorough understanding of the habitat use and movements of the target species is necessary.
- New habitat should be in close proximity to, and on the same side of the road as, other habitat used by the target species.
- The created habitat should be suitable for the target populations.
- Other important habitats should not be manipulated, degraded, or destroyed to create new habitat, e.g., check whether other wildlife depend on the area to be altered.
- Ongoing monitoring and maintenance is required for artificial turtle nesting habitat to avoid high turtle egg/hatchling mortality from invasive plants and predators (wild and domestic), and for suitable hydroperiod at artificial aquatic breeding habitat for amphibians to avoid stranding and mass egg/larval mortality.

CASE STUDY #3 – Creating nesting habitat for the endangered Western Painted Turtle

On the Sunshine Coast, human development has reduced available nesting habitat for Western Painted Turtles. Each year, female turtles are killed on roads as they search for suitable nesting habitat or attempt to nest on road shoulders. Because the life history of this species relies on high adult survival and longevity, the loss of each reproductive female from the population can be devastating. To mitigate this threat, the Sunshine Coast Wildlife Project has built turtle nesting beaches at six sites where turtle road mortality was a concern. In general, this approach has been extremely effective, but results vary from population to population. At North Lake, Lily Lake, and Ruby Lake Lagoon, turtles immediately used the beaches, road mortality declined dramatically, hatchling success rate was high, and population monitoring through time showed an increase in juvenile age classes. At Sakinaw Lake, Trout Lake, and Garden Bay Lake, it took several years before turtles started using the new beaches.

INSERT PHOTOS – asked Michelle Evelyn

5.0 GUIDANCE FOR ROAD CONSTRUCTION ACTIVITIES

This section provides general considerations for mitigation during road construction work in areas with amphibians and reptiles. The following considerations address two components: 1) timing construction activities to avoid construction-related impacts, and 2) installing mitigation measures to minimize interactions with amphibians and reptiles and their habitats during construction.

Consultation with local species experts is strongly recommended because activity times for the target species vary annually with changing climatic conditions and can be site- and region-specific.

5.1 Timing of Construction Activities

When road construction occurs within or near amphibian and reptile habitat, some impacts can be minimized by carefully scheduling the timing of the work to avoid impacts to habitats when they are occupied or impacts to animals during sensitive periods. Construction during the overwintering period should avoid wetlands, underground burrows, large downed wood, potential snake hibernacula and other sites that are used for hibernation. This includes direct disturbance as well as indirect disturbance, such as decreasing water levels in overwintering wetlands and noise and vibration disturbance near potential hibernacula. Construction during the active season should avoid key habitat features or times when the species is most sensitive (see Appendix C and Table 1). The timing and duration of seasonal activities of amphibians and reptiles vary across the province. For example, amphibian and reptile populations are active from February to November along south-coastal BC, with the duration of activity decreasing as one moves northward. Also, the onset and end of the surface activity period can vary by almost two months depending on the weather. For example, the majority of Western Toads tracked on Vancouver Island using radio telemetry went into hibernation in November during each year of the three-year study but hibernation emergence timing varied from year to year, occurring in February in 2015, January in 2016, and March in 2017 (Wind 2018). Consultation with local QP species experts, provincial Ministry of Environment and Climate Change biologists, and the regional Ministry of Forests, Land, Natural Resource Operations and Rural Development office may provide information on annual variations in site-specific movements of the target species during construction activities.

5.2 Mitigation Measures for Construction Activities

Temporary mitigation measures can be implemented on-site at all road projects that occur within or adjacent to amphibian and reptile habitat to help avoid harming or killing individuals. The following are guidelines for temporary measures:

1) Consult Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014). This document discusses measures such as maintaining hydrological features; preventing the introduction of non-native species; reducing pollution in aquatic breeding habitats, such as erosion and sediment control plans and having an emergency response plan in place to contain and clean up oil and fuel spills safely and quickly; communicating measures with construction workers; avoiding compaction and/or disturbance of loose soils, the litter layer, coarse woody debris, and sensitive habitats, such as rocky slopes; and considerations for habitat enhancement and restoration (e.g., taking advantage of heavy equipment already onsite, as well as any surplus woody debris, rocks, gravel and soil, thus saving time and money compared to doing the work post-construction).
2) **Develop an amphibian and reptile salvage and relocation plan**. Assess and plan for the probability that amphibians and reptiles may be encountered during construction. Any animals within the construction area will need to be moved in order to avoid their injury or death and infractions under the *Wildlife Act*. Develop a salvage plan following the protocols outlined in the Best Management Practices for Amphibian and Reptile Salvages in British Columbia.

   Salvage and translocation should only be used when other measures fail; they should never be used as a primary mitigation measure.
3) **Submit an application to the province to obtain a wildlife handling permit at least six weeks (longer if possible) prior to the onset of construction work**.
   - Applicants must submit a General Permit Application, detailed project proposal, and complete BC Animal Care Form to Front Counter British Columbia via mail, in person, or online at http://www.frontcounterbc.gov.bc.ca/Start/fish-wildlife/.
   - Should an emergency salvage become necessary during construction because amphibians and reptiles are unexpectedly found on the project site, all construction that impacts the animals needs to be halted immediately and the regional Ministry of Forests, Lands, Natural Resource Operations and Rural Development office should be contacted for further direction. It is illegal, under the *Wildlife Act*, to knowingly harm or kill amphibians, reptiles, or other wildlife.
   - When amphibians and reptiles are found on a construction site, proper handling procedures should be followed. One of the permit requirements for salvage of amphibians is that all staff follow the Interim Hygiene Protocols for Amphibian Field Staff and Researchers (B.C. MOE 2008) to reduce risk of disease transmission between sites and among animals within a site.
4) **Consult with a QP**. A qualified species expert should be consulted to provide guidance around salvage needs and the permit application. The QP needs to be present or available at all times prior to and during construction to provide guidance around fencing design and installation, if needed (see below), to conduct searches, handle encounters, and to relocate animals.
   - Searches should be conducted daily prior to and during construction activities if work occurs in high-quality or designated amphibian habitat or during the activity period of the target species.

5) **Exclusion fencing**. Where needed, install exclusion fencing between the road construction zone and amphibian and reptile habitats.
    - Use fencing that will last the duration of the road construction project (e.g., a light duty geotextile fence for projects completed within one year or a heavy-duty geotextile fence for longer projects (see section 5.2, Province of British Columbia 2014)). If permanent fencing is going to be installed as part of the mitigation plan (i.e., along roads), the permanent fence can be installed instead of temporary construction fence to avoid extra costs (Photo 63).
    - Fencing should be inspected daily for animals trying to cross the landscape, especially during migratory periods, and for gaps or damage. Animals should be carried across and released on the opposite side of road if it is a known migratory route. Fences should be repaired daily to maintain effectiveness and avoid potential breaches.
    - Fencing should be installed so that construction sediment does not enter into wetlands or aquatic systems.
    - When possible, alternative measures (e.g., rock barriers) should be integrated to create a sufficient barrier between construction sites and adjacent amphibian and reptile habitat.
6) **Control blast size and vibrations** within or adjacent (up to 250 m) to snake habitat using blast mats and other approved measures (Ontario MNR 2011).
7) **Reporting**. Project-specific reporting and handling protocols should be developed in compliance with the requirements of the salvage permit. Observation records should include the observer's name, date and time, species, location (descriptive and georeferenced), photographs, and action(s) taken. Conditions of the Wildlife Act permit require that data and associated reports be submitted to the Wildlife Data & Information site.

6.0 GUIDANCE FOR ROAD MAINTENANCE ACTIVITIES

Road maintenance activities are undertaken to maintain user safety or for engineering and infrastructure concerns. However, as described in Section 2.7, these activities can have ongoing impacts on nearby amphibian and reptile populations and habitat. This section provides information to develop guidance that can be provided to road maintenance contractors for safeguarding amphibians and reptiles and their habitats.

6.1 Assessing and Prioritizing Application of Mitigation Guidelines During Road Maintenance Activities

As with new road construction and expansion projects, road maintenance activities should be preceded by a screening exercise to assess maintenance activities that pose a risk to amphibians and reptiles (Section 2 of this document). The steps outlined in Section 3 (Screening Tool) may be applied to road maintenance activities to create a map of potentially vulnerable habitats (such as wetlands and ditches) and conservation areas (such as identified critical habitat). The maintenance activities should also be assessed for high risk activities (such as removal of a beaver dam that may dramatically change hydrology) and vulnerable time periods (such as during the breeding or migration season (Table 1)). This information can be provided to road maintenance contractors to apply the additional guidelines described below when implementing road maintenance activities.

6.2 Road Surface Maintenance Guidelines

Dust control and stabilization is used to minimize the impact of dust for road users, adjacent properties, and watercourses adjacent to dirt or gravel roads/highways and is usually applied early in the calendar year. De-icers, aggregate, and salt/brine are applied on roads to proactively monitor, anticipate, manage and minimize the development of slippery conditions and restore traction.

Guidelines for amphibians and reptiles:

- Consider alternative, non-chloride/"green" forms of dust control and de-icing agents, especially near sensitive habitats (e.g., adjacent to aquatic breeding sites and streams; see text box below).
- Minimize run-off of dust control agents into adjacent habitats, especially wetlands. Techniques might include pre-wetting surfaces to ensure proper adhesion, not applying dust control agents before, during or immediately after rain, and minimizing spraying on the shoulder.
- Install silt fencing adjacent to wetlands to prevent treated dust and sediment from washing into the wetlands.
- Store hazardous materials, such as de-icing compounds, on impermeable surfaces to prevent their release into soils and groundwater.
- Where possible, avoid depositing large snow and ice accumulations removed from roads into or immediately adjacent to roadside ponds, wetlands, and ditch habitats (where amphibians may breed).
- Reduce sediment runoff from aggregate storage piles to nearby watercourses (e.g., cover storage piles of materials containing de-icing compounds (road salt)).
- Consult the salt management plans outlined in Transportation Association of Canada's Syntheses of Best Practices - Road Salt Management (2013).

6.2 Drainage Maintenance Guidelines

The objective with ditch maintenance is to provide unobstructed drainage for roads.

Guidelines to mitigate potential impacts of drainage maintenance on amphibians and reptiles:

- Ditches in areas of known areas of concern, including critical habitat, should be surveyed for the presence of amphibians (all life stages) and reptiles before drainage maintenance activities are initiated.
- Culverts should be surveyed for the presence of amphibians (e.g., eggs and/or larvae in standing water) and reptiles prior to culvert maintenance activities.
- Ditches containing amphibians or reptiles need to be salvaged prior to the onset of maintenance work, especially where water drainage and/or culvert replacement is occurring. The salvage plan should include monitoring spoil piles for emerging amphibians and reptiles, and a protocol for relocating individuals exposed during excavation (e.g., reptile eggs and/or adults that were underground). An amphibian and reptile QP should assess the likelihood of amphibians and/or reptiles living in the soils within the ditches that require excavating and develop an environmental work window and salvage program, if necessary.
- Refer to the Government of B.C.'s *Best Practices for Drainage Maintenance Works in Oregon Spotted Frog Habitat* for details on BMPs for ditches containing water and aquatic-breeding amphibians.

- Prevent the collection of standing water in ditches, which act as "sink" habitats, by facilitating drainage (sink habitats are aquatic sites that attract amphibians for breeding but dry prematurely, resulting in high egg or larval mortality).
- Where maintenance activities occur within or adjacent to known, important amphibian or reptile habitats (e.g., snake egg-laying and gestating site, snake den, aquatic amphibian breeding site), remove spoil materials to predetermined dumping sites instead of spreading them on site where they may degrade important amphibian and reptile habitats.
- Avoid rip-rap materials where they might impede normal amphibian and reptile movements or impact habitats used by amphibians and reptiles seasonally as part of their life-cycle. Instead, re-seed affected areas with fast-growing, native vegetation to reinforce and maintain shoreline bank stability and provide habitat and cover for amphibians and reptiles.
- If maintenance activities require in-stream work, schedule activities during environmental timing windows (see definition and website links in the Glossary and Resources sections; Sections 5 & 6, respectively). Consult with a QP, as site, species and season specific plans may be required.
- Consult the BC Ministry of Environment's Beaver Dam Removal best management practices document.

6.3 Roadside Vegetation and Wildlife Fence Maintenance Guidelines

Roadside maintenance can include vegetation control and the maintenance of fences that prevent wildlife from entering the road surface. These activities are undertaken to increase visibility for drivers and to prevent mortality of wildlife on roads. Fences are often used to lead amphibians and reptiles to safe crossing structures and in most cases these fences require ongoing maintenance.

The following recommendations can be used to mitigate potential impacts of vegetation, fence and roadside maintenance on amphibians and reptiles:

- Do not mow in sites that have been chemically treated with herbicides within 14 days of treatment. These areas are marked with white treatment signs.
- Specialty wildlife fences along highways, such as the elk fencing along Highway 19 near Courtenay on Vancouver Island, have ¼" galvanized hardware cloth attached to the bottom to direct amphibians (Western Toads) and other smaller wildlife towards wildlife underpasses. The location of these specialty fences needs to be clearly identified for maintenance workers, and guidelines on specific maintenance requirements should be provided.
- Contractors need to be trained in vegetation maintenance along fences to avoid damaging the fence with mowing and trimming equipment (see Photo. X).
- Specialty fences leading amphibians and reptiles towards wildlife underpasses require annual maintenance by trained staff to repair holes and gaps (e.g., from removal of snow and debris off roads, tunnels created by mammals), and to clear away vegetation that can enable animals to climb over the fence (see Section 4.3.4.3). Vegetation within 0.25 m of an amphibian/reptile fence needs to be cut at least annually, timed in advance of seasonal movements of animals.
- Consult with a QP to design a vegetation management plan for use where specialty wildlife fences are installed.
- Research on wildlife fencing materials is rapidly evolving as many materials are tested and modified. At this time, an adaptive management approach is needed regarding allowable material use.

- Limit the use of herbicides for vegetation management where possible—especially in and around aquatic habitats and during the egg and larval development period for amphibians (see Table 1).

In addition to the above guidelines specific to amphibians and reptiles, some road authorities have developed documents that provide general environmental considerations and safety specifications, such as B.C. Ministry of Transport's Environmental Best Practices for Highway Maintenance Activities (2018).

7.0 MONITORING

BC is in the early stages of developing ways to mitigate the impacts of roads on amphibians and reptiles. There is uncertainty about how well best management practices developed in other areas will work for BC's unique set of species and physical landscapes. Adaptive management, or "learning by doing," uses monitoring to reduce uncertainty. **Monitoring is a systematic and long-term process** that gathers information about an implemented project and evaluates whether it has reached its goals and delivered what was expected. Monitoring is essential for improving our knowledge base and ensuring that we are using the most effective techniques.

There are various phases of road projects, including construction, retrofitting, and maintenance activities, that require different types of monitoring:

- **Compliance monitoring** – Did the contractor do as required as laid out in the service contract and the BMPs/guidelines?
- **Maintenance monitoring** – Are the mitigation features (e.g., tunnels and fencing) being maintained so that they function as intended?
- **Effectiveness monitoring** – Are the mitigation features working effectively, keeping amphibians and reptiles off roads and/or allowing animals to pass safely, and are they helping to maintain viable populations of amphibians and reptiles at the site?

Currently, only compliance monitoring may be required as part of a development permit condition, whereas post-construction maintenance and effectiveness monitoring are not often stipulated under permits or regulation. Further, ongoing routine monitoring and maintenance of mitigation structures are not usually factored into annual budgets or contractor or staff scheduling. In a few cases, effectiveness assessments have been conducted when there is collaboration between the road construction proponents and either university or independent researchers. These research projects contribute to improving effectiveness of mitigation measures and also contribute to making implementation more cost-effective. To effectively mitigate the impacts of road management activities on amphibians and reptiles, all three monitoring programs need to be adopted by the road construction and management authorities.

7.1 Compliance Monitoring

Compliance monitoring focuses on **quality assurance and adherence to the mitigation specifications** for each project. For example, routine quality checks are needed during the installation of directive and exclusion fencing to avoid small gaps or folds, which render the fences ineffective.

7.2 Maintenance Monitoring

Maintenance monitoring should be done at critical times throughout the year. Fences should be monitored at the end of the winter/storm season, prior to the active season for amphibians and reptiles (see Table 1): winter weather and snow removal can damage fencing; flooding can erode soil at the base

of fences, especially where they attach to crossing structures, and can also carry cover objects (e.g., logs) out of passageways. Over the spring and early summer, vegetative growth creates "ramps" that allow amphibians and reptiles to climb over fences. Fences should be inspected during the summer to ensure that this overgrown vegetation is cleared away before the late summer and fall migration season. Because vegetation removal techniques can sometimes damage fencing, after roadside work any fences in the area should be inspected for gaps and fixed.

A monitoring checklist should be followed to efficiently reveal when key design features become degraded and need repair. These data can be easily recorded and maintained digitally via a tablet or smart phone:

Example checklist for routine maintenance monitoring of crossing structures with fencing:

Date checked	Maintenance Issue	Y/N	Location (coordinate; UTM or Lat./Long.)	Description of repairs needed, and other comments	Photo #	Date Fixed
	Fence collapse (partial or complete)					
	Holes or gaps through/under fence					
	Bottom of fence still buried					
	Vegetation growing along fence					
	Fence abuts crossing structure					
	Cover objects remain in crossing structure					
	Opening blocked by vegetation or debris					
	Carcasses along fence					
	Carcasses along roadway					

7.3 Effectiveness Monitoring

Effectiveness monitoring focuses on answering the question: how well do the mitigation measures and/or structures reduce the impacts of the road on amphibians and reptiles? Where fences and crossing structures have been constructed, effectiveness monitoring should include, at minimum, data on whether these structures are keeping amphibians and reptiles off roadways and providing safe passage for habitat connectivity. More intensive effectiveness monitoring involves assessing whether the target populations of amphibians and reptiles that were impacted by the road remain stable after mitigation measures are implemented.

A recent review of 50 studies that quantified the relationship between road mortality and mitigation measures designed to reduce road mortality showed that there are insufficient data to answer many of the most pressing questions that road planners ask (Rytwinski et al. 2016). There were two main reasons. First, there was not enough variation in the attributes of the applied mitigation to test for effectiveness, e.g., fence heights were too similar across studies to see an effect on road mortality. Second, key information was unreported, e.g., length of crossing structures and distance between crossing structures was not reported in over 65% of the studies. This highlights the importance of developing a rigorous effectiveness monitoring plan with better research and data reporting for mitigation projects.

7.3.1 Developing an Effectiveness Monitoring Plan & Study Design

An effectiveness monitoring plan includes clear goals, objectives, and questions, and involves a team of experts and collaborators during the early stages of the project to develop a statistically well supported monitoring plan to quantify effectiveness (Rytwinski et al. 2015; Fig. 10). Effectiveness monitoring requires a plan for collecting data in a way that will allow for a comparison of conditions (1) before and after mitigation and (2) along sections of road with and without mitigation. This is referred to as a **Before-After-Control-Impact (BACI)** study design, which is the most reliable way to detect a change in the variable(s) of interest (i.e., rate of road mortality, movements through crossing structures, population size; see Case Study #4 below).

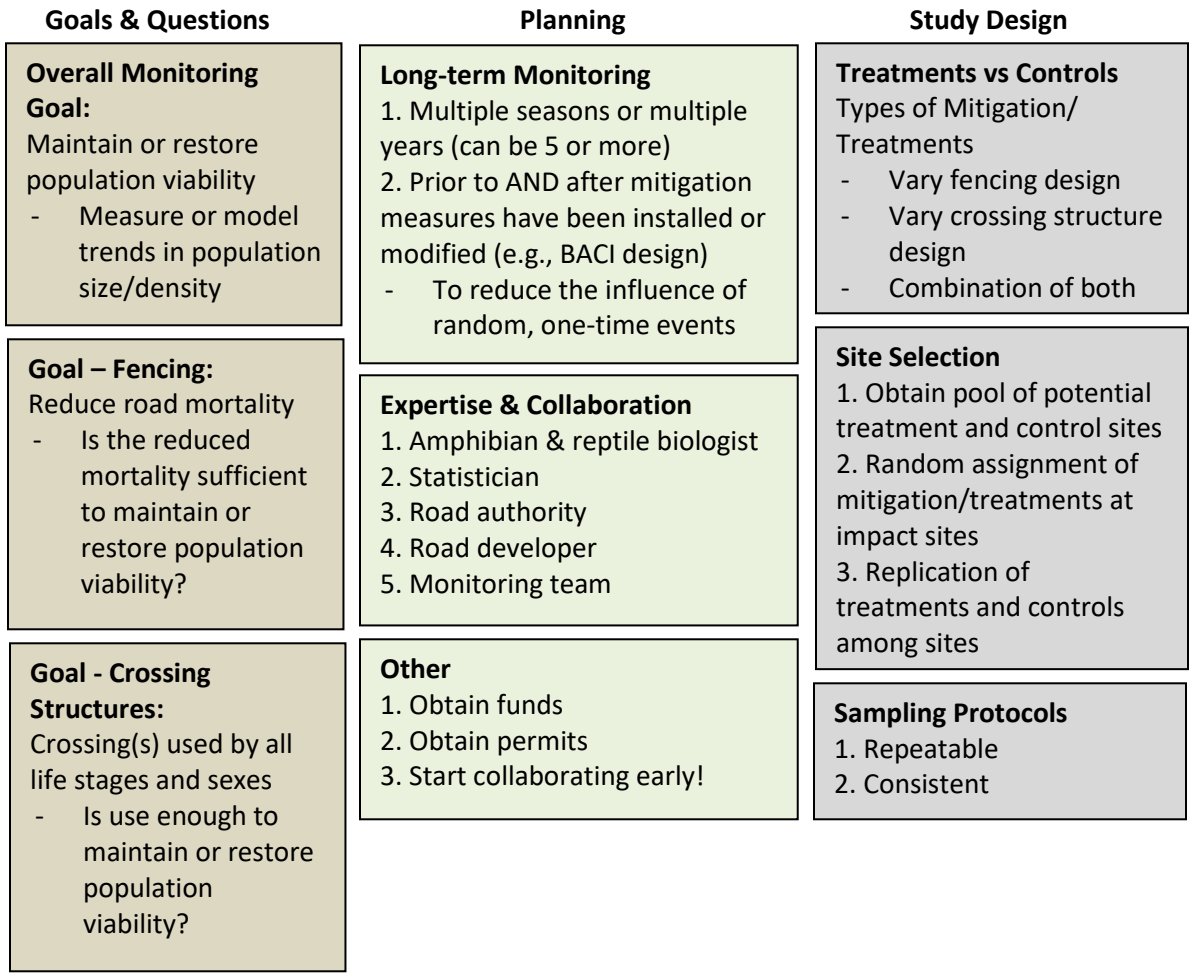


Figure 10. Overview and key elements for planning a rigorous study design that will assess the effectiveness of road mitigation for amphibians and reptiles.

Several seasons of monitoring data from both before and after a road mitigation project are recommended to measure changes. A minimum of four years or four sites in a BACI study design has been recommended by Rytwinski et al. (2016), although the appropriate time frame and number of sites

to monitor should be determined by consulting with experts, including a statistician and a biologist with knowledge of the species' movement patterns at the site(s) of interest. Building a collaborative partnership that includes the road developer, road authority, monitoring group, and experts should be done early. This team needs to work together to obtain funding and permits to carry out multi-season sampling and, ultimately, integrate the results of monitoring into improving mitigation in the future.

Case Stud Study #4 – Before-After-Control-Impact Study on Effectiveness of Fencing Material

The Association of Wetland Stewards for Clayoquot and Barkley Sounds wanted to install barrier fences to reduce amphibian road mortality at a known hotspot along Highway 4 near Ucluelet, B.C. They created a fence using plastic materials (UV-treated HDPE "puckboard") that had the top edge bent to create a rigid overhanging lip (6 cm across and 4 cm down). The purpose of the lip was to make it difficult for amphibians, especially Pacific Treefrogs (*Pseudacris regilla*) to climb over the fence onto the highway. Before installing the fence, they set up a simple BACI study to test the effectiveness of the new fence design in reducing road mortality. They surveyed for dead amphibians on the surface of the road in the morning after rainy nights in the autumn of 2012 (N=11 surveys before installation) and 2013 (N=16 surveys after installation). They compared the amount of road mortality before and after the fence was installed at both fenced (150 m) and unfenced sections (200 m) of the highway. The number of amphibians killed in the fenced section was reduced to 19% of what was found before the installation. Mortality in unfenced areas changed by less than 1%. Mapping of carcasses before and after the fence installation showed that there was no major increase in the numbers killed at each end of the fencing. Thus, the BACI comparison revealed that the new fencing was 80% effective at reducing amphibian road mortality.

Insert images - Barb

7.3.2 Sampling Protocols and Techniques for Effectiveness Monitoring

A variety of sampling protocols and techniques can be used to monitor the effectiveness of mitigation structures, which will depend on the questions being asked:

- *Road Surveys* – Counting the number of dead and alive amphibians and reptiles on the road surface to assess **reductions in road mortality**
- *Fence and Crossing Structure Surveys* – Following the movements of individuals to see if they travel along guiding fences and through crossing structures to **assess habitat connectivity**
- *Population Surveys* – Repeatedly counting the number of individuals in a population over the long term to **assess population viability**

It is very important that protocols and techniques are repeatable and consistent over time and across sites (Fig. 10). Less time, effort and technical skill are generally required for protocols that sample road mortality than protocols that sample habitat connectivity or population viability (Fig. 11). For example, measuring population viability requires a much greater time investment—at least 5 years before and 5 years after mitigation.

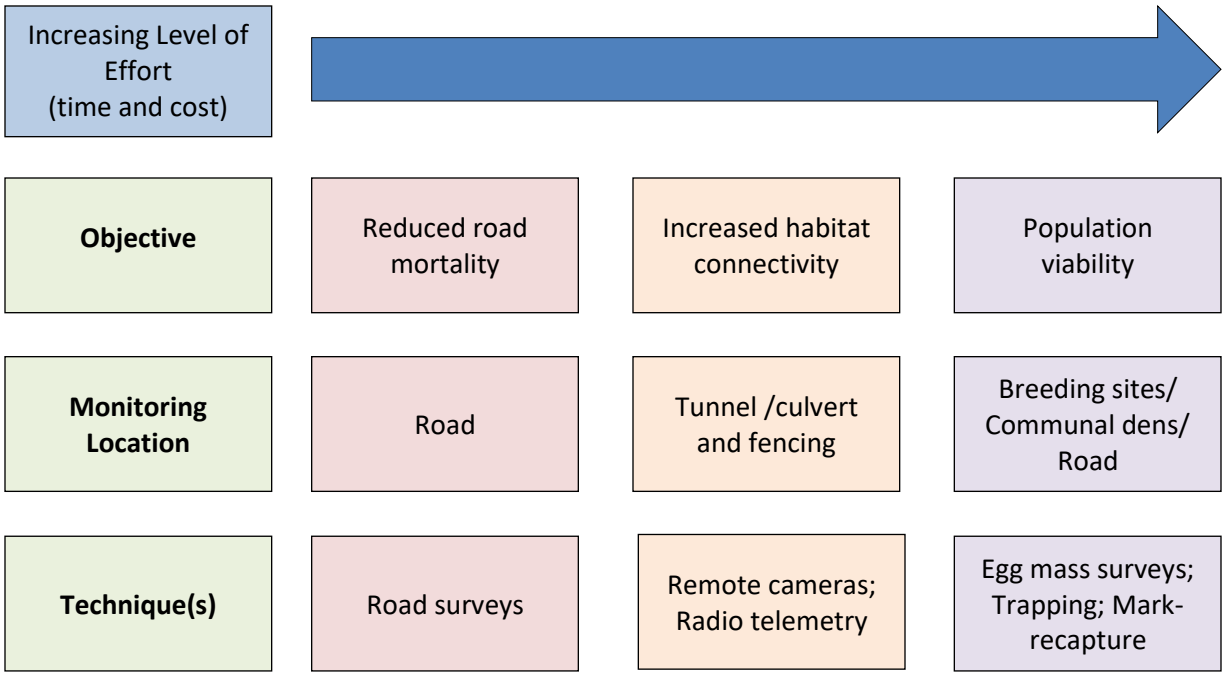


Figure 11. Relative level of effort required to collect data to meet different monitoring objectives, including where the monitoring takes place and example sampling techniques used for each.

7.3.2.1 Road Surveys

Methodical road surveys have been shown to more accurately quantify road mortality rates compared to opportunistic/incidental monitoring of roadkill (Winton 2018). Road surveys gather baseline data on the number and location of amphibians and reptiles crossing and getting killed on the road. Data gathered before mitigation help inform where to position mitigation structures and provide comparisons for after mitigation to see if mortality has been reduced.

Data are collected by driving, cycling, or walking along a selected length of road while looking for alive or dead individuals. Driving surveys allow surveyors to cover a greater distance of road over a sampling period; however, the detectability of small amphibians and reptiles is much lower from vehicles compared with surveying on foot (Langen et al. 2007). Surveys should be conducted with consistent and repeatable methods so that the road can be surveyed the same way before and after mitigation.

Important considerations:

- When a species is common, road surveys may generate adequate data in one or two seasons; however, for rare species, more time may be required.
- Surveys should take place during the active season or movement period for the target species (Table 1).
- Weather conditions, time of day, presence of scavengers, and traffic volumes will all impact detectability of carcasses. Data for these factors need to be recorded, at least during the duration of the road survey. Traffic counters should be installed to count the number of vehicles on an hourly basis daily throughout the active migration season (though traffic counters may not be necessary where road authorities are already collecting and reporting traffic volume data:

http://www.th.gov.bc.ca/trafficData/). Data on the amount of rainfall and temperature throughout the day and night can be obtained from local weather stations.

- For animals that move on rainy nights (e.g., the majority of amphibian species), surveys should be conducted at night, before rain, runoff and morning traffic obliterate carcass remains (Hels and Buchwald 2001, Langen et al. 2007). Bright lights positioned low to the pavement will detect individuals more effectively at night, as will lowering light levels inside the vehicle (i.e., turning headlamps down/off).
- Once mortality occurs and time elapses since mortality, carcasses can disappear or not be detected for a variety of reasons such as predation. Detectability measures (text box) should be obtained by marking and resurveying to assess the number of carcasses that remain or, at minimum, use known detectability multipliers to estimate undetected animals.
    - Amphibians are the most difficult to detect over time because of their small and soft bodies are easily obliterated by traffic, and these mortality surveys are best conducted at night time during the movement period.
    - More than 50% of snake carcasses will disappear in 24 hours, so surveys should be conducted daily during peak movements in spring and fall.
    - Dead turtles persist on roads the longest, so a survey frequency of two to three times per week during nesting season is recommended.
- Note that road surveys may not detect depleted populations (e.g., where road mortality has already depleted the number of individuals adjacent to the road), or species that avoid crossing roads all together.
    - If a population has declined due to road mortality in the past, then the density of amphibians and reptiles killed on the road may be low. Focusing mitigation efforts only on roadkill hotspots may ignore sites with the greatest historical road impact on population size (Eberhardt et al. 2013). Check sites with high traffic where good habitat is near the road, especially where it straddles the road. These may be particularly important locations for mitigation to restore populations.
    - Other survey techniques may be required to detect depleted, rare, or elusive amphibians and reptiles in habitats surrounding roads. Examples of survey techniques include coverboards for snakes, pitfall traps for amphibians, and hoop-net traps for turtles.
    - When information is lacking for rare species, data from a similar but more common species may indicate where road mortality of the rare species occurred.
- Each individual found on the road should be carefully examined and photographed to determine the species, sex, and age class. If possible, the length of the animal should be recorded (e.g., plastron of a turtle, total length of snakes, snout-vent length of frogs and salamanders; Photos x and x).
- Record direction of travel, with the understanding that this information is not always reliable because the individual may have been redirected by traffic.
- Depending on the project, it may also be important to collect a DNA sample or to mark individuals or their locations to avoid double-counting when surveys are repeated.
- Estimates of road mortality rates should account for the factors that might influence the accuracy of the estimate. For example, the equation developed in Winton (2018) for road mortality rate can be applied to surveys of any frequency, as long as survey effort, time between surveys, carcass persistence time/scavenger removal rates, and observer detection probability all are taken into account.

WHY SHOULD WE CONSIDER "DETECTABILITY"?

Numerous factors affect our ability to detect dead amphibians and reptiles on roadways, including observer characteristics (e.g., skill level, mode of travel, fatigue), scavengers, traffic volumes, and variability in carcass deterioration rates. Species that are more vulnerable to scavengers and/or that have carcasses that degrade rapidly may be detected less often by surveyors, making their population numbers or their likelihood of being hit by vehicles appear lower compared to other species. For example, after marking amphibian carcasses and then having different observers survey for them afterwards, < 7% of known salamander carcasses and 32-67% of frog carcasses were refound (detected) by surveyors during walking road surveys (Hels and Buchwald 2001). Using planted snake carcasses, Winton (2018) investigated the rate of carcass removal by scavengers and observer detection probability during road surveys. Fifty-two percent of carcasses were removed from the road by scavengers in two days, while 11% remained for >14 days. The mean observer detection probability was 0.76 for a team of two observers conducting surveys by walking.

CORRECTING FOR DETECTABILITY during road surveys:

To account for missed detections, the number of road-killed amphibians and reptiles found on the roadway can be multiplied by a compensation factor. In the case of the study by Hels and Buchwald (2001), their detections required multiplication of 1.5 and 15 for frogs and salamanders, respectively, for walking surveys. Corrections for driving surveys would have increased the compensation factor to 30 and 300, respectively, because the probability of detection is much lower from a vehicle than on foot (Beebee 2013). Winton (2018) estimated the true number of rattlesnake deaths as 2.7 times the number of dead rattlesnakes detected through all road surveys and incidental observations combined. Note that compensation factors are specific to the species, traffic levels, scavengers, etc. at each site and should not be applied across studies.

There is a great deal of uncertainty in these detectability factors which makes it challenging to accurately relate road kill numbers to actual deaths, but it is possible to calculate relative changes over time at the same place with repeated use of standard methods (Beebee 2013).

Photo x. Length of XX is recorded by...

Photo x. Length of XX is recorded by...

7.3.2.2 Monitoring Crossing Structures and Fencing

Amphibians and reptiles observed along fences and not on the road are evidence that the fences are helping to reduce road mortality; likewise, animals observed moving through tunnels serve as evidence and that crossing structures are providing safe passage and habitat connectivity. Assessments of the **proportion of animals that encounter the fence AND enter into the crossing structure**, and the **proportion of animals that enter crossing structures AND go through them**, are needed to best inform mitigation designs.

A variety of monitoring techniques are used for following the movements of amphibians and reptiles along fences and through crossing structures (see Appendix E for examples of crossing structures that are and have been monitored in BC):

Camera traps: Remote digital cameras are a non-intrusive sampling technique that does not require a wildlife sampling permit. The time lapse setting is used to take pictures of ectothermic (cold-blooded) animals, such as amphibians and reptiles, at regularly spaced intervals (e.g., every minute). In this scenario, approximately 20,000 images are taken over a two-week period. In some cases, camera detection software can help to find wildlife in images (Dillon Consulting Limited 2011). Setting the camera to take photos over shorter intervals (e.g., every 10 seconds) will improve the quality of the data but would require the batteries and SD cards to be replaced more regularly. Some researchers have experimented with using a standard digital camera and a light beam aimed across the bottom of an underpass, which triggers the shutter when the beam is broken by a passing animal (Dulisse 2017). Cameras should be placed at both ends of the underpass, securely fastened, and locked to the underpass structure (photo x). At larger underpasses, cameras should be mounted closer to the ground.

Photo X. Digital camera mounted and locked to crossing structure.

Sand pits, ink pads, and fluorescent powder: Surfaces at the entrance or inside crossing structures can be set up to receive tracks. Sand, cleaned and free of plant seeds, can be laid down on top of existing soil and litter and raked smooth after each inspection. Sticky ink or fluorescent powder can be placed in a shallow well or on a card adjacent to blank cardboard where animals will leave prints after they have moved across the ink/powder. These techniques rely on being able to identify the tracks of species. It may be challenging to distinguish tracks if there are a number of animals moving across the track pad.

Pitfall traps with fencing: Pitfall traps are buckets, cans, or other containers buried flush with the ground along a fence. The fence directs moving animals towards the traps. The use of pitfall traps requires a wildlife sampling permit from the provincial government. Pitfall traps need to be large enough that the target species cannot climb or jump out of the containers. In addition, once traps are set they need to be checked regularly (at least twice per day, and as frequently as every 6 hours in some areas) to avoid drowning, desiccation, or predation of individuals. Traps can be set at the entranceway and exit of a crossing structure to assess how many animals are moving to and through the crossing

structure. Traps can also be set in arrays within nearby habitats to assess the number of animals in the vicinity of the road. This technique provides a useful opportunity to capture, mark, and recapture individuals (see next technique).

Capture-mark-recapture: Capturing, marking, and recapturing animals can be used to determine if individuals are crossing a road, and as a method of assessing population levels. Several methods exist for marking amphibians and reptiles, including inserting Passive Integrated Transponders (PIT), notching scutes on turtles, marking salamanders and frogs with visible implant elastomer dye (e.g., MacNeil et al. 2011), and using image recognition software. Some of these techniques are discussed in more detail in the Canadian Council on Animal Care (2004) manual. Mark-recapture methods for turtles are discussed in detail in Robertson et al. (2013) and for all reptiles in McDiarmid et al. (2012).

Radio telemetry and passive data loggers/PIT tag readers: Radio-telemetry can be used to monitor amphibian and reptile movements using a handheld receiver (photos x and x), while passive data loggers (photo x) or PIT tag readers can be mounted near crossing structure entrances (James et al. 2011, Caverhill et al. 2011) to record the movement of marked individuals.

Table 5 provides a comparison of the advantages and disadvantages of these methodologies. A combination of several methods will provide the most robust data set and eliminate most of the disadvantages of any one method. For example, using both hand-held radio telemetry and passive receivers mounted in the crossing structures will provide high-quality data on crossing events as well as the detailed movements of individuals in relation to the crossing structures and the road.

Table 5. Advantages and disadvantages of techniques used to monitor road crossing structures.

Technique	Advantages	Disadvantages
Mounted digital cameras	• Provides information on the time and date of the crossing event • Should detect most individuals using the crossing structure if cameras are set to take photos regularly (e.g., every minute)	• Does not provide detailed information on the individuals using the structure (e.g., sex) • Effective cameras are expensive, and there is a risk of theft • It can be very time-consuming to review photographs and maintain cameras (downloading pictures, adjustments, batteries, water levels, etc.) • Cameras typically do not work under aquatic conditions
Pitfall and Funnel Traps	• Traps within a crossing structure provide information on the individuals using the structure (e.g., sex) and the date of the crossing event • Trapped animals can be used for genetic sampling to assess genetic mixing across roads	• Labour-intensive and costly for set up and sampling, as the traps should be checked at least twice per day • Risk of animals dying in traps • Risk of attracting predators to crossing structures
Capture-Mark-	• May be possible to capture and	• Does not provide direct evidence that

Technique	Advantages	Disadvantages
Recapture	recapture marked individuals from one side of the road to the other • The best way to obtain estimates of absolute population abundance using a crossing structure (with enough sampling)	animals used the crossing structure (e.g., cannot rule out crossing through holes in fence or at fence ends) • May not provide information on the time and date of crossings • Detection of individuals crossing the road is limited to the number of animals captured and subsequently recaptured • Labour- and time-intensive
Radio-telemetry and passive data loggers	• Provides information on the individuals using the structure (e.g., sex) and the time and date of crossing (PIT tags only) • Passive data loggers and PIT tag readers in the structure provide direct evidence that the structures are used (if placed at each end of the tunnel) • Radio-telemetry can track movements in relation to the road (e.g., home range size) • Will work under aquatic conditions	• Considerable field time, effort, and cost may be required to capture, handle, and monitor animals • Detection of individuals crossing the road is limited to the type and number of animals that are captured and tagged or tracked (e.g., only larger adults of some species are large enough to be tagged) • Radio-telemetry is unlikely to provide direct evidence that the structure is used, so it is ideal to combine this with passive readers mounted inside the structure

7.3.2.3 Monitoring Population Trends

The best sampling protocol for monitoring population sizes over the long term depends on the species' life cycle. Communal breeding sites or hibernacula may be the most efficient places to do annual surveys. Road survey data for species that move in large numbers all at once can also be used to estimate population trends; however, possible changes in traffic volume or changes in movement patterns due to habitat loss over time need to be considered. For a few species of amphibians in BC, it is possible to measure relative abundance by counting the number of egg masses laid in ponds near roads or by doing auditory surveys of the breeding calls. For many species, however, more time-intensive sampling or capture-mark-recapture projects are needed to monitor changes in relative abundance and population size. To prevent disease transmission among amphibians and between habitats, it is important for all field workers to follow the hygiene protocols developed by the B.C. Ministry of Environment (B.C. MOE 2008) and the decontamination protocols developed by the Canadian Herpetofauna Health Working Group (HHWG 2017).

A variety of sampling protocols can be used to monitor population trends for amphibians and reptiles:

Capture-mark-recapture techniques may be used to estimate population size, but a large number of individuals need to be marked and recaptured to produce statistically significant estimates. Population

trends (decreasing, increasing, or stable) can be observed if capture-mark-recapture sampling is repeated over time.

Relative abundance surveys (counts of animals per area and standardized by search effort) require a systematic study design with regular surveys by trained individuals to reduce observer bias. Surveys are carried out using standardized methods, such as timed searches, grids, or transects, that allow for comparisons over time or between sites. Visual searches, coverboards, and/or pitfall traps may be employed. Two effective measures of relative abundance for certain species of amphibians are counts of egg masses and call surveys.

Counts of egg masses provide efficient and non-invasive measures of the relative abundance of breeding amphibians. This technique can only be used for species in which individual breeding females lay single egg masses that are easy to distinguish and detect. Protocols should follow those outlined by provincial standards (RISC 1998a). Egg mass identification guides are available (Thoms et al. 2006, http://saltspringconservancy.ca/wp-content/uploads/2016/04/Pictorial-aquatic-egg-key6-logos.pdf). In BC, counts are possible for egg masses of Northern Red-legged Frogs (*Rana aurora*), Oregon Spotted Frogs (*Rana pretiosa*), Columbia Spotted Frogs (*Rana luteiventris*), Wood Frog (*Lithobates sylvaticus*), Northern Leopard frog (*Lithobates pipiens*), and Northwestern Salamanders (*Ambystoma gracile*).

Call surveys may be used to collect relative abundance data for toads and frogs at breeding ponds near roads, and do not require direct observation of the animals. Data logger monitoring devices can also be employed. However, in BC this monitoring technique is limited because few frog and toad species produce audible (surface detectable) calls. This technique is applicable to the Great Basin Spadefoot Toad (*Spea intermontana*), Wood Frog (*Lithobates sylvaticus*), Boreal Chorus Frog (*Pseudacris maculata*), and Northern Pacific Treefrog (*Pseudacris regilla*). Northern red-legged frogs (*Rana aurora*) produce calls underwater, which can be detected with the aid of a handheld hydrophone.

Genetic sampling involves taking blood or tissue samples from live or dead individuals to compare genetic relatedness and structuring (e.g., sex and age ratios) across the landscape bisected by the road before and after a road mitigation project (e.g., James et al. 2011).

Further information regarding methods for surveying amphibians and reptiles can be found in Heyer et al. (1994), Konze et al. (1997), and McDiarmid et al. (2012). RISC (1998b) and the Canadian Council on Animal Care (CCAC 2004) provide excellent manuals for handling and capturing amphibians and reptiles.

7.3.2.4. Population Viability Modelling

If it is not feasible to measure population size or relative abundance, then population viability modelling can be used to analyze the effect of mitigation on population levels (Section 2.4). **This approach integrates data on the changes in road mortality and movements across roads with life-history traits**.

Life-history traits are quantified as "vital rates" and include:

- average female fecundity (number of eggs laid per year per female),
- hatching success (number of eggs that hatch),
- juvenile survival (number of juveniles that grow from hatchling to sub-adult),
- sub-adult survival (number of sub-adults that reach adulthood), and
- adult survival (annual survival rates of adults from one breeding season to the next).

Vital rates for the female component of the population are necessary, and models improve with information about males. It can take years of effort to measure vital rates for local populations. Therefore, estimates from the literature are often used. Overall, this approach is a useful way of predicting relative, long-term changes in populations with and without mitigation. The accuracy of the model depends on the accuracy of the data input.

Data that need to be monitored for modeling purposes include:

- sex and age classes of individuals killed on the road
- sex and age classes of individuals moving through crossing structures in each direction
- proportion of individuals, by sex and age class, killed on the road

If particular individuals, such as breeding females, do not use a crossing structure to access breeding sites, this will lead to reduced breeding success and population declines. This would be true even if traffic mortality overall for the species has been reduced because some individuals, such as juveniles, use the crossing structure.

HOW DIFFERENCES IN LIFE-HISTORY TRAITS INFLUENCE POPULATIONS AFFECTED BY ROADS

The results from population viability models show that differences in life history traits across species are important when considering population responses to road mortality. Finding many dead animals of a specific species on a road does not necessarily reflect greater population impacts for that species. Species with lower reproductive output (e.g., some snake species) suffer more by the loss of only a few individuals than species with high reproductive output (e.g., some frog and toad species). In addition, the loss of only a few reproductively mature individuals has a greater impact on the population than the mortality of hundreds of subadults attempting to cross a road. For more information, see Section 2.4.

7.4 Communication Needs for Adaptive Management

Adaptive management consists of using the results from monitoring to inform decision-making. Monitoring, research, and open communication among project partners (e.g., people conducting the monitoring, the road authority, contractors, experts, etc.) and across projects facilitate this process. The B.C. Herpetofauna and Roads conferences and working group provide an opportunity to share information and build a pool of experts working in this field. Ongoing communication through annual conference calls of the B.C. Herpetofauna and Roads working group and face-to-face workshops once every five years will ensure that these guidelines are kept up-to-date and that road impacts on amphibians and reptiles are prevented and mitigated using the most current science and adaptive management techniques available.

8 REFERENCES

Alberta Northern Leopard Frog Recovery Team. 2005. Alberta Northern Leopard Frog Recovery Plan, 2005-2010. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No.7. Edmonton, AB. 26 pp.

Allaback, M. L., and D. M. Laabs. 2002. Effectiveness of road tunnels for the Santa Cruz Long-toed Salamander. Transactions of the Western Section of the Wildlife Society 38:5–8.

Amphibian and Reptile Conservation. 2009. Common toads and roads: Guidance for planners and highways engineers (England). Booklet, published by Amphibian and Reptile Conservation.

Andrews, K. M., and J. W. Gibbons. 2005. How do highways influence snake movement? Behavioral responses to roads and vehicles. Copeia 2005:772–782.

Andrews, K. M., J. W. Gibbons, and D. M. Jochimsen. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. Pages 121–143 in R. E. Mitchell, J. Brown, and B. Bartholomew, editors. Urban Herpetology, Society for the Study of Amphibians and Reptiles.

Antworth, R. L., D.A. Pike, and E.E. Stevens. 2005. Hit and Run: Effects of scavenging on estimates of roadkilled vertebrates. Southeastern Naturalist 4:647-656

Ardea Biological Consulting Ltd. 1999

Aresco, M. J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69:549–560.

Arizona Game and Fish. 2010. Safe roads for people and wildlife: culverts and fencing to reduce wildlife-vehicle collisions and maintain permeability. Available from http://www.rtamobility.com/images/stories/pdfs/RTAWLL/2010/RTAWLL-2010-05-14-Presentation%20Safe%20Roads%20for%20%20People%20and%20Wildlife.pdf.

Ascensão, F., and A. Mira. 2007. Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. Ecological Research 22:57–66.

Ashley, E. P., and J. T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110:403–412.

Ashley, E. P., A. Kosloski, and S. A. Petrie. 2007. Incidence of intentional vehicle-reptile collisions. Human Dimensions of Wildlife 12:137–143.

Ashpole, S.L., J. Crosby and B. Persello. 2018. Evaluating roadkill mitigation structure cost and longevity. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Austin, M.A., D.A. Buffett, D.J. Nicolson, G.G.E. Scudder and V. Stevens (eds.). 2008. Taking nature's pulse: the status of biodiversity in British Columbia. Biodiversity BC, Victoria, B.C. 268 pp. Accessed at www.biodiversitybc.org 19 March 2018.

Babbitt, K. J. 2005. The relative importance of wetland size and hydroperiod for amphibians in southern New Hampshire, USA. Wetlands Ecology and Management 13:269–279.

Bain, T.K. 2014.Evaluating the effect of moisture in wildlife crossing tunnels on the migration of the California tiger salamander, *Ambystoma californiense.* Master of Science thesis. Sonoma State University, Rohnert Park, California.

Barthelmess, E. L., and M. S. Brooks. 2010. The influence of body-size and diet on road-kill trends in mammals. Biodiversity and Conservation 19:1611–1629.

Baxter-Gilbert, J. H. 2014. The long road ahead: understanding road-related threats to reptiles and testing if current mitigation measures are effective at minimizing impacts. Master of Science thesis. Laurentian University.

Baxter-Gillbert, J.H., J.L. Riley, D. Lesbarreres and J.D. Litzgus. 2015. Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness. PLoS ONE 10(3): e0120537.

Beasley, B. 2006. A study of the incidence of amphibian road mortality between Ucluelet and Tofino, British Columbia. Wildlife Afield, 3:1 Supplement: 23-28.

Beasley, B.A. 2012. Amphibian rite of passage: designing and testing the effectiveness of culverts for connecting habitats in coastal British Columbia, Canada. Abstract. World Congress of Herpetology, Vancouver, 2012.

Beasley, B. A. 2013. The SPLAT project: Mitigating amphibian road mortality in the Clayoquot Sound UNESCO Biosphere Reserve. FrogLog 21:20–22.

Beasley, B. 2018a. Designing effective barriers to reduce road mortality and guide amphibians to crossing structures on Highway 4 on the west coast of Vancouver Island. Part 2: BACI design to test roadside HDPE fencing. Abstract and poster at the Herpetofauna and Roads Workshop II, B.C. Ministry of Environment, Kamloops, September 21, 2018.

Beasley, B. 2018b. SPLAT Project update: mitigation and monitoring of road effects on amphibians crossing Highway 4 on the west coast of Vancouver Island. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141:2550–2563.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2009. Seasonally dynamic habitat use by Spotted (*Clemmys guttata*) and Blanding's turtles (*Emydoidea blandingii*) in Maine. Journal of Herpetology 43:636–645.

Beaudry, F., P. G. deMaynadier, and M. L. Hunter. 2010. Nesting movements and the use of anthropogenic nesting sites by Spotted Turtles (*Clemmys guttata*) and Blanding's Turtles (*Emydoidea blandingii*). Herpetological Conservation and Biology 5:1–8.

Beben, D. 2016. Crossings construction as a method of animal conservation. Transportation Research Procedia 14:474-483.

Beebee, T.J.C. 2013. Effects of road mortality and mitigation measures on amphibian populations. Conservation Biology **27**:657-668.

Beckmann, C. and R. Shine. 2012. Do drivers intentionally target wildlife on roads? Austral Ecology 37:629-632.

Bellis, M., S. Jackson, C. Griffin, P. Warren, and A. Thompson. 2007. Utilizing a multi-technique, multi-taxa approach to monitoring wildlife passageways on the Bennington Bypass in Southern Vermont. Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Beresford, H. 2018. Western Toad Tunnel. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Bertram, N., K. Larsen, and J. Surgenor. 2001. Identification of critical habitats and conservation issues for the Western Rattlesnake and Great Basin Gopher Snake within the Thompson-Nicola region of British Columbia. BC Ministry of Water, Land and Air Protection and the Habitat Conservation Trust Fund of BC, Kamloops, British Columbia. 55 pp.

Biolinx Environmental Research and Nicola Naturalist Society. 2013. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July - August 2013. Unpublished report to BC Parks. 26 pp.

Biolinx Environmental Research and Nicola Naturalist Society. 2014. Western Toad monitoring study in Kentucky Alleyne Provincial Park, July - August 2014. 36 pp. Unpublished report to BC Parks. 26 pp. Website: http://www.nicolanaturalists.ca/files/KA-Toad-Report-15-Dec-2014-sm.pdf (accessed June 2018)

Bings, B. and J. Steciw. 2018. Western Pond Turtle Highway Crossing. Abstract Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment. March 9, 2018.

Bissonette, J., C. A. Kassar, and L. J. Cook. 2008. Assessment of costs associated with deer–vehicle collisions: human death and injury, vehicle damage, and deer loss. Human-Wildlife Conflicts 2:122-130.

Bissonette, J. A., and W. Adair. 2008. Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. Biological Conservation 141: 482-488.

Blood and Henderson 2000

Bouchard, J., A. T. Ford, F. E. Eigenbrod, and L. Fahrig. 2009. Behavioral responses of Northern Leopard Frogs (*Rana pipiens*) to roads and traffic: Implications for population persistence. Ecology and Society 14. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art23/.

B.C. Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). 2004. Guidelines for Amphibians and Reptiles conservation during urban and rural land development in British Columbia. Victoria, British Columbia. 156 pp. http://www.env.gov.bc.ca/wld/BMP/bmpintro.html#second

B.C. Ministry of Environment (MOE). 2008. Interim Hygiene Protocols for Amphibian field staff and

researchers. Ecosystems Branch, Ministry of Environment, Victoria, B.C. [online] URL: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/bc_protocol-amphibian_field_researchers.pdf

B.C. Ministry of Environment (MOE). 2014. Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures). Version 1.0. B.C. Ministry of Environment, Victoria, BC. 70 pp.

B.C. Ministry of Environment (MOE). 2015. Management plan for the Coeur d'Alene Salamander (*Plethodon idahoensis*) in British Columbia. B.C. Ministry of Environment, Victoria, BC. 23 pp.

B.C. Ministry of Transportation and Infrastructure (MOTI). 2019. Recognized Products List January 1st 2019 Edition. New Products Evaluation Standing Committee, B.C. Ministry of Transportation and Infrastructure, Victoria, BC. 99 pp.

B.C. Ministry of Water, Land and Air Protection 2004

B.C. Species and Ecosystem Explorer. 2018. BC Ministry of Environment. Victoria, BC Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Feb 21, 2018).

Brooks, R. J., G. P. Brown, and D. A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the Common Snapping Turtle (*Chelydra serpentina*). Canadian Journal of Zoology 69:1314–1320.

Brown, J. 2006. The movement patterns, activity range size, and habitat preference of the Great Basin Gopher Snake (Pituophis melanoleucus) at Vaseux Lake: 2005 preliminary results. Unpubl. report prepared for Environment Canada.

Brown, W.S., and W.S. Parker. 1976. Movement ecology of Coluber constrictor near communal hibernacula. Copeia 1976:225-242.

Browne, C. 2010. Habitat use of the Western Toad in north-central Alberta and the influence of scale. Ph.D. dissertation, Department of Biological Sciences, University of Alberta, Edmonton, Alberta.

Browne, C. L., and C. A. Paszkowski. 2010. Factors affecting the timing of movements to hibernation sites by western toads (*Anaxyrus boreas*). Herpetologica 66: 250-258.

Buchanan, I. D., and D. Basso. 2007. Under the boardwalk – case history – St. John's sideroad at the Mckenzie wetland, Aurora, Ontario, Canada. Pages 100–113 in C. L. Irwin, D. A. Nelson, and K. P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. Available from http://escholarship.org/uc/item/6vr0n5bq (accessed February 25, 2014).

Bull, E. L. 2006. Sexual differences in the ecology and habitat selection of western toads (Bufo boreas) in northeastern Oregon. Herpetological Conservation and Biology 1: 27-38.

Canadian Council on Animal Care. 2004. CCAC species-specific recommendations on: AMPHIBIANS AND

REPTILES. Canadian Council on Animal Care, Ottawa, Ontario. Available from http://www.ccac.ca/Documents/Standards/Guidelines/Add_PDFs/Wildlife_Amphibians_Reptiles.pdf.

Canadian Environmental Assessment Agency. 2006. Glossary –Terms Commonly Used in Federal Environmental Assessments. Canadian Environmental Assessment Agency Training and Guidance. Ottawa, ON. Obtained from the World Wide Web March 23, 2018: http://publications.gc.ca/collections/collection_2008/ec/En106-58-2006E.pdf.

Canadian Herpetofauna Health Working Group (HHWG). 2017. Decontamination Protocol for Field Work with Amphibians and Reptiles in Canada. Obtained from the World Wide Web January 11, 2019: http://www.cwhc-rcsf.ca/docs/HHWG%20Decontamination%20Protocol%202017-05-30.pdf

Carr, L. W., and L. Fahrig, 2001. Effect of road traffic on two amphibian species of differing vagility. Conservation Biology 15: 1071–1078.

Carsignol. J. 2005 (translated to English 2007). Facilities and measures for small fauna: technical guide. Ministry of Transportation and Infrastructure, Technical Department for Transport, Road and Bridges Engineering and Road Safety. Bagneux Cedex, France.

Caverhill, B., B. Johnson, J. Phillips, E. Nadeau, M. Kula, and R. Holmes. 2011. Blanding's tTurtle (*Emydoidea blandingii*) and Snapping tTurtle (*Chelydra serpentina*) habitat use and movements in the Oakland Swamp wetland complex, Ontario, Canada, and their response to the Provincial Highway 24 exclusion fence and aquatic culvert ecopassage from 2010-2011. Report prepared by the Toronto Zoo, Adopt-A-Pond Programme, Toronto, ON.

Central Lake Ontario Conservation Authority March 2015. Watershed Wildlife and Corridors Protection and Enhancement Plan - Action Plan #5. Oshawa, ON.

Chan-McLeod, A.A. 2003. Factors affecting the permeability of clearcuts to red-legged frogs. Journal of Wildlife Management 67:663–671.

Charry B., and J. Jones. 2009. Traffic volume as a primary road characteristic impacting wildlife: a tool for land use and transportation planning. Session 142. Technical Tools for Integrating Ecological Considerations in Planning and Construction. ICOET Proceedings 2009. Pp. 159-172. https://escholarship.org/uc/item/4fx6c79t.

Church, D., L. Bailey, H. Wilbur, W. Kendall, and J. Hines. 2007. Iteroparity in the variable environment of the salamander Ambystoma tigrinum. Ecology 88(4):891- 903.

Clark, R. W., W.S. Brown, R. Stechert, and K.R. Zamudio. 2010. Roads, interrupted dispersal, and genetic diversity in timber rattlesnakes. Conservation Biology 24:1059-1069.

Clark, R.W., M.N. Marchand, B.J. Clifford, R. Sechert and S. Stephens. 2011. Decline of an isolated timber rattlesnake (*Crotalus horridus*) population: interacions between climate change, disease, and loss of genetic diversity. Biological Conservation 144:886-891.

Clarke, R. and A. Gruenig 2002. Summary Report: Painted Turtle (*Chrysemys picta belli*) nest site enhancement and monitoring Elizabeth Lake, Cranbrook, B.C. Unpublished report for Columbia Basin Fish and Wildlife Compensation Program Rocky Mountain Naturalists, Nelson, B.C.

Clayton, G. and D. Bywater. 2012. BMPs for Public Works Department working within the Georgian Bay Biosphere Reserve. Georgian Bay Biosphere Reserve. Parry Sound, Ontario. 16 pp. http://www.gbbr.ca/download/Species%20at%20Risk/BMPs%20Working%20in%20SAR%20Habitat.pdf

Clegg, S. 2011. Assessing the impacts of vehicular mortality of migrating amphibians near Ryder Lake, B.C. Report for the Fraser Valley Conservancy. http://fraservalleyconservancy.ca/wp-content/uploads/2011/11/RLAPP-Data-Report-24-02-2011-updated-01-11-11.pdf

Clevenger, A. P. 2012. Mitigating continental-scale bottlenecks: How small-scale highway mitigation has large-scale impacts. Ecological Restoration **30**:300–307.

Clevenger, A. P., and M. Huijser. 2011. Wildlife crossing structures handbook: Design and evaluation in North America. Report # FHWA-CFL/TD-11-003. Federal Highway Administration, Washington, D.C. 223 pp.

Clevenger, A. P., B. Churszcz, K. Gunson, and J. Wierzchowski. 2002. Roads and wildlife in the Canadian Rocky Mountain Parks – movement, mortality, and mitigation. Final Report to Parks Canada. Banff, AB.

Clevenger, A. P., M. McIvor, D. McIvor, B. Chruszcz, and K. Gunson. 2001. Tiger salamander, *Ambystoma tigrinum*, movements and mortality on the Trans-Canada Highway in southwestern Alberta. Canadian Field-Naturalist **115**:199–204.

Coffin, A. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15(5):396-406.

Colley, M., Lougheed, S.C., Otterbein, K. and J.D. Litzgus 2017. Mitigation reduces road mortality in a threatened rattlesnake. Wildlife Research 44:48-59.

Collins, S.J., and R.W. Russell. 2009. Toxicity of road salt to Nova Scotia amphibians. Environmental Pollution. Volume 157 (1): 320-324.

Collinson, W. J., D.M. Parker, R.T. Bernard, B.K. Reilly, and H.T. Davies-Mostert. 2014. Wildlife road traffic accidents: a standardized protocol for counting flattened fauna. Ecology and Evolution, 4:3060-3071.

Compton, B. W., and P. R. Sievert. 2002. An evaluation of turtle tunnels and curbs at Towermarc Office Park. Unpublished report. University of Massachusetts, Amherst, MA, USA.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology **7**:826–833.

COSEWIC. 2002a. COSEWIC assessment and update status report on the Spiny Softshell Turtle *Apalone spinifera* in Canada. Page vii + 17. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2002b. COSEWIC assessment and status report on the Milksnake *Lampropeltis triangulum* in Canada. Page vi + 29. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2004. COSEWIC assessment and update status report on the Spotted Turtle *Clemmys guttata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2005. COSEWIC assessment and update status report on the Blanding's Turtle *Emydoidea blandingii* in Canada. Page viii + 40. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2006. COSEWIC assessment and update status report on the Lake Erie watersnake *Nerodia sipedon insularum* Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007a. COSEWIC assessment and update status report on the Eastern Hog-nosed Snake *Heterodon platirhinos* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007b. COSEWIC assessment and update status report on the Wood Turtle *Glyptemys insculpta* in Canada. Page vii + 42. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007c. COSEWIC assessment and update status report on the Gray Ratsnake *Elaphe spiloides* (Great Lakes/St. Lawrence population and Carolinian population) in Canada. Page vii + 33. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2007d. COSEWIC assessment and update status report on the Five-lined Skink *Eumeces fasciatus* (Carolinian population and Great Lakes/St. Lawrence population) in Canada. Page vii + 50. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC 2007. COSEWIC assessment and update status report on the Great Basin Spadefoot Spea intermontana in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 34 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2008a. COSEWIC assessment and status report on the Snapping Turtle *Chelydra serpentina* in Canada. Page vii + 47. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2008b. COSEWIC assessment and update status report on the Eastern Foxsnake *Elaphe gloydi*, Carolinian population and Great Lakes/St. Lawrence population, in Canada. Page vii + 45. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010a. COSEWIC assessment and status report on the Jefferson Salamander *Ambystoma jeffersonianum* in Canada. Page xi + 38. Committee on the Status of Endangered Wildlife in Canadaa. Ottawa.

COSEWIC. 2010b. COSEWIC assessment and status report on the Fowler's Toad *Anaxyrus fowleri* in

Canada. Page vii + 58. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010c. COSEWIC assessment and status report on the Butler's Gartersnake *Thamnophis butleri* in Canada. Page xi + 51. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2010d. COSEWIC assessment and status report on the Queensnake *Regina septemvittata* in Canada. Page vii + 34. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012a. COSEWIC assessment and status report on the Eastern Musk Turtle *Sternotherus odoratus* in Canada. Page xiii + 68. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012b. COSEWIC assessment and status report on the Eastern Ribbonsnake *Thamnophis sauritus* Atlantic population, Great Lakes population in Canada. Page xii + 39. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012c. COSEWIC assessment and status report on the Massasauga *Sistrurus catenatus* in Canada. Page xiii + 84. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012d. COSEWIC assessment and status report on the Western Toad *Anaxyrus boreas* in Canada. Page 21. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 71 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the Great Basin Gophersnake *Pituophis catenifer deserticola* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 53 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the Northern Map Turtle *Graptemys geographica* in Canada. Page xi + 63. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2014a. COSEWIC status appraisal summary on the Western Skink *Plestiodon skiltonianus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xvi + pp.

COSEWIC. 2014b. COSEWIC assessment and status report on the Wandering Salamander Aneides vagrans in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 44 pp

COSEWIC 2014 – Coastal Giant Salamander

COSEWIC. 2015a. COSEWIC assessment and status report on the Western Rattlesnake Crotalus oreganus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 44 pp.

COSEWIC. 2015. COSEWIC assessment and status report on the Eastern Yellow-bellied Racer Coluber constrictor flaviventris and Western Yellow-bellied Racer Coluber constrictor mormon in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xvii + 64 pp.

COSEWIC. 2016. COSEWIC assessment and status report on the Northern Rubber Boa Charina bottae in

Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 38 pp. (http://www.registrelep-sararegistry.gc.ca/default_e.cfm)..

Cosgrove, A.J., T.J. McWhorter and M. Maron. 2018. Consequences of impediments to animal movements at different scales: a conceptual framework and review. Diversity and Distributions 24:448-459. https://doi.org/10.111/ddi/12699

Crisafulli C.M., Trippe L.S., Hawkins C.P., MacMahon J.A. (2005) Amphibian Responses to the 1980 Eruption of Mount St. Helens. In: Dale V.H., Swanson F.J., Crisafulli C.M. (eds) Ecological Responses to the 1980 Eruption of Mount St. Helens. Springer, New York, NY

Crosby, J. 2014. Amphibian occurrence on South Okanagan roadways: investigating movement patterns, crossing hotspots, and roadkill mitigation structure use at the landscape scale. MSc Thesis, University of Waterloo, Ontario. 95 pp.

Crowley, J. F. 2006. Are Ontario reptiles on the road to extinction? Anthropogenic disturbance and reptile distributions within Ontario. Master's thesis. University of Guelph, Guelph, Ontario.

Cushman, K.A., and C. Pearl. 2007. A conservation assessment for the Oregon spotted frog (Rana pretiosa). USDA Forest Service Region 6. USDI Bureau of Land Management, Oregon and Washington. 47 pp.

Cunnington, G.M., E. Garrah, E. Eberhardt and L. Fahrig. 2014. Culverts alone do not reduce road mortality in anurans, Écoscience, 21:1, 69-78, DOI: 10.2980/21-1-3673

Daugherty C.H. and A.L. Sheldon 1982. Age-specific movement patterns of the frog Ascaphus truei. Herpetologica 38:468-474.

Davis, T.M. 1991. Natural history and behavior of the salamander, Aneides ferreus Cope. M.Sc. thesis. University of Victoria, Victoria, B.C. 149 pp

Davis, T. M. 2000. Ecology of the western toad (Bufo boreas) in forested areas on Vancouver Island. Final Report; unpublished report for Forest Renewal B.C., Ministry of Forestry, Victoria, British Columbia.

Davies, T.W., J. Bennie and K.J. Gaston. 2012. Street lighting changes the composition of invertebrate communities. Biology Letters 8:764-767.

Deguise, I., and J.S. Richardson. 2009a. Movement behaviour of adult western toads in a fragmented, forest landscape. Canadian Journal of Zoology 87:1184-1194.

deMaynadier, P. G., and M. L. Hunter Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Review 3:230–261.

deMaynadier, P. G., and M. L. Hunter Jr., 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal 20: 56–65.

De Rivera, C. E., and L. L. Bliss-Ketchum. 2010. The effectiveness of vertebrate passage and prevention

structures: a study of Boeckman Road in Wilsonville. Final report for Oregon Transportation Research and Education Consortium.

Dillon Consulting Limited. 2011. Terry Fox Drive extension project wildlife guide system monitoring report, Year 1 of 3. 10-3663. City of Ottawa, Ottawa, Ontario.

Dillon Consulting Limited. 2013. Terry Fox Drive extension project wildlife guide system monitoring report, Year 3 of 3; and, three year summary. 12-6019. City of Ottawa, Ottawa, Ontario.

Dodd, N. L., J. W. Gagnon, A.L. Manzo, and R. E. Schweinsburg. 2007. Video surveillance to assess highway underpass use by elk in Arizona. The Journal of Wildlife Management 71: 637-645.

Dodd, K. J., W. J. Barichivich, and L. L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118:619–631.

Dole, J.W. 1965. Summer movements of adult leopard frogs, Rana pipiens Schreber, in northern Michigan. Ecology 46:236–255.

Dougherty C.K., and G.R. Smith. 2006. Acute effects of road de-icers on the tadpoles of three anurans. Applied Herpetology. Volume 3 (2): 87 – 93.

Dulisse 2006b

Dulisse, J. 2014. Western Toad Migration at Summit Lake 2014 Field Season. Unpublished report prepared for Ministry of Forests, Lands and Natural Resource Operations Fish & Wildlife Compensation Program-Section. Nelson, BC.

Dulisse, J. 2015. Amphibian Underpass Design Considerations for Highway 3A at Grohman Narrows Provincial Park. Report prepared for the B.C. Ministry of Water, Land and Air Protection. Nelson, BC.

Dulisse J. and R. Clarke. 2018. Swansea Bridge replacement turtle nesting site enhancement and exclusion fencing. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Dulisse, J. J. Boulanger and I. Manley. 2017. Summit Lake Western Toad Project 2016 Field Season. Report prepared for the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Nelson, BC.

Dupuis and Friele 2002

Dupuis and Friele 2003

Dupuis and Friele 2004

Dyer, O. 2018. Tiger Salamander structured decision making process example. Abstract presented at Online Herpetofauna and Roads Meeting, 9 March 2018.

Eads, B. 2013. Behavioral responses of two syntopic snakes (genus *Thamnophis*) to roads and culverts. Master of Science thesis. Purdue University, Fort Wayne, Indiana.

Eads, B., L. Hayter, and B. Kingsbury. 2012. Road responses and culverts as a tool for increasing habitat connectivity for the federally threatened Copper-bellied Watersnake (*Nerodia erythrogaster neglecta*) and other wetland snakes. Conference abstract, World Congress of Herpetology. Victoria, BC.

Eastern Foxsnake Recovery Team. 2010. Recovery strategy for the Eastern Foxsnake (*Pantherophis gloydi*) – Carolinian and Georgian Bay populations in Ontario. Page vi + 39. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Eberhardt, E., S. Mitchell, and L. Fahrig. 2013. Road kill hotspots do not effectively indicate mitigation locations when past road kill has depressed populations. The Journal of Wildlife Management **77**:1353–1359.

EcoPlans. 2006. Environmental guide for wildlife in the Oak Ridges Moraine. Environmental Standards and Practices. Ontario Ministry of Transportation.

Eigenbrod, F., S. J. Hecnar, and L. Fahrig. 2008a. Accessible habitat: an improved measure of the effects of habitat loss and roads on wildlife populations. Landscape Ecology 23:159–168.

Eigenbrod, F., S. J. Hecnar, and L. Fahrig. 2008b. The relative effects of road traffic and forest cover on anuran populations. Biological conservation 141:35–46.

Engelstoft, C. and K. Ovaska. 1999. Sharp-tailed Snake study on the Gulf Islands and southeastern Vancouver Island, March-November 1998. Unpublished report prepared by Alula Biological Consulting for the BC Ministry of Environment, Lands and Parks (now Ministry of Environment), Vancouver Island Regional Office, Nanaimo, B.C. Project # PA-96-242-IN. 53pp.

Engelstoft, C., K. Ovaska, and N. Honkanen. 1999. The harmonic direction finder: a new method for tracking movements of small snakes. Herpetological Review 30:84–87.

Engelstoft, C., K. Ovaska, A. Taylor, and D. Copley. 2011. Mitigating road mortality of the Western Painted Turtle in the municipality of Saanich: road sign installation in 2010. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Environmental Reporting BC. 2018. Roads & Roadless Areas in British Columbia. State of Environment Reporting, Ministry of Environment and Climate Change Strategy, British Columbia, Canada. http://www.env.gov.bc.ca/soe/indicators/land/roads.html (accessed on <Aug 2018>).

Ernst, C.H., and J.E. Lovich. 2009. Turtles of the United States and Canada. Second edition. Johns Hopkins University Press.

Ernst et al. 1994

Ervin, E.L., R.N. Fisher, and K.R. Crooks. 2001. Factors influencing road-related amphibian mortality in Southern California. In G.L. Evink, P. Garrett, and K.P. McDermott, eds. Proceedings of the 2001 International Conference on Ecology and Transportation. P. 43. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Evelyn, M. 2018. Mitigating turtle road mortality by building nesting beaches. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Eye, D., J. Maida, O. McKibbin, K. Larsen and C. Bishop. 2018. Oosoyoos snake fence Outline. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Faggyas, S., and M. Puky. 2012. Construction and preliminary monitoring results of the first ACO Wildlife Pro amphibian mitigation system on roads in Hungary. Állattani Közlemények 97: 85–93.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177–182.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14:21-40. http://www.ecologyandsociety.org/vol14/iss1/art21/

Farmer, R. G., and R.J. Brooks. 2012. Integrated risk factors for vertebrate roadkill in southern Ontario. The Journal of Wildlife Management 76:1215-1224.

Fenech, A., B. Taylor, R. Hansell, and G. Whitelaw. 2001. Major road changes in southern Ontario 1935–1995: Implications for protected areas. Available from http://www.utoronto.ca/imap/papers/road_changes.htm (accessed April 10, 2014).

Findlay, C. S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000–1009.

Ford, A. T., A. P. Clevenger, and K. Rettie. 2010. The Banff Wildlife Crossings Project: an international public-private partnership. Pages 157–173 in J.P. Beckmann, A.P. Clevenger, M.P. Huijser, J.A. Hilty, editors. Safe passages—highways, wildlife and habitat connectivity. Island Press, Washington, DC. Island Press, Washington, DC.

Forman, R. and L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Forman, R., D. Sperling, J. A. Bissonette and A. Clevenger. 2003. Road ecology: science and solutions. Island Press, Washington D.C.

Fortney, A. N., R. G. Poulin, J.A. Martino, D.L. Parker, and C.M. Somers. 2013. Proximity to hibernacula and road type influence potential road mortality of snakes in southwestern Saskatchewan. Canadian Field-Naturalist 126:194-203.

Fraser Valley Conservancy 2018. Ryder Lake amphibian protection project. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Frey and Conover 2006

Fyfe, L. and E. Wind. 2008. Emergency Response and Mitigation Measures for Two Western Toad Migrations Along Highway 19 near Courtenay, British Columbia. Unpublished report. BC Ministry of Transportation.

Gallagher, M.T., J.W. Snodgrass, A.B. Brand, R.E. Casey, S.M. Lev and R.J. Van Meter. 2014. The role of pollutant accumulation in determining the use of stormwater ponds by amphibians. Wetlands Ecol. Manage. 22:551-564.

Garrah, E. 2012. Wildlife road mortality on the 1000 islands parkway in southeastern Ontario: peak times, hot spots, and mitigation using drainage culverts. Master of Environmental Studies thesis. Queen's University, Kingston, Ontario.

Gartner Lee and EcoPlans. 2009. 407 East individual Environmental Assessment and preliminary design study: Natural environmental (terrestrial) impact assessment of the recommended design. Report to the Ministry of Transportation.

Gartshore, R. G., M. Purchase, R. I. Rook, and L. Scott. 2005. Bayview Avenue extension, Richmond Hill, Ontario, Canada habitat creation and wildlife crossings in a contentious environmental setting: a case study. Pages 55-76 in C.L. Irwin, P. Garrett, and K.P. McDermott, editors. Proceedings of the 2005 International Conference on Ecology and Transportation, Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Gates, J. E., and J. L. J. Sparks. 2012. An investigation into the use of road drainage structures by wildlife in Maryland, USA. Human-Wildlife Interactions 6:311–326.

Gibbs, J. P., and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647–1652.

Gibbs, J. P., and W. G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13:281–289.

Gillies and St. Clair 1997

Gillingwater, S. D. 2011. Recovery strategy for the Queensnake (*Regina septemvittata*) in Ontario. Page vi + 34. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Glenside Ecological Services. 2011. Community mobilization and habitat modelling. Pages 24 – 109. Species at Risk. Ontario Ministry of Natural Resources, Haliburton Highlands Land Trust.

Glista, D.J., T.L. DeVault and J.A. DeWoody. 2009. A review of mitigation measures for reducing wildlife mortality on roadways. Landscape and Urban Planning 91:1-7.

Gomez, L.M. 2007. Habitat use and movement patterns of the Northern Pacific Rattlesnake (Crotalus o.

oreganus) in British Columbia. M. Sc. Thesis, University of Victoria, Victoria, British Columbia. 81 pp.

Gomez, L., K. Larsen and P.T. Gregory. 2015. Contrasting Patterns of Migration and Habitat Use in Neighboring Rattlesnake Populations. Journal of Herpetology 49 (3): 371–376.

Government of British Columbia. 2014. Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures). Version 1.0. Victoria. BC. Accessed via the internet Aug. 30, 2018. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-policy-legislation/environmental-mitigation-policy/em_procedures_may27_2014.pdf.

Govindarajulu, P. 2011. Do roads affect herpetofauna in B.C.? Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Govindarajulu, P., E. Wind and B. Beasley. 2012. British Columbia's response to herpetofauna and road issues. Abstract presented at 2012 Annual Meeting of the Society for Northwestern Vertebrate Biology, Hood River, Oregon. Northwestern Naturalist 93:170.

Graham, K.G. 1997. Habitat use of Long-toed Salamanders (Ambystoma macrodactylum) at three different scales. M.Sc. thesis, University of Guelph, Guelph, ON. 71 pp.

Grift et al. 2009 - https://library.wur.nl/WebQuery/wurpubs/fulltext/185626

Gravel, M., M.J. Mazerolle and M. Villard. 2012. Interactive effects of roads and weather on juvenile amphibian movements. Amphibia-Reptilia 33:113-127.

Gregory and Campbell 1987

Grods, J. and J. Garner. 2018. Using telemetry as a pre-development tool to inform planning and mitigation measures that decrease the impacts of development. Abstract submitted to the Online Herpetofauna and Roads Meeting. B.C. Ministry of Environment. 9 March 2019.

Griffin, K. 2005. Use of low fencing with aluminum flashing as a barrier for turtles. Pages 366-368 in C.L. Irwin, P. Garrett, and K.P. McDermott, eds. Proceedings of the 2005 International Conference on Ecology and Transportation, Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Gunson, K. E., G. Mountrakis, and L. J. Quackenbush. 2011. Spatial wildlife-vehicle collision models: A review of current work and its application to transportation mitigation projects. Journal of Environmental Management 92:1074–1082.

Gunson, K. E., and F. W. Schueler. 2012. Effective placement of road mitigation using lessons learned from turtle crossing signs in Ontario. Ecological Restoration 30:329–334.

Gunson, K.E., Ireland, D., Schueler, F.W. 2012. A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in southern Ontario, Canada. NorthWestern Journal of Zoology

8:409-413.

Gunson, K. E., D. Lesbarrères, and D. C. Seburn. 2013. Monitoring turtle movements across highways 7 and 41: Final report. Unpublished report to Highway Infrastructure Innovation Funding Program. Ontario Ministry of Transportation.

Gunson, K.E., and F.Z. Teixeira. 2015. Road-wildlife mitigation planning can be improved by identifying the patterns and processes associated with wildlife-vehicle collisions. Pages 101-019 in R. van der Ree, D. Smith, C. Grilo, editors. Handbook of Road Ecology. Wiley-Blackwell Publications.

Hagood, S., and M. J. Bartels. 2008. Use of existing culverts by eastern box turtles (*Terrapene c. carolina*) to safely navigate roads. Pages 169–170 in J. C. Mitchell, R. E. J. Brown, and B. Bartholomew, editors. Urban Herpetology, Society for the Study of Amphibians and Reptiles.

Hammerson 2005

Hardy, A., S. Lee, and A.F. Al-Kaisy. 2006. Effectiveness of animal advisory messages on dynamic message signs as a speed reduction tool: case study in Rural Montana. Transportation Research Record: Journal of the Transportation Research Board 1973:64-72.

Harless, M.L., Huckins, C.J., Grant, J.B., and T.G. Pypker. 2011. Effects of six chemical deicers on larval wood frogs (*Rana sylvatica*). Environmental Toxicology and Chemistry. Volume 30 (7): 1637-1641.

HAT (Habitat Acquisition Trust). 2015a. Website: http://www.hat.bc.ca/i-want-to/report-a-turtle-slug-or-snake/amphibian-roads for maps (accessed June 2018).

HAT (Habitat Acquisition Trust). 2015b. Website http://www.hat.bc.ca/data for 2015 data (accessed June 2018).

Haxton, T. 2000. Road mortality of Snapping Turtles, *Chelydra serpentina*, in central Ontario during their nesting period. Canadian Field-Naturalist 114:106–110.

Hayes, M.P., C.A. Pearl, and C.J. Rombough. 2001. Rana aurora aurora. Movement. Herpetological Review 32:35-36.

Hayes, M.P., C.J. Rombough, and C.B. Hayes. 2007. Rana aurora aurora (Northern Red-legged Frog), movement. Herpetological Review 38:192-193

Helferty, N. J. 2002. Natural Heritage Planning for amphibians and their habitats with reference to populations on the south slope of the Oak Ridges Moraine. Page 71. Supplementary Report for Oak Ridges Moraine Richmond Hill, Ontario Municipal Board Hearing. Save the Rouge Valley System Inc. and the City of Toronto.

Hels, T., and E. Buchwald, 2001. The effect of road kills on amphibian populations. Biological Conservation 99: 331–340.

Heyer, W. R., M. A., Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds). 1994. Measuring and monitoring biological diversity. Standard methods for amphibians. Smithsonian Institution Press, Washington, D. C. 364 pp.

Hine et al. 1981

Hobbs, J. 2013. Den survey and population assessment of the Northern Pacific Rattlesnake in BC: Final Report. Unpubl. report prep. for BC Ministry of Forests, Lands and Natural Resource Operations, Victoria, British Columbia. 85 pp.

Hocking, D.J. and K.J. Babbitt. 2014. Amphibian contributions to ecosystem services. Herpetological Conservation and Biology 9:1-17.

Holling, C. S. 1978. Adaptive environmental assessment and management. Adaptive environmental assessment and management. Available from http://www.cabdirect.org/abstracts/19800666996.html (accessed April 10, 2014).

Houston 2010

Huijser, M. P., P. T. McGowen, J. Fuller, A. Hardy, and A. Kociolek. 2007. Wildlife-vehicle collision reduction study: report to congress. U.S. Department of Transportation, Federal Highway Administration, Washington, DC, USA. Available from http://trid.trb.org/view.aspx?id=884083 (accessed April 10, 2014).

IUCN. 2010. IUCN Red list of threatened species 2010. International Union for the Conservation of Nature (IUCN), Gland, Switzerland. [online] URL: http://www.iucn.org

Iuell, B. 2003. COST 341: Wildlife and Traffic: A European handbook for identifying conflicts and designing solutions. Utrecht, The Netherlands: KNNV Publishers.

Jackson, S. D., and T. F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders *Ambystoma maculatum* under roads. Pages 93–99 in T. E. S. Langton, editor. Amphibians and Roads, Proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England. Available from http://works.bepress.com/cgi/viewcontent.cgi?article=1017andcontext=scott_jackson (accessed April 10, 2014).

Jackson, S. D. 1996. Underpass systems for amphibians. In G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in Addressing Transportation Related Wildlife Mortality: Proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Environmental Management Office. Tallahassee, FL. FL-ER-58-96.

Jackson, S. D., and M. N. Marchand. 1998. Use of a prototype tunnel by Painted Turtles, *Chrysemys picta*. Unpublished report.

Jackson, S. D. 2003. Ecological considerations in the design of river and stream crossings. Page 10 in C. L. Irwin, P. Garrett, and K. P. McDermott, editors. 2003 Proceedings of the International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina. Available from

http://works.bepress.com/scott_jackson/11/ (accessed April 10, 2014).

Jackson, S.D., and Griffin, C.R., 2000. A strategy for mitigating highway impacts on wildlife. In: Messmer, T.A., West, B. (Eds.), Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society, Bethesda, MD, pp. 143–159

Jackson, S. D., D. J. Smith, and K. E. Gunson. 2015. Sharing the road: Mitigating road impacts on small vertebrates. Pages 177-208 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

James, P.W., R.S. Wagner, K.A. Ernest, D. Beck, and J. Irwin. 2011. Monitoring fish and low-mobility vertebrates along a major mountain highway: a snapshot before construction of I-90 wildlife crossing structures. Pages 527-533 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Jochimsen, D. M., C. R. Peterson, K. M. Andrews, and J. W. Gibbons. 2004. A literature review of the effects of roads on amphibians and reptiles and the measures used to minimize those effects. US Forest Service report. 79 pp.

Jacobson, S. L. 2007. An alternative to the openness "ratio" using underpass physical attributes and behavioral implications of deer vision and hearing capabilities. Page 605 in C.L. Irwin, D. Nelson, and K.P. McDermott, editors.Proceedings of the 2007 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Johnston, B. 1998. Terrestrial Pacific Giant Salamanders (Dicamptodon tenebrosus Good): natural history and their response to forest practices. M.Sc. thesis. Univ. of British Columbia, Vancouver, BC. 98 pp.

Johnston, B. and L. Frid. 2002. Clearcut logging restricts the movements of terrestrial Pacific Giant Salamanders (Dicamptodon tenebrosus Good). Can. J. Zool. 80:2170–2177.

Joyce, T. L., and S. P. Mahoney. 2001. Spatial and temporal distributions of moose-vehicle collisions in Newfoundland. Wildlife Society Bulletin 29:281–291.

Karlson, M. A. Seiler, U. Mortberg. 2017. The effect of faunal passages and landscape characteristics on barrier mitigation success. Ecological Engineering 105:211-220.

Karraker, N. E. 2008. Impacts of road deicing salts on amphibians and their habitats. Pages 211–223 in Urban herpetology. R. E. Jung, and J. C. Mitchell, editors. Herpetological conservation Vol. 3. Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah, USA.

Karraker, N. E., and J. P. Gibbs. 2011. Contrasting road effect signals in reproduction of long-versus short-lived amphibians. Hydrobiologia 664:213–218.

Kaye, D. R., K. M. Walsh, E. L. Rulison, and C. C. Ross. 2005. Spotted Turtle use of a culvert under relocated Route 44 in Carver, Massachusetts. Pages 426-432 in C.L. Irwin, P. Garrett, and K.P.

McDermott, editors. Proceedings of the 2005 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Kilburn, V. and A. Mitchell. 2011. Western Painted Turtle Monitoring at Alaksen National Wildlife Area (NWA). March 2011. Prepared for Canadian Wildlife Service, Delta, BC.

Kilburn, V.L., A.M. Mitchell, M.J. Evelyn and D.A. Stiles. 2011. Creation of Western Painted Turtle nesting habitat reduces road mortality on the South Coast of B.C. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Kingsbury, B.A. 2011. The benefits and limitations of telemetry data and modeling to explore road permeability for snakes. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011. http://www.env.gov.bc.ca/wld/frogwatch/docs/2011/Herpetofauna_and_RoadsWorkshopProgram_Feb222011.pdf

Kintsch, J., and P. C. Cramer. 2011. Permeability of existing structures for terrestrial wildlife: A passage assessment system. WA-RD 777.1. Washington State Department of Transportation, Olympia, WA.

Kintsch, J., K. E. Gunson, and T. A. Langen. 2015. Engaging the public through public education and citizen science. Pages 94-110 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Konze, K. and McLaren, M. 1997. Wildlife monitoring programs and inventory techniques for Ontario. Ontario Ministry of Natural Resources. Northeast Science and Technology. Technical Manual TM-009. 139 pp.

Kraus, T., B. Hutchinson, S. Thompson, and K. Prior. 2010. Recovery strategy for the Gray Ratsnake (*Pantherophis spiloides*) – Carolinian and Frontenac Axis populations in Ontario. Page vi + 23. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Laidig, K. J., and D. M. Golden. 2004. Assessing Timber Rattlesnake movements near a residential development and locating new hibernacula in the New Jersey Pinelands. Unpublished report to the Pinelands Commission, New Lisbon, NJ. Available from http://199.20.64.195/pinelands/images/pdf%20files/final%20Sanctuary%20report.pdf (accessed April 10, 2014).

Lang, J. W. 2000. Blanding's turtles, roads and culverts at Weaver Dunes. File report on culvert utilization, The Nature Conservancy and Minnesota Department of Natural Resources, Contract# CFMS AO 9492.

Langen, T. A., A. Machniak, E. K. Crowe, C. Mangan, D. F. Marker, N. Liddle, and B. Roden. 2007. Methodologies for surveying herpetofauna mortality on rural highways. The Journal of Wildlife

Management 71:1361–1368.

Langen, T.A., K.M. Andrews, S.P. Brady, N.E. Karraker and D.J. Smith. 2015. Road effects on habitat quality for small animals. Chapter 4 In K.M. Andrews, P. Nanjappa, S.P.D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Langen, T. A. 2011. Design considerations and effectiveness of fencing for turtles: three case studies along northeastern New York State highways. Pages 521-532 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Langton, T. 2014. Safe passage for all: A review of the adoption of surface tunnels and stop channels on roadways for wildlife/road impact mitigation worldwide. Report prepard for ACO Tunnel Safety Review July 2014.

Lawrence, D.P. 2003. Environmental Impact Assessment: Practical solutions to recurrent problems. John Wiley and Sons, Hoboken, New Jersey.

Lesbarrères, D., T. Lodé, and J. Merilä. 2004. What type of amphibian tunnel could reduce road kills? Oryx 38:220–223.

Lesbarrères, D., and L. Fahrig. 2012. Measures to reduce population fragmentation by roads: what has worked and how do we know? Trends in Ecology and Evolution 27:374–380.

Le Viol I., F. Chiron, R. Julliard, and C. Kerbiriou. 2012. More amphibians than expected in highway stormwater ponds. Ecological Engineering 47:146–154.

Lininger, M., and M. Perlik. 2014. Effectiveness of the TRU-88 wildlife roadway crossing culverts and exclusion fencing. Unpublished report to the Ohio Department of Transportation.

Little, S.J., R.G. Harcourt, A.P. Clevenger. 2002. Do wildlife passages act as prey traps? Biological Conservation 107:135-145.

Lomas, E. 2013. Effects of disturbance on the Northern Pacific Rattlesnake (Crotalus oreganus oreganus) in British Columbia. M.Sc. Thesis. Thompson Rivers University, Kamloops, British Columbia. 107 pp.

Lowcock, L.A. and V. Woodruff. 2014. Observations on the distribution, ecology, movements and reproduction of Rubber Boas (*Charina bottae*) in the Pemberton Valley, British Columbia: implications for population studies and conservation. Canadian Herpetological Society, 12-15 Sept. 2014.

Macartney, J.M. 1985. The ecology of the Northern Pacific Rattlesnake, Crotalus viridis oreganus, in British Columbia. M.Sc. Thesis, University of Victoria, Victoria, British Columbia. 289 pp.

MacKinnon, C. A., L. A. Moore, R. J. Brooks, G. Nelson, T. Nudds, M. Beveridge, and B. Dempster. 2005. Why did the reptile cross the road? Landscape factors associated with road mortality of snakes

and turtles in the southeastern Georgian Bay area. Pages 18–25 Parks and Research Forum. Available from http://casiopa.mediamouse.ca/wp-content/uploads/2010/05/PRFO-2005-Proceedings-p153-166-MacKinnon-Moore-and-Brooks.pdf (accessed February 27, 2014).

Machmer, M.M. 2015. 2014 terrestrial surveys and monitoring for the Waneta Expansion Project. Report prepared by Pandion Ecological Research Ltd. for Columbia Power Corporation, Castlegar, BC. 40pp. (annual reports available for 2009, 2011, 2012, 2013).

Machmer, M.M. 2012. Impacts of increased road use associated with major project development on listed and other wildlife species in southern BC. Pp.19-24 In Proceedings of Resource Roads in BC: Environmental Challenges at the Site Level. Columbia Mountains Institute of Applied Ecology, November 7-8, 2012, Cranbrook, BC.

MacNeil, J. E., G. Dharmarajan, and R.N. Williams. 2011. Salamarker: A code generator and standardized marking system for use with visible implant elastomers. Herpetological Conservation and Biology 6:260-265.

Malt, J. 2012. Assessing the effectiveness of amphibian mitigation on the Sea to Sky Highway: population-level effects and best management practices for minimizing highway impacts. Final Report Oct 1, 2012. Ministry of Forests, Lands and Natural Resource Operations, South Coast Region. Surrey.

Maltby 2000

Marchand, M. N., and J. A. Litvaitis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758–767.

Marsh, D.M. and J.A.G. Jaeger. 2015. Direct effects of roads on small animal populations. Chapter 3 In K.M. Andrews, P. Nanjappa, S.P.D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Marsh, D., R. Page, T. Hanlon, R. Corritone, E. Little, D. Seifert, and P. Cabe, 2008. Effects of roads on patterns of genetic differentiation in red-backed salamanders, *Plethodon cinereus*. Conservation Genetics 9: 603–613.

Materi 2008

Mazzerolle, M.J., M. Huot, and M. Gravel. 2005. Behavior of amphibians on the road in response to car traffic. Herpetologica 61:380-381.

McCarthy K., R.G. Lathrop. 2011. Stormwater basins of the New Jersey coastal plain: subsidies or sinks for frogs and toads? Urban Ecosystems 14:395–413.

McCrory, W. and M. Mahr. 2018. Fish/Bear Lakes Western Toad (Anaxyrus boreas) ecology and Highway 31A mortality mitigation study. Abstract and presentation at the Herpetofauna and Roads Workshop II, B.C. Ministry of Environment, Kamloops, September 21, 2018.

McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). 2012. Reptile Biodiversity: Standard Methods for Inventory and Monitoring. Berkeley: University of California Press.

Meese, R.G., F.M. Shilling, and J.F. Quinn. 2009. Wildlife crossings guidance manual. Report to the California Department of Transportation. Sacramento, CA. 111 pp.

Merrow, J. 2007. Effectiveness of amphibian mitigation measures along a new highway. Pages 370-376 n C.L. Irwin, D. Nelson, and K.P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation. Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Ministry of Forests, Lands, and Natural Resource Operations. 2016. Best Management Practices for Amphibian and Reptile Salvages in British Columbia. Version 1.0., June 2, 2016. Victoria, BC.

Meyer, A.H., B.R. Schmidt and K. Grossenbacher. 1998. Analysis of three amphibian populations with quarter-century long time-series. Proc. R. Soc. Lond. B. 265:523-528.

Nelson, D.V., H. Klinck, A. Carbaugh-Rutland, C.L. Mathis, A.T. Morzillo and T.S. Garcia. 2017. Calling at the highway: the spatiotemporal constraint of road noise on Pacific chorus frog communication. Ecology and Evolution 7:429-440. https://doi.org/10.1002/ece32622

Neilson, J. 2018. Ryder Lake Amphibian Protection Project. Abstract presented at the Online Herpetofauna and Roads Meeting. B.C. Ministry of Environment, March 9, 2018.

Ohanjanian, I.A. 2000. The Coeur d'Alene Salamander (P. idahoensis) in the Kootenay Lake and Arrow Forest Districts. Report to B.C. Ministry of Environment, Lands and Parks and the Habitat Conservation Trust Fund. 43 pp.

Ohanjanian, I.A. 2003. The Coeur d'Alene Salamander (Plethodon idahoensis) in southeastern British Columbia – final report. Report for B.C. Ministry of Water, Land and Air Protection and the Habitat Conservation Trust Fund. 44 pp.

Ohanjanian, I.A., and M.- A. Beaucher. 2002. Coeur d'Alene Salamander inventory results, Year 5. Report to Wynndel Box and Lumber Co. Ltd., and Min. of Water, Land and Air Protection. Nelson, B.C. 19 pp

Olson, D. 2018. White Lake area road crossing culverts. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh Jr., and D.F. Bradford. 2007. Biodiversity management approaches for stream riparian areas: perspectives for Pacific Northwest headwater forests, microclimate and amphibians. For. Ecol. Manag. 246:81–107.

Ontario Ministry of Natural Resources (MNR). 2011. Massasauga search protocol where site alteration will occur in gestation habitat for Highway 69/400 ESA authorization requirements. Ontario Ministry of Natural Resources, Parry Sound Sudbury District. 5pp.

Ontario Ministry of Natural Resources (MNR). 2013. Reptile and Amphibian Exclusion Fencing: Best Practices, Version 1.0. Species at Risk Branch technical note. Prepared for the Ontario Ministry

of Natural Resources, Peterborough, Ontario. 11 pp. Available from http://files.ontario.ca/environment-and-energy/species-at-risk/mnr_sar_tx_rptl_amp_fnc_en.pdf (accessed February 26, 2014).

Ontario Ministry of Natural Resources and Forestry (MNRF). 2016. Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario. Queen's Printer for Ontario. 112 pp.

Ontario Ministry of Transportation (MT). 2012. Wildlife Habitat Awareness Signs. Policy Number 2012-03. Traffic Office, St. Catharines, Ontario.

Ontario Wood Turtle Recovery Team. 2010. Recovery strategy for the Wood Turtle (*Glyptemys insculpta*) in Ontario. Page vi + 25. Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Ostergaard, E.C., K.O. Richter and S.D. West. Amphibian use of stormwater ponds in the Puget Lowlands of Washington, USA. In Urban Herpetology. J.C. Mitchell, R.E. Jung Brown, and B. Bartholomew, eds., Herpetological Conservation 3:259-270.

Ottburg, F. G. W. A., and E. A. van der Grift. 2013. Effectiveness of road mitigation for preserving a common toad population. Proceedings of the 2013 International Conference on Ecology and Transportation. Poster. Retrieved from http://www.icoet.net/ICOET_2013/proceedings.asp.

Ovaska, K. 1988. Spacing and movements of the salamander *Plethodon vehiculum*. Herpetologica 44:377 – 386.

Ovaska, K. and C. Engelstoft. 2005. Identification of critical habitat components for Sharp-tailed Snake. Unpublished report prepared for Endangered Species Recovery Fund (Environment Canada), Hull, Quebec. Project # 2005-ESR1116

Ovaska and Engelstoft 2011

Ovaska, K., C. Engelstoft, and L. Sopuck. 2016. Community-based amphibian monitoring program in multi-use landscapes in south-central British Columbia, 2011 -2015. Unpubl. report prepared for Habitat Conservation Trust Fund. 57 pp. Website: http://www.nicolanaturalists.ca/files/Nicola-Amphibian-Report-2011-2015-copy.pdf (accessed June 2018).

Ovaska, K, L. Sopuck, C. Engelstoft, A. Burger, and A. Lawrence. 2018. Western Toad roadkill mitigation in Kentucky-Alleyne Provincial Park. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Pagnucco, K. S., C. A. Paszkowski, and G. J. Scrimgeour. 2011. Using cameras to monitor tunnel use by Long-toed Salamanders (*Ambystoma macrodactylum*): an informative, cost-efficient technique. Herpetological Conservation and Biology 6:277–286.

Pagnucco, K. S., C. A. Paszkowski, and G. J. Scrimgeour. 2012. Characterizing movement patterns and spatio-temporal use of under-road tunnels by long-toed salamanders in Waterton Lakes National Park, Canada. Copeia 2012:331–340.

Painter, M. L., and M. F. Ingraldi. 2007. Use of simulated highway underpass crossing structures by flat-tailed horned lizards (*Phrynosoma mcallii*). Final Report 594. Arizona Department of Transportation, Phoenix, AZ.

Parent, C and R. Black. 2006. Construction of artificial gestation sites for the Massasauga, Eastern Georgina Bay Population. Unpublished report submitted to the Ministry of Natural Resources.

Parren, S. G. 2013. A twenty-five year study of the Wood Turtle (*Glyptemys insculpta*) in Vermont: Movements, behavior, injuries, and death. Herpetological Conservation and Biology 8:176–190.

Paterson, J. E., B.D. Steinberg, and J.D. Litzgus. 2013. Not just any old pile of dirt: evaluating the use of artificial nesting mounds as conservation tools for freshwater turtles. Oryx 47:607-615.

Patrick, D.A., and Gibbs, J.P. 2009. Snake occurrences in grassland associated with road versus forest edges. Journal of Herpetology 43:716-720.

Patrick, D. A., C. M. Schalk, J. P. Gibbs, and H. W. Woltz. 2010. Effective culvert placement and design to facilitate passage of amphibians across roads. Journal of Herpetology 44:618–626.

Patrick, D. A., J. P. Gibbs, V. D. Popescu, and D. A. Nelson. 2012. Multi-scale habitat-resistance models for predicting road mortality "hotspots" for turtles and amphibians. Herpetological Conservation and Biology 7:407–426.

Paulson, D. J. 2010. Evaluating the effectiveness of road passage structures for freshwater turtles in Massachusetts. Master of Science thesis. University of Massachusetts, Amherst, Amherst, MA.

Peaden, J.M., Nowakowski, A.J., Tuberville, T.D., Buhlmann, K.A., and B.D. Todd. 2017. Effects of roads and roadside fencing on movements, space use, and carapace temperatures of a threatened tortoise. Biological Conservation, 2017; 214: 13 DOI: 10.1016/j.biocon.2017.07.022.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-893.

Perry, G., B.W. Buchanan, R.N. Fisher, M. Salmon and S.E. Wise. 2008. Effects of artificial night lighting on urban reptiles and amphibians. Pages 239-246 in Urban Herpetology, R.E. Jung and J.C. Mitchell, eds. Herpetological Conservation Vol. 3. Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah, USA.

Persello, B., J.E. Crosby, S.L. Ashpole and S. Murphy. 2011. Amphibian occurrence on South Okanagan roadways, B.C.: realising movement corridors and improving connectivity. Abstract presented at Herpetofauna and Roads Workshop – Is there light at the end of the tunnel? Vancouver Island University, Nanaimo, B.C. Feb 22-23, 2011.

Pickard, D. 2009. Snakes on a lane: Analysis of snake observations on a rural road in southern British Columbia. Unpubl. report prepared for Ecosystems Branch, BC Ministry of Environment, Victoria, British Columbia.

Pickard, D., M.J. Sarell, and A. Haney. 2009. Snakes on a Lane. Presented at the Annual Meeting of the

Society for Northwestern Vertebrate Biology, Feb 18-21, 2009. Stevenson, Washington.

Pike, D.A., L. Pizzatto, B.A. Pike and R. Shine. 2008. Estimating survival rates of uncatchable animals: the myth of high juvenile mortality in reptiles. Ecology 89:607-611.

Pojar, T.M., D. F. Reed, and T.C. Reseigh. 1975. Effectiveness of a lighted, animated deer crossing sign. Journal of Wildlife Management 39:87-91.

Province of British Columbia. 2014. Guidelines for Amphibian and Reptile Conservation during Urban and Rural Land Development in British Columbia (2014). A companion document to Develop with Care. Victoria, BC.Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-895.

Puky, M., J. Farkas, and M. T. Ronkay. 2007. Use of existing mitigation measures by amphibians, reptiles, and small to medium-size mammals in Hungary: crossing structures can function as multiple species-oriented measures. Pages 521-530 in C.L. Irwin, D. Nelson, and K.P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation, . Raleigh, NC.: Center for Transportation and the Environment, North Carolina State University.

Puky, M., B. Mester, and T. Mechura. 2013. How much does size matter? Tunnel size significantly influence amphibian crossings at Parassapuszta, Hungary according to mid-term monitoring used to delineate mitigation measure improvement plans. Proceedings of the 2013 International Conference on Ecology and Transportation. Available from http://www.icoet.net/ICOET_2013/proceedings-poster-sessions.asp.

Reconyx. 2010. HyperFireTM instruction manual. Holman, Wisconsin.

Reed, D. F., T. D. I. Beck, and T. N. Woodward. 1979. Regional deer-vehicle accident research. FHWA-RD-79-11. US Department of Transportation, Federal Highway Administration, Washington, DC.

Regester, K.J., K.R. Lips and M.R. Whiles. 2006. Energy flow and subsidies associated with the complex life cycle of ambystomatid salamanders in ponds and adjacent forest in southern Illinois. Oecologia 147:303-314.

Reid and Dunne 1984

Richardson, J.S., W. Klenner, and J. Shatford. 2000. The tiger salamander in British Columbia: an amphibian in an endangered desert environment. In Proc. Biology and management of species and habitats at risk. L.M. Darling (ed.). Kamloops, BC. pp. 407–412.

Riley, J. L., J. H. Baxter-Gilbert, and J. D. Litzgus. 2013. A trifecta of insight: merging field biology, infrastructure planning and aboriginal community knowledge to design successful highway mitigation for at-risk reptiles. Proceedings of the 2013 International Conference on Ecology and Transportation. Available from http://www.icoet.net/ICOET_2013/proceedings.asp (accessed February 27, 2014).

RISC 1998a. Inventory methods for pond-breeding amphibians and painted turtle. Standards for components of British Columbia's Biodiversity No. 37. Prepared by Ministry of Environment,

Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee. March 13, 1998. Version 2.0. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/pond.pdf

RISC 1998b. Live animal capture and handling guidelines for wild mammals, birds, amphibians and reptiles. Standards for components of British Columbia's Biodiversity No. 3. Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee. December 4, 1998. Version 2.0. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/capt.pdf

Roberts, D. 2010. Mitigation of Red-sided Garter Snake mortality on provincial trunk Highway #17 at the Narcisse snake dens: A progress report. Unpublished report to Manitoba Conservation.

Robertson, C., N. Richards and M. Karch. 2013. Standard turtle handling and research practices and protocols. Prepared for the Ontario Turtle Conservation Group.

Robson, L. E., and G. Blouin-Demers. 2013. Eastern Hognose Snakes (*Heterodon platirhinos*) avoid crossing paved roads, but not unpaved roads. Copeia 2013:507–577.

Roedenbeck, I. A., L. Fahrig, C. S. Findlay, J.E. Houlahan, J. A. G. Jaeger, N. Klar, S. Kramer- Schadt and E. A. van der Grift. 2007. The Rauischholzhausen agenda for road ecology. Ecology and Society 12: 11. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art11/

Rogers, L., D. Stimson, K. Holden, D. Kay, D. Kaye, R. McAdow, B. Metcalfe, B. Windmiller, and N. Charney. 2009. Wildlife tunnels under a busy, suburban Boston roadway. Pages 102-115 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2009 International Conference on Ecology and Transportation. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Rosen, P. C., and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68:143–148.

Rouse, J. 2005. Monitoring the Eastern Massasauga and Eastern Hog-nosed Snake along the Highway 69 Extension. Ontario Ministry of Natural Resources, Parry Sound, ON.

Rouse, J. D., R. J. Willson, R. Black, and R. J. Brooks. 2011. Movement and spatial dispersion of *Sistrurus catenatus* and *Heterodon platirhinos*: implications for interactions with roads. Copeia 2011:443–456.

Row, J. R., G. Blouin-Demers, and P. J. Weatherhead. 2007. Demographic effects of road mortality in Black Ratsnakes (*Elaphe obsoleta*). Biological Conservation 137:117–124.

Rowe 2003

Rutherford, P.L., and P.T. Gregory. 2001. Habitat Use and Movement Patterns of Northern Alligator Lizards and Western Skinks in Southeastern British Columbia. Columbia Basin Fish and Wildlife Compensation Program, BC Hydro, B.C. Minist. Environ, Lands and Parks, B.C. Fish. in

partnership with Creston Valley Wildl. Manage. Area, Columbia Basin Trust and Univ. Victoria. 52pp.

Rutherford, P.L. and P.T. Gregory. 2003. Habitat use and movement patterns of Northern Alligator Lizards (*Elgaria coerulea*) and Western Skinks (*Eumeces skiltonianus*) in southern British Columbia. Journal of Herpetology 37:98-106.

Rytwinski, T., and L. Fahrig. 2012. Do species life-history traits explain population responses to roads? A meta-analysis. Biological Conservation 147:87–98.

Rytwinski, T., R. van der Ree, G.M. Cunnington, L. Fahrig, C.S. Findlay, J. Houlahan, J.A.G. Jaeger, K. Soanes, E.A. van der Grift. 2015. Experimental study designs to improve the evaluation of road mitigation measures for wildlife. Journal of Environmental Management 154:48-64.

Rytwinski, T., K. Soanes, J.A.G. Jaeger, L. Fahrig, C.S. Findlay, J. Houlahan, R. van der Ree, E.A. van der Grift. 2016. How effective is road mitigation at reducing road-kill? A meta-analysis. PLoS ONE 11(11): e0166941. Doi:10.137/journal.pone.0166941.

Santos, S. M., F. Carvalho, and A. Mira. 2011. How long do the dead survive on the road? Carcass persistence probability and implications for road-kill monitoring surveys. PloS one [electronic resource] 6:e25383–e25383.

Sanzo, D. and S.J. Hecnar. 2006. Effects of road de-icing salt (NaCl) on larval wood frogs (Rana sylvatica). Environmental Pollution 140:247-256.

Sarell, M. Undated. Snake Barrier Fencing. Part of the Living in Nature Series. Prepared for the South Okanagan Similkameen Stewardship Program, Penticton, BC.

Sarell 1993

Sarell, M.J. 2004. Racer. Pp 1 – 7 in Accounts and Measures for Managing Identified Wildlife. BC Ministry of Environment, Victoria, British Columbia. Web site: http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Reptiles/r_racer.pdf [accessed Feb 2019]

Sarell, M.J., and S. Robertson. 1994. Survey of tiger salamanders (Ambystoma tigrinum) in the Okanagan Sub-region (1994). B.C. Environment, Victoria, British Columbia. 5 p.

Schmetterling, D. A., and M. K. Young. 2008. Summer movements of boreal toads (Bufo boreas boreas) in two western Montana basins. Journal of Herpetology 42:111-123.

Schmidt, B. R., and S. Zumbach. 2008. Amphibian road mortality and how to prevent it: A review. Pages 157–167 in J. C. Mitchell, R. E. Jung Brown, and B. Bartolomew, editors. Urban Herpetology. Society for the Study of Amphibians and Reptiles.

Seburn, D. C. 2007. Recovery strategy for species at risk turtles in Ontario. Draft Report for the Ontario Multi-species Turtles at Risk Recovery Team, Ontario, Canada.

Semlitsch, R. D. 2008. Differentiating migration and dispersal processes for pond-breeding amphibians. Journal of Wildlife Management 72:260-267.

Serra Shean, J.T.S. 2002. Post-breeding movements and habitat use by the Northern Red-legged Frog, Rana aurora aurora, at Dempsey Creek, Thurston County, Washington. M.Sc. dissertation. Evergreen State College, Olympia, Washington. 89 pp.

Sheppard, R. F. 1977. The ecology and home range movements of Ambystoma macrodactylum krausei (Amphibia: Urodela). M. Sc. thesis, University of Calgary, Calgary, AB. 138 pp.

Shewchuk, C.H. 1996. The natural history of reproduction and movement patterns in the gopher snake (Pituophis melanoleucus) in Southern British Columbia. MSc thesis, Dept. of Biology, University of Victoria, Victoria, British Columbia.

Shewchuk, C.H., and H.L. Waye 1995. Status of the Western Yellow-bellied Racer in British Columbia. Unpubl. report prepared for Ministry of Water, Land and Air Protection, Lands and Parks. Victoria, British Columbia. 16 pp.

Shine, R., M. Lemaster, M. Wall, T. Langkilde, and R. Mason. 2004. Why did the snake cross the road? Effects of roads on movement and location of mates by garter snakes (*Thamnophis sirtalis parietalis*). Ecology and Society 9:9.

Slater, F. M. 2002. An assessment of wildlife road casualties–the potential discrepancy between numbers counted and numbers killed. Web Ecology 3:33–42.

Smith, D. J. 2003. Monitoring wildlife use and determining standards for culvert design. Unpublished report to Florida Department of Transportation.

Smith, D. J., D. Marsh, K. E. Gunson, and S. Tonjes. 2015. Monitoring and adaptive management of road impacts and mitigation. Pages 240-261 in K. M. Andrews, P. Nanjappa, and S. P. D. Riley, editors. Roads and Ecological Infrastructure: Concepts and Applications for Small Animals. Johns Hopkins University Press, Baltimore, MD.

Snook and Blaine 2012

Smith, D. J., and R. F. Noss. 2011. A reconnaissance study of actual and potential wildlife crossing structures in Central Florida, final report. UCF-FDOT Contract No. BDB-10. Florida Department of Transportation.

Souder 2000

Southern Interior Reptile and Amphibian Working Group. 2016. Recovery plan for the Blotched Tiger Salamander (*Ambystoma mavortium*) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, BC. 39 pp.

Spalding 1995

Steen, D. A., and J. P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.

Steen, D., L. Smith, G. Miller, and S. Sterrett. 2006. Post-breeding terrestrial movements of Ambystoma tigrinum (Eastern Tiger Salamanders). Southeastern Naturalist 5(2):285-288.

Steen, D.A., J.P. Gibbs, K.A. Buhlmann, J.L. Carr, B.W. Compton, J.D. Congdon, J.S. Doody, J.C. Godwin, K.L. Holcomb, D.R. Jackson, F.J. Janzen, G. Johnson, M.T. Jones, J.T. Lamer, T. Langen, M.V. Plummer, J.W. Rowe, R.A. Saumure, J.K. Tucker, and D.S. Wilson. 2012. Terrestrial habitat requirements of nesting freshwater turtles. Biological Conservation 150:121–128.

Steciw, J. 2018. Snake den construction 2016. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Stevens et al. 2006

Stevens et al. 2007

Sullivan, B.K. 1981. Observed differences in body temperature and associated behaviour of four snake species. Journal of Herpetology 15:245-246.

Summit Environmental Consultants 2010

Taylor, B. D., and R. L. Goldingay. 2003. Cutting the carnage: wildlife usage of road culverts in north-eastern New South Wales. Wildlife Research 30:529–537.

Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos 68:571–573.

Thoms, C., C.C. Corkran and D.H. Olsen. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. In D.H. Olsen, W.P. Leonard and R.B. Bury (eds.) Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Society for Northwestern Vertebrate Biology, Olympia, Washington.

Torres, A., C. Palacín, J. Seoane, and J.C. Alonso. 2011. Assessing the effects of a highway on a threatened species using Before–During–After and Before–During–After-Control–Impact designs. Biological conservation 144, 2223–2232.

TRCA. 2013. Heart Lake Road Ecology Volunteer Monitoring Project, Phase II. Toronto and Region Conservation Authority (TRCA), Toronto, Ontario. Available from http://www.trca.on.ca/dotAsset/187823.pdf

Tuttle and Hawkes 2011

United States Department of Agriculture (USDA). n.d. Dust Palliative Selection and Application Guide. Technology & Development Program, Forest Services, United States Department of Agriculture. Retrieved from https://www.fs.fed.us/eng/pubs/html/99771207/99771207.html#Pall (Accessed 14 December 2018).

van der Grift, E., F. Ottburg, and R. Snep. 2009. Monitoring wildlife overpass use by amphibians: Do artificially maintained humid conditions enhance crossing rates? Pages 341-347 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2009 International Conference on Ecology and Transportation. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

van der Grift, E. A., S. Findlay, R. van der Ree, L. Fahrig, J. Houlahan, L. F. Madriñan, J.A.G. Jaeger, Nina Klar, and L. Olson. 2013. Evaluating the effectiveness of road mitigation measures. Biodiversity Conservation DOI 10.1007/s10531-012-0421-0.

van der Ree R., J.A.G. Jaeger, T. Rytwinski, and E. van der Grift. 2015. Good science and experimentation are needed in road ecology. Pages 71-81 in: R. van der Ree, C. Grilo, and D. Smith, editors. Handbook of Road Ecology. Wiley Publications.

van Gelder, J.J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo bufo L.* Oecologia 13: 93-95.

Vos, C. C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology 35:44–56.

Wahbe, T. R., F.L. Bunnell, and R.B. Bury. 2004. Terrestrial movements of juvenile and adult tailed frogs in relation to timber harvest in coastal British Columbia. Canadian Journal of Forest Research 34: 2455-2466.

Watson, J.W., K.R. McAllister, and D.J. Pierce. 2003. Home ranges, movements, and habitat selection of Oregon spotted frogs (Rana pretiosa). Journal of Herpetology 37:292–300.

Waye, H.L. and J.M. Cooper. 2000. Status of the Northern Leopard Frog (Rana pipiens) in the Creston Valley Wildlife Management Area 1999. Columbia Basin Fish and Wildlife Compensation Program.

Waye, H., and C.H. Shewchuk. 2002. COSEWIC status report on the Gophersnake Pituophis catenifer in Canada, in COSEWIC assessment and status report on the Gophersnake Pituophis catenifer in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. 33 pp.

Wershler, C.L. 1991. Status of the Northern Leopard Frog in Alberta - 1990. Alberta Forestry Lands & Wildlife, Edmonton, Alberta.

White, K. 2008. Spatial ecology and life history of the Great Basin Gopher Snake (Pituophis catenifer deserticola) in British Columbia's Okanagan Valley. M.Sc. Thesis, University of British Columbia, Department of Biology, Vancouver, British Columbia.

Whitelock, C. 2014. 2013 Long Point causeway monitoring and adaptive management report. Unpublished report.

White, K. 2008. Spatial ecology and life history of the Great Basin Gopher Snake (Pituophis catenifer deserticola) in British Columbia's Okanagan Valley. M.Sc. Thesis, University of British Columbia, Department of Biology, Vancouver, British Columbia.

Williams, K.E., K.E. Hodges, and C.A. Bishop. 2012. Small reserves around hibernation sites may not adequately protect mobile snakes: the example of Great Basin Gopher Snakes in British Columbia. Canadian Journal of Zoology 90(3):304-312.

Willson, R. J., and G. M. Cunnington. 2014. DRAFT Recovery strategy for the Blue Racer (*Coluber constrictor foxii*) in Ontario. Page vi + 35. Ontario Recovery Strategy Series. Prepared for the

Ontario Ministry of Natural Resources, Peterborough, Ontario.

Willson, R.J. 2005. Artificial hibernation site construction for Eastern Massasaugas in Georgian Bay. Report submitted to the Ontario Ministry of Natural Resources.

Wilson, J.S. and S. Topham. 2009. The negative effects of barrier fencing on the Desert Tortoise (*Gopherus agassizii*) and non-target species: is there room for improvement? Contemporary Herpetology 2009:1-4.

Wind, E. 2012. Amphibian road surveys and mitigation assessments at three sites on Vancouver Island. Unpublished report produced for Environmental Management Section, Ministry of Transportation and Infrastructure, Victoria, B.C. E. Wind Consulting, Nanaimo. B.C.

Wind and Willmott 2012

Wind, E. 2014. Amphibian road surveys and mitigation assessments at Wake Lake on Vancouver Island in 2012. Unpublished report to the BC Ministry of Transportation and Infrastructure.

Wind, E. 2018. Western Toad Winter Habitat Requirements in Modified Landscapes on Vancouver Island Year 3. Unpublished report prepared for the MFLNRO, Nanaimo, BC and the Habitat Conservation Trust Foundation, Victoria, BC.

Wind, E. 2018. Amphibian road surveys and mitigation assessments at two sites on Vancouver Island for MoTI. Abstract presented at the Online Herpetofauna and Roads Meeting, B.C. Ministry of Environment, March 9, 2018.

Winton, S. 2017. Road mortality hot spots and movement corridors of at-risk snake species in the White Lake Basin of British Columbia. Unpublished report prepared for Orville Dyer, Ecosystems Branch, BC Ministry of Environment, Penticton, BC.

Winton, S. 2018. Impacts of Road Mortality on the Western Rattlesnake (Crotalus oreganus) in British Columbia. Master of Science thesis, Thompson Rivers University, Kamloops, BC.

Woltz, H. W., J. P. Gibbs, and P. K. Ducey. 2008. Road crossing structures for amphibians and reptiles: informing design through behavioral analysis. Biological Conservation 141:2745–2750.

Yannis, I. 2011. Effectiveness of road barriers and underpasses for reptiles: The case of Milos viper (*Macrovipera schweizeri*). Proceedings of the 2011 IENE conference.

Yorks, D. T., P. R. Sievert, and D. J. Paulson. 2011. Experimental tests of tunnel and barrier options for reducing road mortalities of freshwater turtles. Page 1034 in P.J. Wagner, D. Nelson, and E. Murray, editors. Proceedings of the 2011 International Conference on Ecology and Transportation. Center for Transportation and the Environment, Raleigh, NC.

9.0 APPENDICES

Appendix A – Amphibian and Reptile Species, their status (federally SARA listed species are highlighted in bold), and the TRANS region(s) where they occur. (current to June 2018; please check SARA registry and BC Species and Ecosystem Explorer for updates)

Scientific Name	English Name	COSEWIC*	BC List	Identified Wildlife	SARA*	MOE Region(s)**	TRAN Region(s)
TERRESTRIAL-BREEDING SALAMANDERS							
Aneides vagrans	**Wandering Salamander**	**SC (2014)**	**Blue**		**1-SC (2018)**	**1**	**1,2,3 (some Georgia Strait islands - 3 or 5?)**
Ensatina eschscholtzii	Ensatina	NAR (1999)	Yellow			1,2,5,6	1,2,3,4,5,6
Plethodon idahoensis	**Coeur d'Alene Salamander**	**SC (2007)**	**Yellow**	**Yes (2004)**	**1-SC (2003)**	**4**	**9,10**
Plethodon vehiculum	Western Red-backed Salamander	NAR (2001)	Yellow			1,2	1,2,3,4,6, south end of 5
STREAM-BREEDING AMPHIBIANS							
Ascaphus montanus	**Rocky Mountain Tailed Frog**	**T (2013)**	**Blue**	**Yes (2004)**	**1-T (2018)**	**4**	**11**
Ascaphus truei	**Coastal Tailed Frog**	**SC (2011)**	**Yellow**	**Yes (2004)**	**1-SC (2003)**	**1,2,3,5,6,8**	**4,5,6,7,17,26**
Dicamptodon tenebrosus	**Coastal Giant Salamander**	**T (2014)**	**Blue**	**Yes (2004)**	**1-T (2003)**	**2**	**7**
POND-BREEDING AMPHIBIANS							
Ambystoma gracile	Northwestern Salamander	NAR (1999)	Yellow			1,2,5,6	1,2,3,4,5,6,7,17,26
Ambystoma macrodactylum	Long-toed Salamander	NAR (2006)	Yellow			1,2,3,4,5,6,7,8,9	1-21, 23-28
Ambystoma mavortium	**Blotched Tiger Salamander**	**E (2012)**	**Red**	**Yes (2004)**	**1-E (2018)**	**8**	**8,9**
Anaxyrus boreas	**Western Toad**	**SC (2012)**	**Yellow**		**1-SC (2005)**	**1,2,3,4,5,6,7,8,9**	**1-28**
Lithobates pipiens	**Northern Leopard Frog**	**E (2009)**	**Red**	**Yes (2004)**	**1-E (2003)**	**1,4,8**	**10,11**
Lithobates sylvaticus	Wood Frog		Yellow			3,4,5,6,7,9	11,12,15-26, 28
Pseudacris maculata	Boreal Chorus Frog		Yellow			7,9	21,22
Pseudacris regilla	Northern Pacific Treefrog		Yellow			1,2,3,4,5,6,7,8,	1-18,20,27
Rana aurora	**Northern Red-legged Frog**	**SC (2015)**	**Blue**	**Yes (2004)**	**1-SC (2005)**	**1;2;5;6**	**1-7,17**
Rana luteiventris	Columbia Spotted Frog	NAR (2000)	Yellow			2,3,4,5,6,7,8,9	4-27,28
Rana pretiosa	**Oregon Spotted Frog**	**E (2011)**	**Red**		**1-E (2003)**	**2**	**6,7**
Spea intermontana	**Great Basin Spadefoot**	**T (2007)**	**Blue**	**Yes (2004)**	**1-T (2003)**	**3,5,8**	**8,9,13-15**
Taricha granulosa	Roughskin Newt		Yellow			1,2,3,5,6	1,2,3,4,5,6,7,17,26
Lithobates catesbeianus	American Bullfrog		Exotic				1,2,6,7
Lithobates clamitans	Green Frog		Exotic				1,2,3,4,5,6,7,8

* SC - Special Concern; NAR - Not at Risk; T - Threatened; E - Endangered

*** MOE Region: 1 - Vancouver Island; 2 - Lower Mainland; 3 = Thompson-Nicola; 4 - Kootenays; 5 - Cariboo; 6 - Skeena-Bulkley Valley; 7 - Omineca; 8 - Okanagan; 9 - Peace*

Scientific Name	English Name	COSEWIC*	BC List	Identified Wildlife	SARA*	MOE Region**	TRAN Region(s)
TURTLES							
Chrysemys picta pop. 1	**Painted Turtle - Pacific Coastal Population**	**T (2016)**	**Red**		**1-E (2007)**	**1,2**	**1,2**
Chrysemys picta pop. 2	**Painted Turtle - Intermountain-Rocky Mountain Pop.**	**SC (2016)**	**Blue**		**1-SC (2007)**	**3,4,5,8**	**south part of 5, 8-11, 13**
Trachemys scripta	Pond Slider		Exotic				1,2,4,6,8,9 (in lakes & ponds in many cities and towns)
LIZARDS							
Elgaria coerulea	Northern Alligator Lizard	NAR (2002)	Yellow			1,2,3,4,5,8	**1-11,13,14**
Plestiodon skiltonianus	**Western Skink**	**SC (2014)**	**Blue**		**1-SC (2005)**	**3,4,8**	**8-10**
Podarcis muralis	Common Wall Lizard		Exotic				1
SNAKES							
Charina bottae	**Northern Rubber Boa**	**SC (Apr 2016)**	**Yellow**		**1-SC (2005)**	**2,3,4,5,8**	**4-11,13-16**
Coluber constrictor	**North American Racer**	**T (2015)**	**Blue**	**Yes (2006)**	**1-SC (2006)**	**2,3,4,5,8**	**8,9, 13-16**
Contia tenuis	**Sharp-tailed Snake**	**E (2009)**	**Red**		**1-E (2003)**	**1,2,3**	**1,4**
Crotalus oreganus	**Western Rattlesnake**	**T (2015)**	**Blue**	**Yes (2006)**	**1-T (2005)**	**3,8**	**8,9,13-15**
Hypsiglena chlorophaea	**Desert Nightsnake**	**E (2011)**	**Red**		**1-E (2003)**	**8**	**8**
Pituophis catenifer	**Gopher Snake - *deserticola* subspecies**	**T (2013)**	**Blue**		**1-T (2005)**	**1,2,3,4,5,8**	**8,9, 13-16**
Thamnophis elegans	Terrestrial Gartersnake		Yellow			1,2,3,4,5,6,7,8,9	1-17
Thamnophis ordinoides	Northwestern Gartersnake	NAR (2003)	Yellow			1,2,3,5	1-7
Thamnophis sirtalis	Common Gartersnake		Yellow			1,2,3,4,5,7,8,9	all

* SC - Special Concern; NAR - Not at Risk; T - Threatened; E - Endangered

*** MOE Region: 1 - Vancouver Island; 2 - Lower Mainland; 3 = Thompson-Nicola; 4 - Kootenays; 5 - Cariboo; 6 - Skeena-Bulkley Valley; 7 - Omineca; 8 - Okanagan; 9 - Peace*

APPENDIX B – Impacts of Roads on Amphibians and Reptiles (federally listed species are highlighted in bold)

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
TERRESTRIAL-BREEDING SALAMANDERS		
Wandering Salamander	Few reported at any site. Highway 4 Ucluelet-Tofino: 21 dead over 6 years, < 1% of the population adjacent to the highway killed each year (Beasley unpubl. data); Lazo Rd, Comox: 1 live, 2 dead in 2011; Nanaimo Lakes Rd: 1 dead from 2007-2011 (Wind 2012). Ross-Durrance Rd, Highlands (CRD): 1 dead adult in 2015 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015b).	Genetic divergence found in several populations of terrestrial-breeding salamanders bisected by large highways (Marsh *et al.* 2008).
Ensatina	Lazo Rd, Comox: 1 live, 1 dead in 2011; Nanaimo Lakes Rd: 97 dead, 33 live from 2007-2011; Riverbottom Rd at Wake Lake near Duncan (Wind 2012). Highlands & Saanich (CRD): 33 live, 8 dead from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b and Ovaska and Engelstoft, unpubl. data).	
Coeur d'Alene Salamander	Mt Revelstoke National Park road: numerous adults and juveniles on wet paved road surface, Sept. 2010 (Ovaska and Sopuck, unpubl. data). Rangewide: Found clinging to rock walls and venturing onto the gravel shoulder of highways on rainy nights (Ohanjanian 2003).	A threat to at least 20 of the 56 known species sites is highway widening and maintenance (COSEWIC 2007). Planned widening of the Trans-Canada Highway near Revelstoke would cause direct mortality and habitat disruption (B.C. MOE 2015). Rock-scaling, ditch-cleaning, culvert repair and replacement, blasting, vegetation clearing, dumping of spoil, and salt application will cause mortality/harm.
Western Red-backed Salamander	Highway 4 Ucluelet-Tofino: 26 dead, 25 live from 2001-2006 (Beasley 2006); Nanaimo Lakes Rd: 57 dead, 13 live from 2007-2011; Riverbottom Rd at Wake Lake near Duncan; Lazo Rd, Comox: 1 live, 1 dead in 2011 (Wind 2012); Highlands, Saanich, and East Sooke (CRD): 9 live, 4 dead from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	
STREAM-BREEDING AMPHIBIANS		
Rocky Mountain Tailed Frog	Not reported. Risk of road mortality may be low because of nocturnal habits and low traffic volumes at night.	Extensive road networks in Yahk and Flathead areas are sources of chronic sedimentation that lower tadpole abundance (Dupuis and Friele 2002, 2004). Full-round culverts are barriers to upstream movements; General Wildlife Measures within Tailed Frog Wildlife Habitat Areas specify the use of bridges or open-bottom (half-round) culverts for road crossings (B.C. Ministry of

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
		Water, Land and Air Protection 2004).
Coastal Tailed Frog	Not reported.	Sedimentation from constructed channel crossings (Ardea Biological Consulting Ltd. 1999, Dupuis and Friele 2003). Road use is chronic source of sedimentation (Reid and Dunne 1984).
Coastal Giant Salamander	Not reported. The majority of roads in the region where this species occurs are in upslope habitats that are less occupied (i.e., not near and parallel to watercourses) (COSEWIC 2014).	Sediments and chemical pollutants to reduce road dust and to de-ice roads; fragmented forest habitats interfere with movement and dispersal of adults and juveniles (COSEWIC 2014).
POND-BREEDING AMPHIBIANS		
Northwestern Salamander	Highway 4 Ucluelet-Tofino: 258 dead, 139 live (Beasley 2006); Lazo Rd, Comox: 6 dead, 3 live in 2011; Nanaimo Lakes Rd: 14 dead, 5 live from 2007-2011 (Wind 2012).	
Long-toed Salamander	Lazo Rd, Comox: 5 dead, 5 live in 2011; Nanaimo Lakes Rd: 25 dead, 6 live from 2007-2011 (Wind 2012); Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 3A at Grohman Narrows Provincial Park: 16 dead, 10 live in Mar/Apr 2015 (Dulisse 2015); White Lake: 23 dead from 2015-2016, though this is an underestimate, as car-based surveys ceased to prevent additional road mortality (Winton 2017); Highlands & Saanich (CRD): 9 dead, 13 live from 2015–2018 (<1% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	
Blotched Tiger Salamander	Highway 97 Oosoyoos: 13 dead, 2 live from 2010-2012 (Crosby 2014); White Lake, Penticton: 240 dead juveniles from 4 surveys, 2-23 Aug 2013 (Dyer 2018); White Lake: 13 dead from 2015-2016 (Winton 2017).	
Western Toad	Vancouver Island sites: Sooke Mainline at Sooke Lake, Riverbottom Rd in Duncan, Spruston Rd in Nanaimo, Katherine Dr in Port Alberni, Highway 19 near Courtenay, Railway Ave in Merville, MU-55 near Gold River—all report high mortality of juveniles and some adults (Wind and Willmott 2012). Also at Nanaimo Lakes Rd in lower numbers (Wind 2012). Mainland/Interior sites: Ryder Lake Rd in Chilliwack (Clegg 2011), Allard Crescent in Langley, Lost Lake in Whistler (Wind and Willmott 2012), Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011), Prince George (Thompson, pers. comm. 2011 in COSEWIC 2012), Dawson Creek (Kinsey pers. comm. 2011 in COSEWIC 2012), Chilliwack, and Summit Lake (Dulisse et al. 2017), Kentucky-Alleyne Provincial Park 2011 - 2014 (Biolinx Environmental Research & Nicola Naturalist Society 2013, 2014), Highway 31A at Fish/Bear Lakes (McCrory and Mahr 2018),	Irrigation ponds/borrow pits created during road construction provide poor larval habitat (Stevens et al. 2006). Beaver control, used to prevent road flooding, can result in loss and deterioration of breeding habitat (Stevens et al. 2007). Roadside culverts and verges of logging roads used as movement corridors (Deguisse and Richardson 2009).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	Highway 22A near Waneta Dam. Most report both juvenile and adult mortality (Machmer 2012, 2015).	
Northern Leopard Frog	Dyke road at Creston Valley Wildlife Management Area: 1 adult and 1 young-of-the-year killed with only 2 cars using the road (Houston 2010a). Remain immobile at the approach of a vehicle (Mazerolle et al. 2005). Very small amount of road mortality impacts the very small population of Northern Leopard Frogs at Creston.	
Wood Frog	No data	
Boreal Chorus Frog	No data	
Northern Pacific Treefrog (a.k.a. Pacific Chorus Frog)	Highway 4 Ucluelet-Tofino: 315 dead, 69 live from 2001-2006 (Beasley 2006); Lazo Rd, Comox: 299 dead, 32 live in 2011; Nanaimo Lakes Rd, Nanaimo, and Riverbottom Rd at Wake Lake near Duncan (Wind 2012); Highway 97 near Oosoyoos: 279 dead, 148 live from 2010-2012 (Crosby 2014); Ryder Lake Rd in Chilliwack (Clegg 2011); Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 3A at Grohman Narrows Provincial Park: 81 dead, 13 live in Mar/Apr 2015 (Dulisse 2015); Highlands, Saanich, Metchosin, East Sooke (CRD): 1099 dead, 256 live from 2015-2018 surveys (74% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data); White Lake: 114 dead from 2015-2016 (Winton 2017); Highway 22A near Waneta Dam: 13 dead during the Waneta Expansion Project 2011-2014 (Machmer 2012, 2015).	
Northern Red-legged Frog	Highway 4 Ucluelet-Tofino: 330 dead, 37 live, 2001-2006, (Beasley 2006); Coombs (Blood and Henderson 2000); Nanaimo Lakes Rd (Wind 2012); Highway 4 within Pacific Rim National Park Reserve; Ryder Lake Rd in the Fraser Valley (Clegg 2011); Laburnum Rd, Qualicum (Materi 2008); Lazo Rd, Comox: 78 dead, 2 live in 2011 (Wind 2012); Wake Lake near Duncan (Wind 2012); Sea-to-Sky Highway at Pinecrest (Malt 2012); Highlands, Saanich, Metchosin (CRD): 30 dead, 10 live (2% of roadkill of amphibians that could be identified to species) (HAT 2015a, 2015b; Ovaska and Engelstoft, unpubl. data).	Road construction along Sea-to-Sky Highway 99 resulted in removal of 4160 m^2 of wetland habitat and salvage of 1,037 amphibians (including 683 Northern Red-legged Frogs). Roads are barriers to movement in dry conditions (B. Beasley, unpubl. data). Road de-icing salts and other pollutants from roads drain into ditches and wetlands where the species spends time, and sometimes breeds (B. Beasley, unpubl. data).
Columbia Spotted Frog	Highway 22A near Waneta Dam: 3 dead during the Waneta Expansion Project 2011-2014 (Machmer 2012, 2015).	
Oregon Spotted Frog	Not reported. Populations at Maintenance Detachment Aldergrove, Maria Slough, and Mountain Slough are close to roads but road mortality is a knowledge gap. Road mortality is not anticipated for this species as it does not spend substantial time out of water. Western Toads and Northern Red-legged Frogs have been found dead on the roads adjacent to the Maria Slough site. Oregon Spotted Frogs	At Maria Slough, improper timing of culvert maintenance and watercourse clearing resulted in water level dropping and stranding eggs out of water. Ditch clearing and deepening alters availability and suitability of habitat, causes direct

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	are thought to move through wetted culverts with low water flow (K. Morgan, pers. comm.).	mortality, and enables American Bullfrog (an invasive competitor/predator) occupation and breeding. Roads isolate populations and prevent new colonization.
Great Basin Spadefoot	Inkaneep Rd near Oliver, July 1990 (R. Cannings, pers. obs.); Highway 97 near Osoyoos: 1,648 dead, 1,894 live from 2010-2012 (Crosby 2014); White Lake: 44 dead from 2015-2016 (Winton 2017); Douglas Lake Rd, Upper Nicola: 21 live adults and juveniles on road from 2011-2015 (Ovaska et al. 2016 and Ovaska unpubl. data).	Effects of magnesium chloride for dust abatement during road maintenance need study (Packham, pers. comm., 2014).
Rough-skinned Newt	Highway 4 near Coombs (Blood and Henderson 2000); Nanaimo Lakes Road: 1,781 dead, 81 live from 2007-2011 (Wind 2012); Highway 4 Ucluelet-Tofino: 65 dead, 6 live from 2001-2006 (Beasley 2006); Ryder Lake Rd in the Fraser Valley (Clegg 2011); Lazo Rd, Comox: 313 dead, 14 live in 2011; Wake Lake, Duncan: 11 dead, 2 live in 2011 (Wind 2012); Highlands, Saanich, Metchosin (CRD): 334 (14% of amphibians) dead, 28 live (22.5% of roadkill of amphibians that could be identified to species) (HAT 2015, Ovaska and Engelstoft, unpubl. data). Gulf Islands - numerous roads (Penn, pers. comm. 2018).	

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
TURTLE		
Painted Turtle	Beaver Lake Rd in Saanich (Ovaska and Engelstoft 2011); Sunshine Coast Highway (Kilburn et al. 2011); Arrow Lakes Reservoir (Tuttle and Hawkes 2011); White Lake: 2 dead from 2015-2016 (Winton 2017); Highway 6 at Summit Lake (Dulisse 2018); Highway 3 in Cranbrook (Gillies and St. Clair 1997). Nesting females are killed when crossing these roads to nest in the fill material or exposed cutbanks along roadsides, or to nest at sites on the opposite side of the road.	Road construction immediately adjacent to wetlands destroys nests (Maltby 2000). Roadways increase predaton by raccoons, skunks, coyotes, and foxes (Frey and Conover 2006).
LIZARDS		
Northern Alligator Lizard	Creston: Not commonly found on roads even though six of ten sites within a study were bordered on one side by a road (Rutherford and Gregory 2001).	Not attracted to roads as heat sources but it is possible that roads serve as barriers between populations (Rutherford and Gregory 2001).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
Western Skink	Creston: Not commonly found on roads even though six of ten sites within a study were bordered on one side by a road (Rutherford and Gregory 2001).	Rock blasting may cause direct mortality and destruction of important basking sites, nesting sites, or hibernacula. Conversely, road and other corridor construction may enhance skink habitat through the creation and maintenance of open areas. Also, blast rock pieces that are created from the construction of roads, power lines, or pipelines may also increase available cover for skinks (Dulisse 2006b).
SNAKES		
Northern Rubber Boa	Okanagan, Creston, Pemberton—Lillooet Highway (P. Gregory, pers. comm. 2014 cited by COSEWIC).White Lake: 19 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 18 dead during the Waneta Expansion Project 2011-2014 and 1 dead prior to the Project 2009 (Machmer 2012, 2015)	Bentley Rd to Okanagan Lake Parkway Highway construction destroyed den and snakes (Summit Environmental Consultants 2010).
Western Yellow-bellied Racer	Okanagan Connector: almost all suitable habitats are intersected by road. White Lake: 128 dead from 2015-2016 (Winton 2017); Highway 22A near Waneta Dam: 29 dead, 3 alive during the Waneta Expansion Project 2011-2014 and 2 dead prior to the Project in 2009 (Machmer 2012, 2015)	Habitat loss and fragmentation.
Sharp-tailed Snake	North Pender and South Pender Islands: 6 dead (Spalding 1995; Engelstoft and Ovaska 1999; C. Engelstoft, pers. comm., 2008). Ferry terminal on Saltspring Island: 45% annual increase in vehicle traffic (from 147,830 vehicle trips in 1992-1993 to 214,787 trips in 2001-2002) within the past decade increases risk to snakes nearby (B. Bourquin, pers. comm., 2002). Another site on Vancouver Island is bisected by a popular recreational trail, and mortality from collisions with bicycles is a possibility although undocumented.	Localities on Gulf Islands: habitat fragmentation hinders dispersal movements.
Western Rattlesnake (a.k.a. North Pacific Rattlesnake)	Osoyoos Indian Reserve: roadkills were 72-100% of known mortalities over the 3-year period reported (Snook and Blaine 2012); White Lake: 92 dead from 2015-2016 (Winton 2017) with 6.6% of rattlesnake population killed on road annually and projected population decline (Winton 2018); Highway 97 between US border and Okanagan Falls: none detected from 2010-2013, though heavy traffic incompatible with species (S. Ashpole, pers. comm., 2014).	Both snakes and hibernacula destroyed by earth-moving equipment during road construction (M. Sarell, pers. obs.).

Species	Examples of Documented Road Mortality Occurrences in B.C.	Other Documented Impacts of Roads
	Across BC range: 50% of 106 dens were subject to regular road mortality or to damage from road construction (Sarell 1993); 86% of 368 confirmed dens located within 2 km of a road (Hobbs 2013).	
Desert Nightsnake	South-central British Columbia: Only about 20 Desert Nightsnakes have been reported in Canada, all from a small region that is under intense development pressure.	Habitat loss and population isolation.
Great Basin Gopher Snake	Highway 1 from Chase to Ashcroft and Highway 97 from Summerland to Peachland: local extirpations/precipitous declines (J. Hobbs, pers. comm., 2013). White Lake: 84 dead from 2015-2016 (Winton 2017).	Highways 3 and 8 bisect prime habitat.
Terrestrial Gartersnake	Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011). White Lake: 9 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 8 dead, 2 alive during the Waneta Expansion Project 2011-2014 and 1 dead, 1 alive prior to the Project 2009 (Machmer 2012, 2015)	
Northwestern Gartersnake		
Common Gartersnake	Airport Rd at Arrow Lakes Reservoir (Tuttle and Hawkes 2011); Highway 4 Ucluelet—Tofino (B. Beasley, unpubl. data); White Lake: 20 dead from 2015-2016 (Winton 2017). Highway 22A near Waneta Dam: 5 dead, 1 alive during the Waneta Expansion Project 2011-2014 and 3 dead, 1 alive prior to the Project 2009 (Machmer 2012, 2015)	

APPENDIX C – General Habitat Associations of Amphibians and Reptiles in BC

Scientific Name	English Name	**Forest** (moist/wet, mesic, dry, mixed, deciduous, Garry Oak coastal bluffs)	**Shrub** (natural, logged, sagebrush steppe, Antelopebrush steppe, hedgerow)	**Meadow / Grassland**	**Rock** (cliff, sparsely vegetated rock, talus)	**Subterreanean** (subsoil, caves)	**Riparian** (forest, shrub, herbaceous)	**Seeps / streams** (stream, river. Splash zone, gravel bar)	**Wetland / Lake** (bog, fen, swamp, marsh, lake, pond / open water, vernal pool)	**Built / Industrial** (urban, suburban)	**Agricultural** (pasture, old field, cultivated field)
TERRESTRIAL-BREEDING SALAMANDERS											
Aneides vagrans	**Wandering Salamander**	**X**	**X**		**X**		**X**				
Ensatina eschscholtzii	Ensatina	X				X	X				
Plethodon idahoensis	**Coeur d'Alene Salamander**	**X**			**X**	**X**	**X**	**X**			
Plethodon vehiculum	Western Red-backed Salamander	X			X	X	X				
STREAM-BREEDING AMPHIBIANS											
Ascaphus montanus	**Rocky Mountain Tailed Frog**	**X**					**X**	**X**			
Ascaphus truei	**Coastal Tailed Frog**			**X**			**X**	**X**			
Dicamptodon tenebrosus	**Coastal Giant Salamander**	**X**					**X**	**X**			
POND-BREEDING AMPHIBIANS											
Ambystoma gracile	Northwestern Salamander	X					X	X	X		
Ambystoma macrodactylum	Long-toed Salamander										
Ambystoma mavortium	**Blotched Tiger Salamander**										
Anaxyrus boreas	**Western Toad**	**X**		**X**			**X**	**X**	**X**		
Lithobates pipiens	**Northern Leopard Frog**			**X**			**X**	**X**	**X**		
Lithobates sylvaticus	Wood Frog	X		X			X	X	X		
Pseudacris maculata	Boreal Chorus Frog						X		X		
Pseudacris regilla	Northern Pacific Treefrog										
Rana aurora	**Northern Red-legged Frog**	**X**		**X**			**X**	**X**	**X**		
Rana luteiventris	Columbia Spotted Frog						X	X	X		
Rana pretiosa	**Oregon Spotted Frog**						**X**	**X**	**X**		
Spea intermontana	**Great Basin Spadefoot**	**X**	**X**	**X**					**X**		
Taricha granulosa	Roughskin Newt										
Lithobates catesbeianus	American Bullfrog							X	X		
Lithobates clamitans	Green Frog										

Scientific Name	English Name	**Forest** (moist / wet, mesic, dry, mixed, deciduous, Garry Oak coastal bluffs)	**Shrub** (natural, logged, sagebrush steppe, Antelopebrush steppe, hedgerow)	**Meadow / Grassland**	**Rock** (cliff, sparsely vegetated rock, talus)	**Subterreanean** (subsoil, caves)	**Riparian** (forest, shrub, herbaceous)	**Seeps / streams** (stream, river. Splash zone, gravel bar)	**Wetland / Lake** (bog, fen, swamp, marsh, lake, pond / open water, vernal pool)	**Built / Industrial** (urban, suburban)	**Agricultural** (pasture, old field, cultivated field)
TURTLES											
Chrysemys picta	**Painted Turtle**						**X**	**X**	**X**	**X**	
Trachemys scripta	Pond Slider										
LIZARDS											
Elgaria coerulea	Northern Alligator Lizard	X		X	X		X	X			
Plestiodon skiltonianus	**Western Skink**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Podarcis muralis	Common Wall Lizard										
SNAKES											
Charina bottae	**Northern Rubber Boa**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Coluber constrictor	**North American Racer**	**X**	**X**	**X**	**X**						
Contia tenuis	**Sharp-tailed Snake**	**X**		**X**	**X**	**X**					
Crotalus oreganus	**Western Rattlesnake**	**X**	**X**	**X**	**X**	**X**	**X**				
Hypsiglena chlorophaea	**Desert Nightsnake**	**X**	**X**	**X**	**X**			**X**			
Pituophis catenifer	**Gopher Snake**										
Thamnophis elegans	Terrestrial Gartersnake										
Thamnophis ordinoides	Northwestern Gartersnake		X	X	X	X	X			X	X
Thamnophis sirtalis	Common Gartersnake										

APPENDIX D – Migration, Dispersal, and Movement Distances of Amphibians and Reptiles in BC (federally listed species are highlighted in bold)

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
TERRESTRIAL-BREEDING SALAMANDERS		
Wandering Salamander	No seasonal migrations, but occasionally found on roads.	94% of movements between recaptures of marked individuals at Rosewall Creek were < 10 m; average distance between captures was 2.8 m and longest distance was 38 m (N=176) (Davis 1991).
Ensatina	No seasonal migrations, but occasionally found on roads.	
Coeur d'Alene Salamander	Annual fall migration from interior of a cave to outside is ~25 m (Ohanjanian 2000).	Longest distance was 52.8 m (Ohanjanian and Beaucher 2002).
Western Red-backed Salamander	No seasonal migrations, but occasionally found on roads.	In Goldstream Provincial Park, Vancouver Island, individuals showed high fidelity to particular cover objects on the forest floor, and their movements over several years were very small: distance between 2 farthest captures was 2.5 m for adult males, 1.7 m for adult females, 2.0 m for juveniles, based on capture-mark-recapture study (Ovaska 1988).
STREAM-BREEDING AMPHIBIANS		
Rocky Mountain Tailed Frog	Seasonal migration mainly follows elevational gradient along streams but dispersal movements between streams are also likely.	Juvenile female moved 360 m over one year 50% of reproductively mature adults had maximum movement of 20 m/yr in Montana (Daugherty and Sheldon 1982).
Coastal Tailed Frog	No seasonal migration reported. Rapid recolonization of Mt. St. Helens following the 1980 eruption (Crisafulli et al. 2005) may indicate they are capable of occasional, long-range dispersal.	Average daily distances on land of 23.3 m ± 7.8 m for females and 16.8 m ± 3.9 m for males in the B.C.'s south coast region (Wahbe et al. 2004).
Coastal Giant Salamander	Johnston (1998) and Johnston and Frid (2002) found 67% of locations of 18 radio-tracked adults in old-growth and mature second-growth forest were within 5 m of the stream bank. Longest distance of an adult from the stream bank was 66 m. Several studies in Oregon have reported the Pacific Giant Salamander up to 400 m from stream edges (reviewed in Olson et al. 2007).	Average movement lengths for individual salamanders ranged from 3 to 21 m (Johnston and Frid 2002). Average adaptive kernel home-range size for individual salamanders ranged from 3 to 35,321 m^2 (Johnston and Frid 2002).
POND-BREEDING AMPHIBIANS		
Northwestern Salamander	Migrate toward breeding ponds in fall and away from ponds in spring, some individuals crossing road > 500 m from breeding pond (Beasley	

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	2006, 2013).	
Long-toed Salamander	Migrate from over-wintering sites to breeding ponds in early spring and away from ponds after egg-laying. Individual captured 750 m from breeding pond in Hinton, Alberta (Graham 1997).	Straight-line distances between capture sites ranged from 135 to 525 m in Hinton, Alberta (Graham 1997). Home range estimates per individual ranged from 115 to 282 m^2 in the Bow Corridor of Alberta (Sheppard 1977).
Blotched Tiger Salamander	Radio-tagged adults rarely moved more than 250 m from the wetland of capture (Richardson et al. 2000; Steen et al. 2006). Juveniles are more likely to disperse than are adults (up to 20% of juveniles versus 3-6% of adults moving between wetlands in any given year; Church and Wilbur, unpubl. data cited in Church et al. 2007). Anecdotal reports exist of salamanders found up to 3 km from the nearest wetland (Sarell and Robertson 1994).	Daily movements were generally constrained within a 5-m radius and were often centred on abandoned animal burrows (Richardson et al. 2000).
Western Toad	On Vancouver Island (Davis 2000) and in east-central Alberta (Browne 2010), most Western Toads used terrestrial habitats within 2 km of breeding sites, although much longer movements have occasionally been reported. Hibernation sites have been found 146-1,936 m (Browne and Paszkowski 2010) and 180-6,230 m (Bull 2006) from breeding sites in Alberta and Oregon, respectively. Average distance from breeding site was 2500 m in Oregon (max. 6,200 m; Bull 2006), 4,400m in Montana (max. 7400m; Schmetterling and Young 2008). From COSEWIC (2012d): "Western Toads are capable of directional long-distance dispersal movements (up to 7.2 km in <24 hours in spring on Vancouver Island; Davis pers. comm. 2004). Schmetterling and Young (2008) documented movements up to 13 km." "Toads moved extensive distances in the fall and spring, averaging 496 m between their point of capture and their hibernation site, and 474 m between their hibernation site and their breeding site. Average distance that 7 non-breeders hibernated from a potential breeding site was 1438 m. Maximum fall movement from point of capture to hibernaculum was 1979 m." (Wind 2018)	Longest straight-line movement of radio-tagged adult male toads released in an unfamiliar area was 1,482 m (Deguise and Richardson 2009).
Northern Leopard Frog	Recently metamorphosized Northern Leopard Frogs disperse in all directions and have been observed 1 km from natal ponds in Creston (Waye and Cooper 2001). In southern Alberta, adults may travel up to 1.6 km from hibernation sites to breeding habitats (Wershler 1991). Seasonal dispersal distances of 8-10 km have been documented in	Adults maintain small home ranges varying from 15 to 600 m^2 (Dole 1965). Adults may move up to 160 m on a single rainy night (Waye and Cooper 2001) but generally remain in the vicinity of breeding areas.

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	Alberta (Alberta Northern Leopard Frog Recovery Team 2005).	
Wood Frog		
Boreal Chorus Frog		
Northern Pacific Treefrog (a.k.a. Pacific Chorus Frog)		
Northern Red-legged Frog	Adults appear to leave breeding sites relatively soon after the breeding period and move substantial distances (commonly 1.5 km to up to 4.8 km from breeding pools) (Hayes et al. 2001, 2007); observed travelling 312 m away in straight-line distance from breeding sites (Serra Shean 2002); some juveniles disperse over 500 m from natal ponds (Beasley unpubl. data 2014).	> 190 m (straight-line distance) through clearcuts during 2-3 rainy days (Chan-McLeod 2003); in Washington, five adult females moved up to 80 m day during the spring migration period (Serra Shean 2002).
Columbia Spotted Frog		
Oregon Spotted Frog		In Washington, home ranges during the breeding and autumn seasons averaged 1.8–1.9 ha, whereas the dry-season home range averaged only 0.9 ha (Watson et al. 2003). The same study reported movements of 32-111 m/day for 2-18 days. The longest reported movement is of an adult female frog along Jack Creek in Oregon, which moved 2,799 m (stream distance) from her original capture location (Cushman and Pearl 2007). In the same study, two juvenile frogs were recorded moving 1,245 m and 1,375 m downstream from their initial capture location.
Great Basin Spadefoot	Little information on movement distances in BC or other areas. Based on anecdotal information on spadefoots in general, spadefoots will move several hundred meters or more from breeding sites and thus, in the absence of more specific information, it can be assumed that spadefoots use terrestrial habitat up to a minimum of 500 m around breeding sites and probably up to 1 km, depending upon the terrain (COSEWIC 2007).	
Rough-skinned Newt		
TURTLE		
Painted Turtle	Movements several hundred metres overland between ponds are not uncommon (Gregory and Campbell 1987). Females, in particular, make	Based on a study of Midland Painted Turtles in a small marsh system in southern Michigan, Rowe

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
	extensive use of the terrestrial environment, laying their eggs up to 150 m or more away from the water's edge. In Nebraska, this species often migrates several kilometres from shallow or dry marshes and basins to permanent water bodies during dry summer months (Ernst et al. 1994).	(2003) documented an average home range size of 1.8 ha in 1999 and 0.7 ha in 2000 in his study, and average daily travel distances of 39 m/day in 2000 and 102 m/day in 1999.
LIZARDS		
Northern Alligator Lizard	Do not make large movements between hibernation or summer sites, as far as known.	Rutherford and Gregory (2001) found an average distance of 16 m between recapture locations in Creston. The maximum distance was 500 m.
Western Skink	Rutherford and Gregory (2003) found that Western Skinks had high site fidelity over 3 years.	Rutherford and Gregory (2003) found that 25 recaptures of tagged Western Skinks in the Creston Valley Wildlife Management Area in B.C. had a mean of 8 m distance from the previous capture in the same year, with a maximum movement of 61.4 m during a season. They estimated home range to be roughly 0.01 ha (a circle with a 10 m diameter is 78 m^2 or approximately 0.01 ha) but it may be higher.
SNAKES		
Northern Rubber Boa	One hibernaculum was about 450 m from the general area that the snake used in summer (St. Clair, unpubl. data cited in COSEWIC 2016). Lowcock and Woodruff (2014) noted that some travel short distances (<100 m) to the valley bottom.	Using telemetry data, St. Clair (unpubl. data) calculated home ranges of two Northern Rubber Boas, including the hibernaculum, as 0.298 and 1.203 ha (COSEWIC 2016).
Western Yellow-bellied Racer	Migration distances from dens are poorly known for the Western Yellow-bellied Racers in British Columbia. In British Columbia, gravid females may travel more than 500 m to suitable egg-laying sites (Sarell 2004).	In Utah, radio telemetry studies by Brown and Parker (1976) indicate maximum movement distances of 1.6 and 1.8 km from two den sites, respectively, with average straight-line distance of less than 1 km (781 m for males and 663 m for females). While on their summer ranges, Shewchuk and Waye (1995) found that daily movements were usually less than 200 m and

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
		sometimes followed a circuit returning to a regular overnight roost.
Sharp-tailed Snake	There is no evidence to suggest that individual snakes undertake migration movements between seasonal habitats, and hibernation and aestivation might take place within habitats occupied year-round but long movements are very difficult to document.	Within a rural residential area on North Pender Island, 16 recaptured adult snakes were found within areas of usually less than 55 m along the greatest dimension (average = 25 m; range: 16-93 m) over a year (Engelstoft and Ovaska 1999). The longest movement was by an adult male that moved a straight-line distance of 93 m within a 3-week period in March-April (Engelstoft et al. 1999). In relatively undisturbed habitat on Vancouver Island, 5 recaptured snakes moved straight-line distances of up to 32 m within one active season (Ovaska and Engelstoft 2005).
Western Rattlesnake (a.k.a. North Pacific Rattlesnake)	The migration distance between summer foraging areas and overwintering dens varies depending on habitat, and distances of 290 to 3,500 m have been reported in BC. Gravid females do not migrate but remain within 400 m of the hibernacula, frequently at group basking areas termed rookeries (Macartney 1985; Bertram et al. 2001). The maximum migration distance of a mature male was 3,568 m (Gomez 2007), but most males remained within 1,400 m of the den (Macartney 1985, Bertram et al. 2001, Gomez 2007, Lomas 2013). Migration from dens in the Okanagan occurs along specific corridors (Macartney 1985).	The linear distance moved by ten adults (non-gravid females and males) from five dens near Kamloops varied from 290 to 3000 m (Bertram et al. 2001). Bertram et al. (2001) reported home ranges of 0.12 to 103.5 ha based on radio-telemetry locations from 12 snakes near Kamloops, with the smallest range being that of a gravid female. Other BC estimates range from 1.2 to 171 ha (Macartney 1985) and average 23 ha (Lomas 2013).
Desert Nightsnake		
Great Basin Gopher Snake	Females may travel long distances (>2 km) to nest sites. The longest single-season movements made by gopher snakes (>2 km) are generally those by females travelling to oviposition sites in summer and fall (Shewchuk 1996, Bertram et al. 2001). Brown (2006) reported that 2 females near Vaseaux Lake oviposited 81.2 m and 40.2 m from their respective hibernacula. White (2008) observed that males in her study in the Okanagan Valley moved farther than females in spring (perhaps searching for mates), while females moved farther than males in summer and fall.	Average movement distances of 350 m – 500 m have been reported from B.C. (Kamloops: average maximum of 453 m Bertram et al. 2001; Osoyoos: 934 ± 185 m (Shewchuk 1996); South Okanagan: 357 m (Williams and Bishop 2011); 520 ± 25 m (Williams et al. 2012), but occasional longer distances up to 2,360 m have been documented (Williams et al. 2012). After reaching their summer ranges, movements of snakes in Osoyoos were relatively short (average 153 ± 96.2 m/day for females and 124.8 ± 23.7 m/day for males) and

Species	Migration/Dispersal Distances from Key Habitats	Distance Between Captures and Home Range Estimates
		were centred on a particular retreat site (Shewchuk 1996). Home ranges of 1.14-33.47 ha have been documented in BC (Bertram et al. 2001, Brown 2006, White 2008).
Terrestrial Gartersnake		
Northwestern Gartersnake		
Common Gartersnake	Travel several kilometers between foraging sites and dens.	

APPENDIX E – Examples of mitigation projects to reduce road impacts on amphibians and reptiles in BC

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Crossing Structures with Fencing				
Western Toad	Park road at Lost Lake Municipal Park, Whistler	A single tunnel (corrugated metal 60 cm diameter culvert approximately 8 m long), and over 100 m of fencing (manufactured by ACO Systems Ltd.) installed in 2014 to keep juvenile toads away from recreational areas with high human use and guide them upslope into forest. Portable ramp installed across a trail allows toads to crawl beneath while people walk overtop.	ACO wildlife fencing works well to exclude juvenile toads from high human use areas as long as it is installed properly (dug in with substrate covering back side with no gaps between panels). Toadlets safely move under ramp and follow fencing into the forest but do not use tunnel despite installing LED lights; Not possible to seal the migration path and lead toadlets to enter tunnel; road closure was more effective in past; future efforts will install new ACO fencing to guide toads to a creek flowing out of park.	Beresford 2018; Williamson pers. comm. 2018
Western Toad	Highway 6 at Summit Lake, near Nakusp	One plastic tunnel (0.86 m diameter x 16.5 m long, 1.2 m depth of fill over culvert) installed in 2006, one concrete box tunnel (1.2 m x 1.5 m wide x 21 m long, 0.58 m depth of fill over culvert) installed in 2014, 1 existing corrugated metal culvert (0.6 m in diameter x 25 m long, 2 m depth of fill over culvert) and 1152 m of fencing (550 m ACO, 310 m mesh, 240 m polypropylene sheeting, and 60 m concrete wing walls);	High use of both tunnels by adults (533) and juveniles (10s of 1000s) caught by camera traps between 2015-2018 in the plastic and concrete tunnels; regular fence maintenance required; portions of the fence will be replaced with a product made by Animex in 2019.	Dulisse et al. 2018; Dulisse, pers. comm. 2019; McGlynn pers. comm. 2019
Western Toad	Highway 31A at Fish/Bear Lakes	In 2018, installed directional fencing made of split pvc pipe (25 cm diameter and 400 m long) to guide migrating toadlets from rest area to a raised wooden structure (dimensions?) crossing under an existing highway bridge. In 2015-17, directional fencing made of ___? guided toadlets to 3 existing culverts (corrugated metal, 60 cm in	In 2018, >100,000 toadlets successfully followed fencing to crawl over the raised wooden structure under the highway bridge and moved along creek bank. Raised structure must be re-constructed each year because of seasonal stream flow. From 2015-17 toadlets followed fencing but would not cross through existing culverts despite	McCrory and Mahr 2018

		diameter?) at highway.	installing LED lights. Toads may have been deterred because one of the culverts was too dry and in the wrong orientation, the others were too wet and possibly too small (verify dimensions of all 3).	
Western Toad	Park road at Kentucky-Alleyne Provincial Park, south of Merritt	Single semi-cylindrical "half culvert" with earthen floor (3.6 m long, 1.8 cm wide at ground level, 0.5 m high, 0.3 m from top to road surface) installed in May 2013. In 2014, a temporary fence was replaced with wooden fencing (~20 cm high with a 5 cm lip) that has a 20 cm strip of landscape cloth stapled to the base of each board and buried to prevent toads from burrowing under the fence. The fence extends 136 m on the pond side of the road and 34 m on the forest side. One-way ramps allow toads to move back towards the pond.	Reduction in road mortality at the crossing location; thousands of post-metamorphic juveniles moved alongside fence and through tunnel; some spillover at fence ends	Biolinx Environmental Research Ltd and Nicola Naturalist Society 2014; Ovaska et al. 2018
Western Toad	Wake Lake	Temporary directional fencing attached to existing drainage culverts	Post-metamorphic juveniles moved through drainage culverts. Housing development plans in hotspot location make it challenging to do permanent mitigation.	Wind 2018
Western Toad	Highway 19 Courtenay	Tunnels (of various sizes) and short sections of guiding fences and barrier fences (made of steel mesh hardware cloth) attached to elk barrier fences	Toads have breached the fencing when it has not been maintained (e.g., thick vegetative growth and holes and small mammal burrows allow toads to move over or through the fence).	Fyfe and Wind 2008
Western Toad and other coastal amphibians	Ryder Lake Rd, Chilliwack	Box culvert with natural substrate and 3 daylighting openings in road surface with temporary directional fencing made of landscape cloth fabric	Camera monitoring shows amphibians are using tunnel, still collecting data to examine changes in road mortality; directional fencing is temporary in some locations due to land use, fencing is most challenging aspect to the long-term sustainability of project	Fraser Valley Conservancy 2018
Northern Red-legged Frog and other coastal	Highway 99, Pinecrest	8 tunnels ranging in length from 21 to 37 m and made of various materials including 3	Frogs reluctant to move through culverts (culvert substrates are very dry because	Malt 2012

amphibians	south of Whistler	plastic polyvinyl chloride (PVC) culverts (1 m diameter), 3 concrete culverts (2 m diameter) and 1 corrugated steel culvert (3 m diameter); fencing is made of black plastic polyethylene mesh (1/4") mounted on rebar posts, and steel mesh hardware cloth (1/4" mesh) on plastic wood stakes.	water drains away from entrances), road kill persisted except where original steel mesh fencing was installed. More fencing has been added but not monitored. Key lesson was the importance of ensuring that an adequate environmental assessment is done at road planning stage.	
Northern Red-legged Frog and other coastal amphibians	Highway 4 at Lost Shoe Creek near Ucluelet	200 m of barrier roadside fencing attached to bridge installed next to constructed salmon off-channel	Reduced road mortality of amphibians by 80% but have not monitored frequency of movements under bridge. Appears that animals stay still at fences. We suspect that rip rap under bridge would be a deterrent to movement.	Beasley 2018a
Northern Red-legged Frog and other coastal amphibians	Highway 4, between Ucluelet and Tofino	1 concrete box tunnel (1.8 m x 0.9 m x 14.5 m) with directional fencing made of fabric/plastic wood/cedar for 150 m leading to box tunnel and existing drainage culvert	Reduced road mortality, Northern Red-legged Frogs and Northwestern Salamanders use passage through both the new tunnel and existing drainage culvert, some predation events in culverts have been observed and frequencies are being monitored. Fences require regular monitoring and maintenance but maintenance costs are inexpensive.	Beasley 2018b
Great Basin Spadefoot, Blotched Tiger Salamander, Western Rattlesnake, Great Basin Gophersnake, Western Yellow-bellied Racer	Highway 97 South Okanagan	Tunnels and ACO fencing installed in 2010	Fenced areas covering both sides of the highway resulted in a 94% reduction in amphibian road occurrence for 2 years post installation. Since 2003, data collected from adjacent wetlands on species detection and reproductive success demonstrate significant variability. Fence degradation by sun, expenditures for fencing upkeep and repair range from $2000 to $10,000 CDN annually since installation.	Ashpole et al. 2018
Western Rattlesnake, Great Basin Gophersnake, Western Yellow-bellied Racer, Great Basin Spadefoot, Blotched Tiger	White Lake	11 pipe arch and 3 round corrugated steel culverts installed in 2017 with directional fencing in development	No monitoring results available yet.	Olson 2018

Salamander				
Western Painted Turtle	Highway 97, south of 150 Mile House	Corrugated metal tunnel (1.6 m diameter) across 4-lane highway with 1-m high fencing made of hardware cloth extending parallel to road from entranceways on each side of tunnel for a total of 150 m. Culvert and fencing installed from 2012 to 2015. Tunnel had to be redone because of erosion (when?)	After 4 years of monitoring with wildlife cameras, turtles do not pass through culvert; some go around the extended fence and get killed on the highway. Rip rap and strong spring current may impede turtle movement through tunnel.	Bings and Steciw 2018; Steciw pers. comm. 2019

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Artificial Habitat and/or Exclusion Fencing				
Western Toad	Highway 23 Mica Dam	Artificial pond was constructed to compensate for road mortality; no barrier fencing was installed	Terrain constrained options for a crossing structure and road mortality was not high enough to warrant exclusion fencing along the road that would restrict migration movements. Toads breed in new artificial pond as well as continuing to breed in original pond.	Wind 2018
Western Rattlesnake	Osoyoos	Exclusion fencing (1/4“ galvanized wire hardware cloth) installed and extended at campground from 2006; cover boards placed as refuges along fence	Mortality due to heat stress along fence, cover boards did not help	Eye et al. 2018
Western Terrestrial and Common Gartersnakes	Highway 97, south of Williams Lake	Constructed artificial hibernaculum (4 m x 4 m x 1.5 m) 650 m west of original hibernaculum that was dug up during highway expansion in October 2016. Released 150 salvaged snakes into artificial hibernaculum in November with a fence around it. Removed a portion of the fence before spring of 2017 to direct snakes towards the lake, away from the highway. There is still fencing along the backside of the den and winged out to either side	A few snakes were observed emerging in the spring of 2017. During the 2017 summer season there was construction adjacent to the den and then wildfires dominated the landscape in the Williams Lake area. An approx. 600-m radius around the den did not burn. It is unsure whether the extreme smoke conditions and fire in the adjacent area affected snake movement and other life stages, or not. Ongoing highway construction has made it	Steciw 2018; Steciw pers. comm. 2019

Species (main target listed first for each location)	Location	Mitigation	Successes & Challenges	Reference
Mitigation: Artificial Habitat and/or Exclusion Fencing				
		encouraging the snakes to move in the opposite direction of the highway.	difficult to monitor. Highway construction is still a major disturbance adjacent to the den site. The highway completion is expected in summer of 2019.	
Western Painted Turtle	Swansea Bridge, Highway 3 west of Cranbrook	Artificial nest pad and 150-200 m of chain link fencing in 2017	No nesting in 2017 but it was under construction; no monitoring since	Dulisse and Clarke 2018
Western Painted Turtle	Lower Sunshine Coast	Nesting beaches installed at 6 sites on lake side to keep turtles from crossing road. Sizes vary and include 15 m x 5 m x 0.5 m deep; 5 m x 5 m	Extremely effective at 3 of the sites in terms of successful nesting and reduction in road mortality; slower progress at other 3 sites because it took several years for turtles to start using new nesting beaches. Lessons learned: good to use pure sand and orient beaches southward.	Evelyn 2018

Appendix F – Instructions for Navigating iMapBC

Visit: https://maps.gov.bc.ca/ess/hm/imap4m/

Critical Habitat for Federally-Listed Species at Risk – Posted:

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Fish Wildlife and Plant Species"
4) Select "Critical Habitat for Federally-Listed Species at Risk – Posted"

For the most up-to-date information, mapped **Critical Habitat** (proposed and approved) for federal species at risk that occur in B.C. can also be found at: http://donnees.ec.gc.ca/data/species/developplans/critical-habitat-for-species-at-risk-british-columbia/?lang=en

Wildlife Habitat Areas – Approved, Proposed, and FRPA

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Fish Wildlife and Plant Species"
4) Select "Wildlife Habitat Areas" Approved and Proposed

Terrestrial Ecosystem Mapping (TEM)

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Forest Grasslands and Wetlands"
4) Select "Terrestrial Ecosystem Mapping"

Vegetation Resources Inventory (VRI)

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Forests Grasslands and Wetlands"
4) Select "Vegetated Land Cover"

BC Freshwater Atlas

1) In iMap, select the tab titled "Data Sources"
2) Click "Add Provincial Layers"
3) Select "Base Maps"
4) Select all layers with Streams, Lakes, Rivers, Wetlands, and Manmade Waterbodies

Technical Memorandum

Date: January 14, 2026
To: Jonathon Campbell, MacDonald Development Corporation
From: Nikita Planz, M.Sc., R.P.Bio, Shane Pedersen, B.Sc., A.Ag
File: 25-5358 |Version 1
Subject: **Lakestone Development Wildlife Corridors and Movement Pathways.**

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) has been retained by the MacDonald Development Corporation (MacDevCorp) to provide a memorandum (memo) commenting on wildlife corridors and movement pathways within the Lakestone Development. Ecoscape understands that this memo was requested by the District of Lake Country (DLC) during the Phased Development Agreement discussions for the larger Lakestone Development.

The consideration of wildlife moment and connectivity post-development is critical to maintaining ecosystem functionality and limiting harm to the natural environment. The benefits of natural area retention, or restoration, are limited if areas are isolated from wildlife (i.e. a patch of intact ecosystem surrounded by development with no safe movement pathways). Isolated natural areas also lead to increased wildlife mortality, via roadkill and other indirect mechanisms, like loss of access to resources. Isolation also results in genetic islands, which may reduce a population's resilience to disease and evolutionary pressures.

In general, pre-existing wildlife pathways, or wildlife corridors, should be maintained post development with sufficient buffers to reduce human-wildlife conflicts and make the corridors appealing to wildlife. Some species will utilize the corridors solely for passage while other species will treat them as core habitat, provided sufficient resources (food, water, shelter) are available. Corridors function best when they are wide, unfragmented, and have abundant cover features like logs, brush piles, burrows, vegetation, and rocky crevices.

When pathways cannot be maintained, wildlife crossings, culverts or overpasses, and signage may be installed to mitigate harm, although the efficacy of these mitigation measures is limited.

1.1. Lakestone Wildlife Pathways

Wildlife corridors on the property indicate probable movement pathways for various species and are ranked as primary, secondary, and tertiary to denote relative importance (**Figure 1**). As the layout provided to Ecoscape was preliminary for the future phases, **Figure 1** represents our best interpretation of wildlife movement across the property; significant grading, retaining walls, and slope changes may impact the presumed paths. It is also assumed that the pathways will be maintained in a natural condition. How these localized corridors fit within the larger context of the other high-level ecological connectivity corridors through Lake Country is displayed in **Figure 2**.

Based on previous site assessments, it is expected that Western Rattle Snake, Great Basin Gopher Snake, Rubber Boa, Western Painted Turtle, Bats and Great Basin Spadefoots may use the property and have been considered. Larger wildlife may include Moose, Mule Deer, Black Bear, Cougar, and other smaller mammals. It is likely that some of these species, especially larger mammals, will no longer use the property, or use it less frequently, with the proposed development.

The primary corridors connect different habitat types to support different trophic levels and facilitate movement within and through the property. They have greater widths compared to secondary and tertiary corridors, and are generally characterized by greater vegetation cover, more complex vegetation communities, and link natural movement pathways such as ridges, gulleys, and linear water features. Corridor 1 contains most of the sites water features and links exterior wetland features. Corridor 2 provides an additional north-south connection along the property's western rocky, open forest slopes, which are favourable for several critical life requisites of reptile species and contain both. Corridor 2 also links corridor 1 to core habitat south of the property. However, corridor 2 loses it effectiveness at the north end, as it is blocked by recently constructed residential lots, which effectively prevent movement north.

Secondary corridors have more defined roles and provide connectivity within the property, particularly to and from wetland and riparian features. They follow usage patterns similar to those of primary corridors but are more aligned with amphibians, small mammals, and birds. Corridor 9 connects the primary corridors beyond the east boundary of the property toward Knopf Brook, a stepping stone to Middle Vernon Creek, the primary north-south riparian corridor in Lake Country.

Tertiary corridors outline possible movement corridors up the south-facing slope, using small gulley features, consistent slopes, and more abundant vegetation cover to define their boundaries. Corridors, like 7 and 8, provide localized connections between similar habitat types for specific species.

1.1.1 Recommendations and Concerns

The following provides a list of concerns in regard to wildlife movement and connectivity:

- Connectivity pinch points and barriers, meaning corridors with a width less than 30 m or that abruptly end due to an anthropogenic barrier, have been identified within the property (**Figure 1**, hatched areas). These pathways are less than ideal and should be flagged for additional consideration; specifically, corridors 1, 2, 3, 5, 7, and 10.
- Development around the large wetland, accessed via corridors 4 and 10, may have an isolating effect for wildlife. The narrowness of corridors 4 and 10 also reduces the quality of habitat. Ideally, this wetland would not be surrounded by lots and roads on all sides so that wildlife use it in a meaningful way for their daily needs, such as hydration and feeding.
- There is a lack of connection north of Lakestone, especially on the northwest boundary, so it is important that the northward extension of corridors 1 and 2 not be blocked further as additional development occurs within the DLC.
- The proposed development relies heavily on culverts to ensure connectivity across roads. These will require permanent fencing to prevent road mortality of amphibians and reptiles. Responsibility for ongoing and long-term maintenance, based on manufacturer guidelines and materials, should be determined and accounted for.
    - Large wildlife will still need to cross over the road to move throughout the property. Mitigation is limited to signage and public education.

2.0 LIMITATIONS

This report has been prepared by Ecoscape and is intended for the sole and exclusive use of MacDonald Development Corporation (MacDevCorp), for the purposes set out in this report. Ecoscape has prepared this report with the understanding that all available information on the past, present, and proposed conditions of the subject property have been disclosed. Ecoscape has relied upon personal communications with MacDonald Development Corporation (MacDevCorp) and other information sources to corroborate the documents and other records available for the subject property. MacDonald Development Corporation (MacDevCorp) has also acknowledged that in order for Ecoscape to properly provide the professional service, Ecoscape is relying upon full disclosure and accuracy of this information.

Any use of this report by a third party, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Ecoscape accepts no responsibility for damages, if any, suffered by any third party as a result of actions or decisions made based on this report.

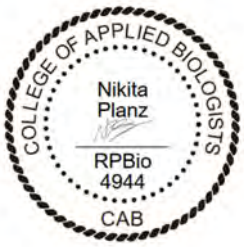
3.0 CLOSURE

We trust that this memo satisfies the present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully Submitted,

Ecoscape Environmental Consultants Ltd.

Written by:



Nikita Planz, M.Sc., R.P.Bio.
Natural Resources Biologist
Direct Line: 778-215-4397
nplanz@ecoscapeltd.com

Shane Pedersen, B.Sc., A.Ag.
GIS Technologist / Environmental Scientist
Direct Line: 778-721-5442
spedersen@ecoscapeltd.com

APPENDIX A: General Terms and Conditions

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
#2 – 2030 Matrix Crescent, Kelowna, BC., V1V 0G5

Tel: 250.491.7337
www.ecoscapeltd.com

General Conditions

This report applies and is subject to these "General Conditions".

Use of Report

This report concerns a specific site and a specific scope of work and is therefore not applicable to any other sites or any other developments not referred to in the report. Any deviation from the specific site or scope of work would require a supplementary investigation and assessment.

Conclusions and recommendations contained in this report are solely intended for the use of Ecoscape's client. Ecoscape bears no responsibility for the accuracy of information, the analysis of data or recommendations contained or referenced in this report when the report is utilized by or relied upon by any party other than Ecoscape's client unless otherwise authorized in writing by Ecoscape. Any unauthorized application of this report is at the discretion and sole risk of its user.

This report is subject to copyright, and therefore shall not be reproduced in part or in whole without prior written consent by Ecoscape. Additional copies of this report may be available upon request, if required, and will be supplied after receipt of payment for expenses associated with report production.

Limitations of Report

This report was derived solely from the conditions that were present on site during Ecoscape's investigation. The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are aware that conditions affecting the environmental condition of the site can vary both temporally and spatially, and that the conclusions and recommendations included in this report are temporally sensitive.

The client, and any other parties making use of this report with the express written consent of Ecoscape and the client, are also aware that conclusions and recommendations included within this report emanate from limited observations and information, and that both on-site and off-site conditions may vary, which in turn could affect the conclusions and recommendations that were made.

The client is aware that Ecoscape is not qualified to, nor is it making any recommendations in terms of purchase, sale, investment, or development of the subject property, as such decisions are the sole responsibility of the client.

Information Provided to Ecoscape by Others

During the extent of the preparation and work carried out in this report, Ecoscape may have relied upon information provided by parties other than the client. While Ecoscape strives to validate the accuracy of such information when instructed to do so by the client, Ecoscape accepts no responsibility for the validity of such information which may affect the report.

Limitation of Liability

The client acknowledges that property containing hazardous wastes and contaminants poses a high risk of claims brought by third parties stemming from the presence of those materials. Accounting for these risks, and in consideration of Ecoscape providing the requested services, the client agrees that Ecoscape's liability to the client, with respect to any issues relating to hazardous wastes or contaminants located on the subject property, shall be limited to the following:

With respect to any claims brought against Ecoscape by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to Ecoscape under this Agreement, whether the action is based on breach of contract or tort;

With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject property, the client agrees to indemnify, defend and hold harmless Ecoscape from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by Ecoscape, whether the claim be brought against Ecoscape for breach of contract or tort.

Disclosure of Information by Client

The client agrees to fully cooperate with Ecoscape with respect to the provision of all available information on the past, current, or proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for Ecoscape to properly provide the service, Ecoscape is relying on full disclosure and accuracy of any such information. Ecoscape does not accept any responsibility for conclusions drawn from erroneous, invalid, or inaccurate data provided to us by another party and used in the preparation of this report.

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.
#2 – 2030 Matrix Crescent, Kelowna, BC., V1V 0G5

Tel: 250.491.7337
www.ecoscapeltd.com

Standard of Care

Services performed by Ecoscape for this report have been completed in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgement has been applied in developing the conclusions and/or recommendations made in this report. No warranty or guarantee, express or implied, is made concerning the results, comments, recommendations, or any other portion of this report.

Notification of Authorities

The client acknowledges that in certain instances the discovery of hazardous materials, contaminants or conditions and materials may require that regulatory agencies and other parties be informed and the client agrees that notification to such parties or persons as required may be done by Ecoscape in its reasonably exercised discretion. Further, Ecoscape reserves the right to notify Provincial agencies when rare or endangered flora or fauna are observed, whether the species classifications are identified as such at the local, Provincial, or Federal levels of government.

Ownership of Instruments of Professional Service

The client acknowledges that all reports, plans, and data generated by Ecoscape during the performance of the work and other documents prepared by Ecoscape are considered its professional work product and shall remain the copyright property of Ecoscape.

Alternate Report Format

Where Ecoscape submits both an electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Ecoscape's instruments of professional service), the client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by Ecoscape shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the client agrees and waives all future right to dispute that the original hard copy signed version archived by Ecoscape shall be deemed to be the overall original for the Project.

The client agrees that both electronic file and hard copy versions of Ecoscape's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party other than Ecoscape. The client warrants that Ecoscape's instruments of professional service will be used only and exactly as submitted by Ecoscape.

The client recognizes and agrees that electronic files submitted by Ecoscape have been prepared and submitted using specific software and hardware systems. Ecoscape makes no representation about the compatibility of these files with the client's current or future software and hardware systems.

APPENDIX B: Figures

FIGURE 1
Wildlife Corridors and Crossings

Project:	Lakestone Wildlife Corridor Plan
Location:	District of Lake Country
Project No.:	25-5358
Prepared for:	Macdonald Communities Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Shane Pedersen, GIS Technologist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Map Date:	January 15, 2026

LEGEND

- Wildlife Crossing Signage
- Streams and Rivers
- Lakestone Lots, Roads, and Phases Linework
- Lakestone Future Subdivisions
- Cadastre
- Subject Property
- Wetland and Riparian Communities
- Connectivity Pinch Points and Barriers

Wildlife Crossings

- Arch Culvert
- Box Culvert
- Ecopassage Tunnel

Wildlife Corridors

- Primary
- Secondary
- Tertiary
- Exterior
- Primary Corridors
- Secondary Corridors
- Tertiary Corridors

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd

0 50 100 200 300 400 500
Meters

FIGURE 2
Landscape Connectivity Context

Project:	Lakestone Wildlife Corridor Plan
Location:	District of Lake Country
Project No.:	25-5358
Prepared for:	Macdonald Communities Ltd.
Prepared by:	Ecoscape Environmental Consultants Ltd. Shane Pedersen, GIS Technologist
Coordinate System:	NAD83-UTM Zone 11
Imagery:	ESRI World Imagery
Map Date:	January 15, 2026

LEGEND

- Streams and Rivers

Wildlife Corridors

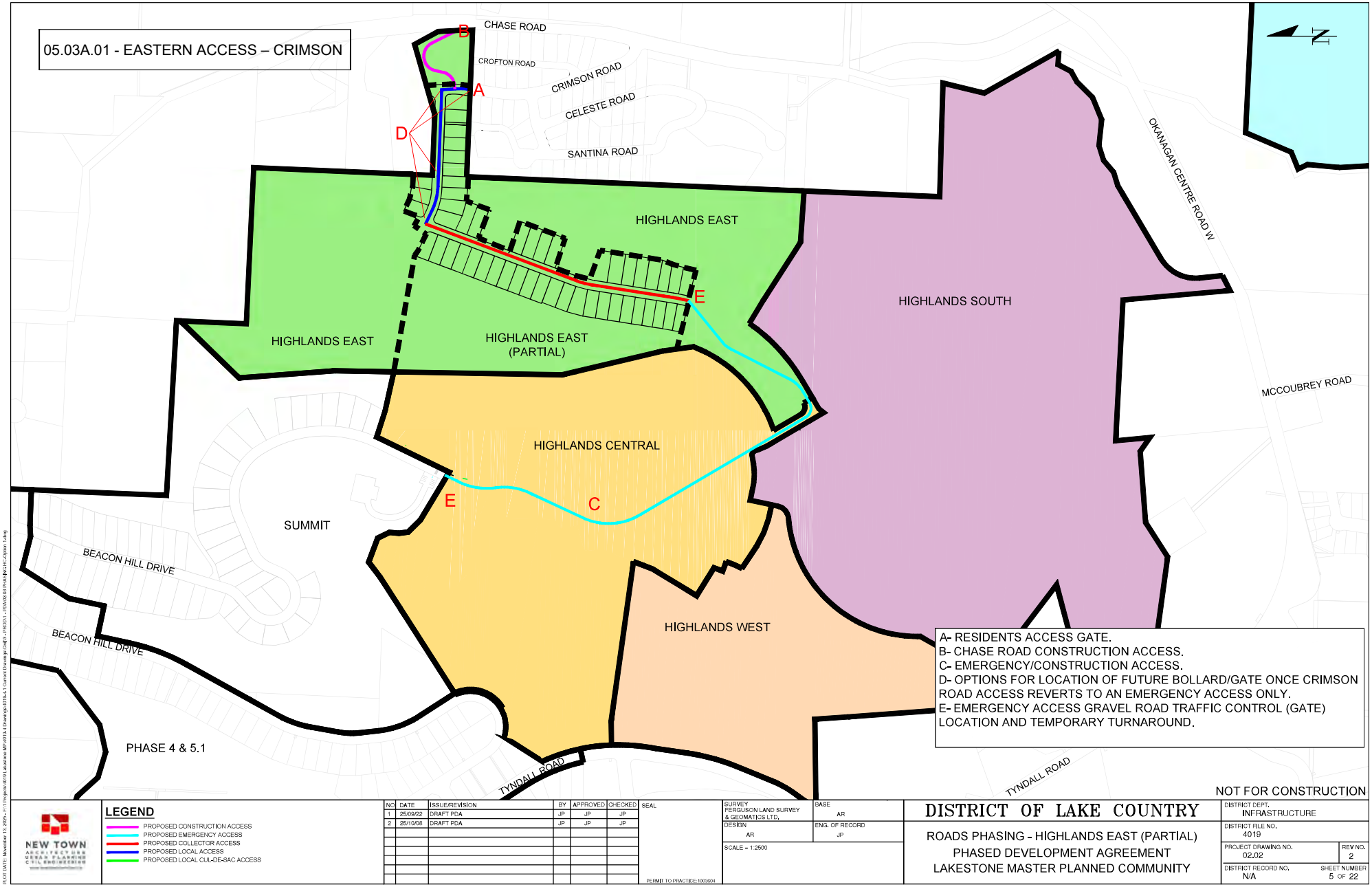
- Primary
- Secondary
- Tertiary
- Exterior
- Primary Corridors
- Secondary Corridors
- Tertiary Corridors
- Wetland and Riparian Communities
- Knox Mountain Ridge Ecosystem Connectivity Corridor
- Okanagan Mountain - k'nmalka Wildlife Corridor
- Knox Ridge to Allan Brooks Connectivity Pathway
- Cadastre
- Phasing Plan
- Subject Property

N

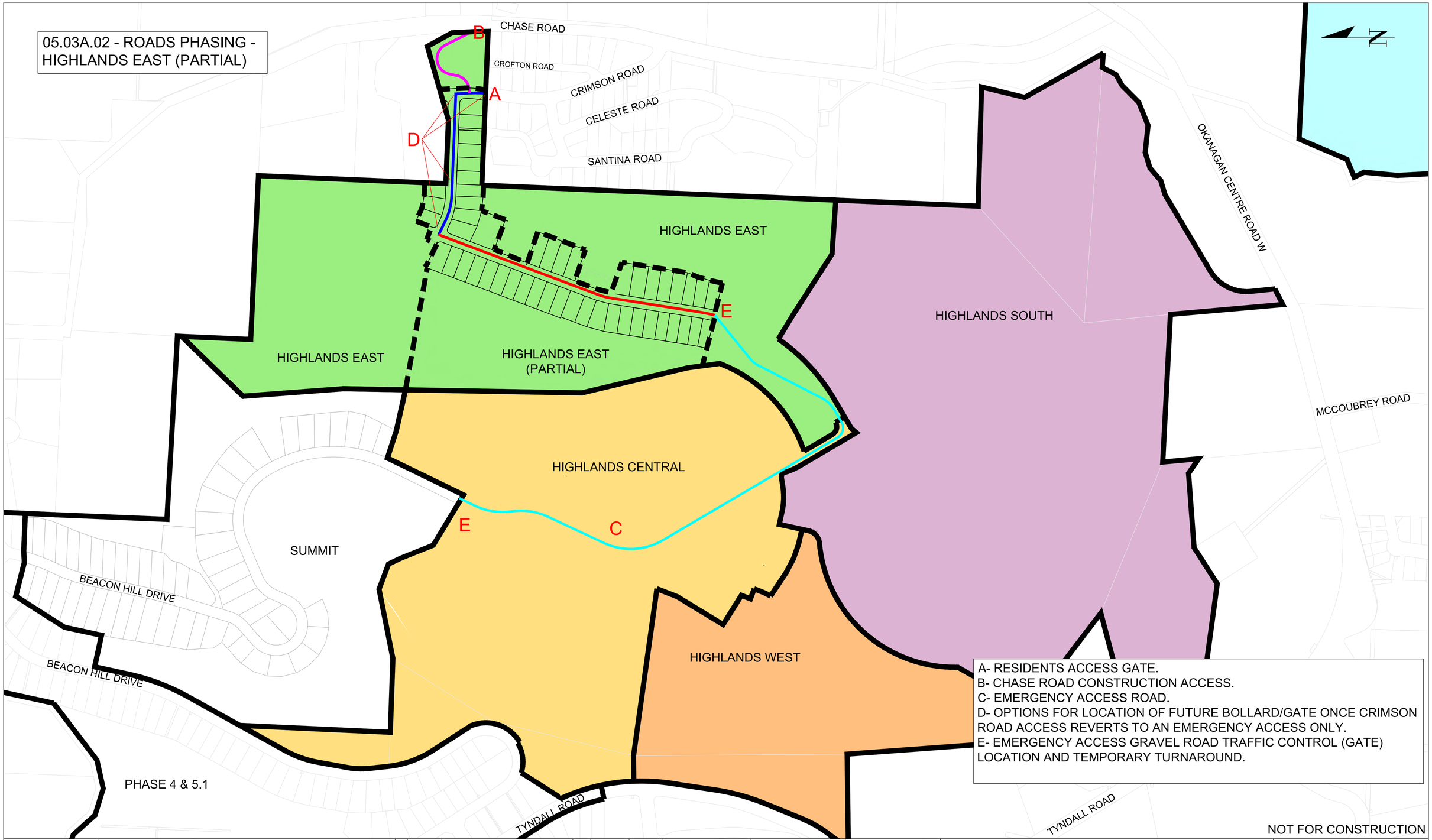
0 200 400 600 800 1,000
Meters

DISCLAIMER
The data displayed is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

ECOSCAPE Environmental Consultants Ltd.


05.03A.01 - EASTERN ACCESS – CRIMSON
CHASE ROAD
CROFTON ROAD
CRIMSON ROAD
CELESTE ROAD
SANTINA ROAD
OKANAGAN CENTRE ROAD W
MCCOUBREY ROAD
HIGHLANDS EAST
HIGHLANDS EAST
HIGHLANDS EAST (PARTIAL)
HIGHLANDS SOUTH
HIGHLANDS CENTRAL
HIGHLANDS WEST
SUMMIT
BEACON HILL DRIVE
BEACON HILL DRIVE
PHASE 4 & 5.1
TYNDALL ROAD
TYNDALL ROAD
A
B
C
D
E
E
A- RESIDENTS ACCESS GATE.
B- CHASE ROAD CONSTRUCTION ACCESS.
C- EMERGENCY/CONSTRUCTION ACCESS.
D- OPTIONS FOR LOCATION OF FUTURE BOLLARD/GATE ONCE CRIMSON ROAD ACCESS REVERTS TO AN EMERGENCY ACCESS ONLY.
E- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.
NOT FOR CONSTRUCTION
LEGEND
PROPOSED CONSTRUCTION ACCESS
PROPOSED EMERGENCY ACCESS
PROPOSED COLLECTOR ACCESS
PROPOSED LOCAL ACCESS
PROPOSED LOCAL CUL-DE-SAC ACCESS
NEW TOWN
NO. DATE ISSUE/REVISION BY APPROVED CHECKED
1 25/09/22 DRAFT PDA JP JP JP
2 25/10/06 DRAFT PDA JP JP JP
SEAL
PERMIT TO PRACTICE: 1003904
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.
BASE AR
DESIGN AR
ENG. OF RECORD JP
SCALE = 1:2500
DISTRICT OF LAKE COUNTRY
ROADS PHASING - HIGHLANDS EAST (PARTIAL)
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY
DISTRICT DEPT. INFRASTRUCTURE
DISTRICT FILE NO. 4019
PROJECT DRAWING NO. 02.02
REV NO. 2
DISTRICT RECORD NO. N/A
SHEET NUMBER 5 OF 22

05.03A.02 - ROADS PHASING - HIGHLANDS EAST (PARTIAL)



A- RESIDENTS ACCESS GATE.
B- CHASE ROAD CONSTRUCTION ACCESS.
C- EMERGENCY ACCESS ROAD.
D- OPTIONS FOR LOCATION OF FUTURE BOLLARD/GATE ONCE CRIMSON ROAD ACCESS REVERTS TO AN EMERGENCY ACCESS ONLY.
E- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PROPOSED CONSTRUCTION ACCESS
- PROPOSED EMERGENCY ACCESS
- PROPOSED COLLECTOR ACCESS
- PROPOSED LOCAL ACCESS
- PROPOSED LOCAL CUL-DE-SAC ACCESS

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY: FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE: AR
DESIGN: AR	ENG. OF RECORD: JP
SCALE = 1:2500	

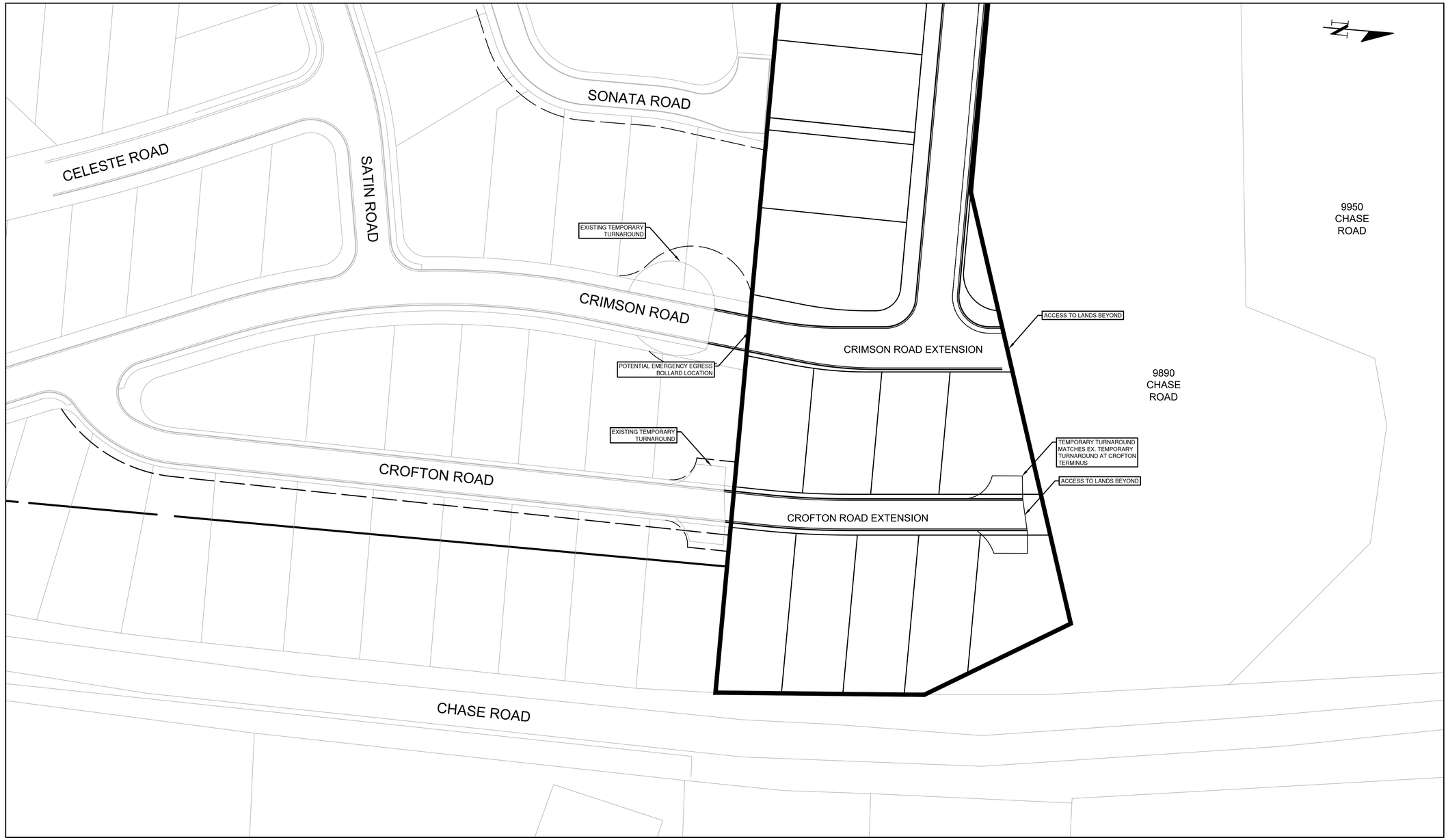
DISTRICT OF LAKE COUNTRY

ROADS PHASING - HIGHLANDS EAST (PARTIAL)
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.: INFRASTRUCTURE	
DISTRICT FILE NO.: 4019	
PROJECT DRAWING NO.: 05.03A.01	REV NO.: 1
DISTRICT RECORD NO.: N/A	SHEET NUMBER: 5 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\02.03 PHASING HC-Option 1.dwg

05.03A.03 - CRIMSON & CROFTON RD EXTENSION



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = H -1:500	

DISTRICT OF LAKE COUNTRY

CRIMSON & CROFTON RD EXTENSION
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 05.03A.03	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 6 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-ER-PLANPROF.dwg

07.01.00- ROADS PHASING
-HIGHLANDS CENTRAL

CHASE ROAD
CROFTON ROAD
CRIMSON ROAD
CELESTE ROAD
SANTINA ROAD
OKANAGAN CENTRE ROAD W
MCCOUBREY ROAD
HIGHLANDS EAST
HIGHLANDS EAST
HIGHLANDS EAST (PARTIAL)
HIGHLANDS SOUTH
HIGHLANDS CENTRAL
HIGHLANDS WEST
SUMMIT
BEACON HILL DRIVE
BEACON HILL DRIVE
TYNDALL ROAD
TYNDALL ROAD
PHASE 4 & 5.1
A
B

PROPOSED EMERGENCY ACCESS ALIGNMENT ADJUSTED TO MATCH ULTIMATE SPINE ROAD ALIGNMENT ROAD AND INFRASTRUCTURE TO BE CONSTRUCTED TO ACCOMMODATE FULL BUILDOUT OF PHASING

A- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC (GATE) LOCATION.
B- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.

NOT FOR CONSTRUCTION

PLOT DATE: November 13, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODs\1 - PDA\02.03 PHASING HC-Option 1.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PROPOSED CONSTRUCTION ACCESS
- PROPOSED EMERGENCY ACCESS
- PROPOSED COLLECTOR ACCESS
- PROPOSED LOCAL ACCESS
- PROPOSED LOCAL CUL-DE-SAC ACCESS

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	25/09/22	DRAFT PDA	JP	JP	JP
2	25/10/08	DRAFT PDA	JP	JP	JP

SEAL

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:2500	

DISTRICT OF LAKE COUNTRY

ROADS PHASING - HIGHLANDS CENTRAL
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 02.03	REV NO. 2
DISTRICT RECORD NO. N/A	SHEET NUMBER 6 OF 22

07.01.00- ROADS PHASING
-HIGHLANDS CENTRAL

CHASE ROAD
CROFTON ROAD
CRIMSON ROAD
CELESTE ROAD
SANTINA ROAD
OKANAGAN CENTRE ROAD W
MCCOUBREY ROAD
HIGHLANDS EAST
HIGHLANDS EAST
HIGHLANDS EAST (PARTIAL)
HIGHLANDS SOUTH
HIGHLANDS CENTRAL
HIGHLANDS WEST
SUMMIT
BEACON HILL DRIVE
BEACON HILL DRIVE
TYNDALL ROAD
TYNDALL ROAD
PHASE 4 & 5.1
A
B

PROPOSED EMERGENCY ACCESS ALIGNMENT ADJUSTED TO MATCH ULTIMATE SPINE ROAD ALIGNMENT ROAD AND INFRASTRUCTURE TO BE CONSTRUCTED TO ACCOMMODATE FULL BUILDOUT OF PHASING

A- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC (GATE) LOCATION.
B- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.

NOT FOR CONSTRUCTION

PLOT DATE: November 13, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODs\1 - PDA\02.03 PHASING HC-Option 1.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PROPOSED CONSTRUCTION ACCESS
- PROPOSED EMERGENCY ACCESS
- PROPOSED COLLECTOR ACCESS
- PROPOSED LOCAL ACCESS
- PROPOSED LOCAL CUL-DE-SAC ACCESS

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	25/09/22	DRAFT PDA	JP	JP	JP
2	25/10/08	DRAFT PDA	JP	JP	JP

SEAL

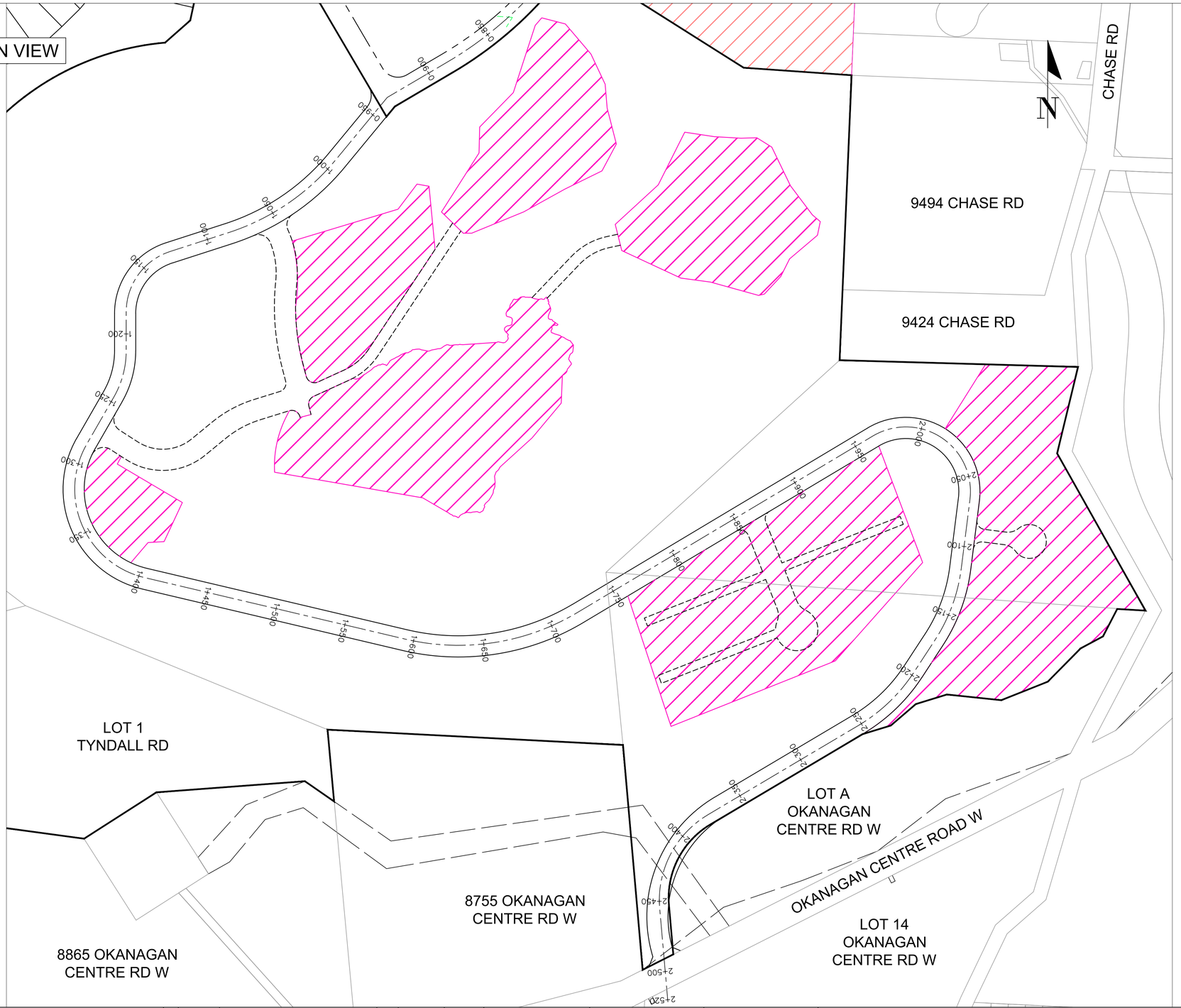
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:2500	

DISTRICT OF LAKE COUNTRY

ROADS PHASING - HIGHLANDS CENTRAL
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 02.03	REV NO. 2
DISTRICT RECORD NO. N/A	SHEET NUMBER 6 OF 22

07.01.01 - ROADS - SPINE PLAN VIEW



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1500	

DISTRICT OF LAKE COUNTRY

ROADS - SPINE PLAN VIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.01.01	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 7 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-SPINE ROAD.dwg

07.02.01 - OKCRW ALIGNMENT

8865 OKANAGAN CENTRE RD W

8755 OKANAGAN CENTRE RD W

REM LOT 4 OKANAGAN CENTRE RD W

EXISTING DRIVEWAY ACCESS RESERVOIR & PRIVATE PROPERTIES)

EXISTING DOG PARK PARKING LOT

LOT A OKANAGAN CENTRE RD W

EXISTING DRIVEWAY (TYP.)

EXISTING EDGE OF ASPHALT (TYP.)

OKANAGAN CENTRE RD W RIGHT-OF-WAY

8832 OKANAGAN CENTRE RD W

8756 OKANAGAN CENTRE RD W

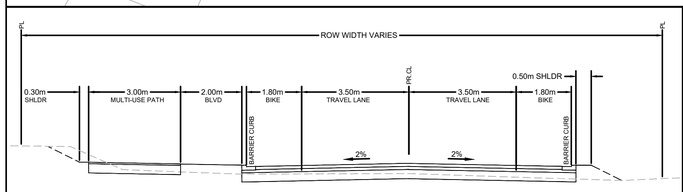
LOT 14 OKANAGAN CENTRE RD W

CHASE ROAD

LOT 15 OKANAGAN CENTRE RD W

8850 OKANAGAN CENTRE RD W

OKANAGAN CENTRE ROAD WEST - EXISTING ROADWAY ALIGNMENT



OKANAGAN CENTRE ROAD WEST TYPICAL SECTION
LAKE COUNTRY BUSINESS PARK
(NTS)
***CONCEPTUAL CROSS-SECTION FROM ALIGN PRELIMINARY DESIGN**

8865 OKANAGAN CENTRE RD W

TIE-IN TO EXISTING TYNDALL ROAD CROSS-SECTION

8755 OKANAGAN CENTRE RD W

REM LOT 4 OKANAGAN CENTRE RD W

DRIVEWAY ACCESS TO BE MAINTAINED

EXISTING DOG PARK ACCESS & PARKING TO BE MAINTAINED

LOT A OKANAGAN CENTRE RD W

DRIVEWAY ACCESS TO BE MAINTAINED

DRIVEWAY ACCESS TO BE MAINTAINED

OKANAGAN CENTRE RD W RIGHT-OF-WAY

DRIVEWAY ACCESS TO BE MAINTAINED

DRIVEWAY ACCESS TO BE MAINTAINED

8832 OKANAGAN CENTRE RD W

8756 OKANAGAN CENTRE RD W

DRIVEWAY ACCESS TO BE MAINTAINED

LOT 14 OKANAGAN CENTRE RD W

CHASE ROAD IMPROVEMENTS APPROXIMATE ALIGNMENT

LOT 15 OKANAGAN CENTRE RD W

8850 OKANAGAN CENTRE RD W

OKANAGAN CENTRE ROAD WEST - PROPOSED ROADWAY ALIGNMENT

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE 1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1000	

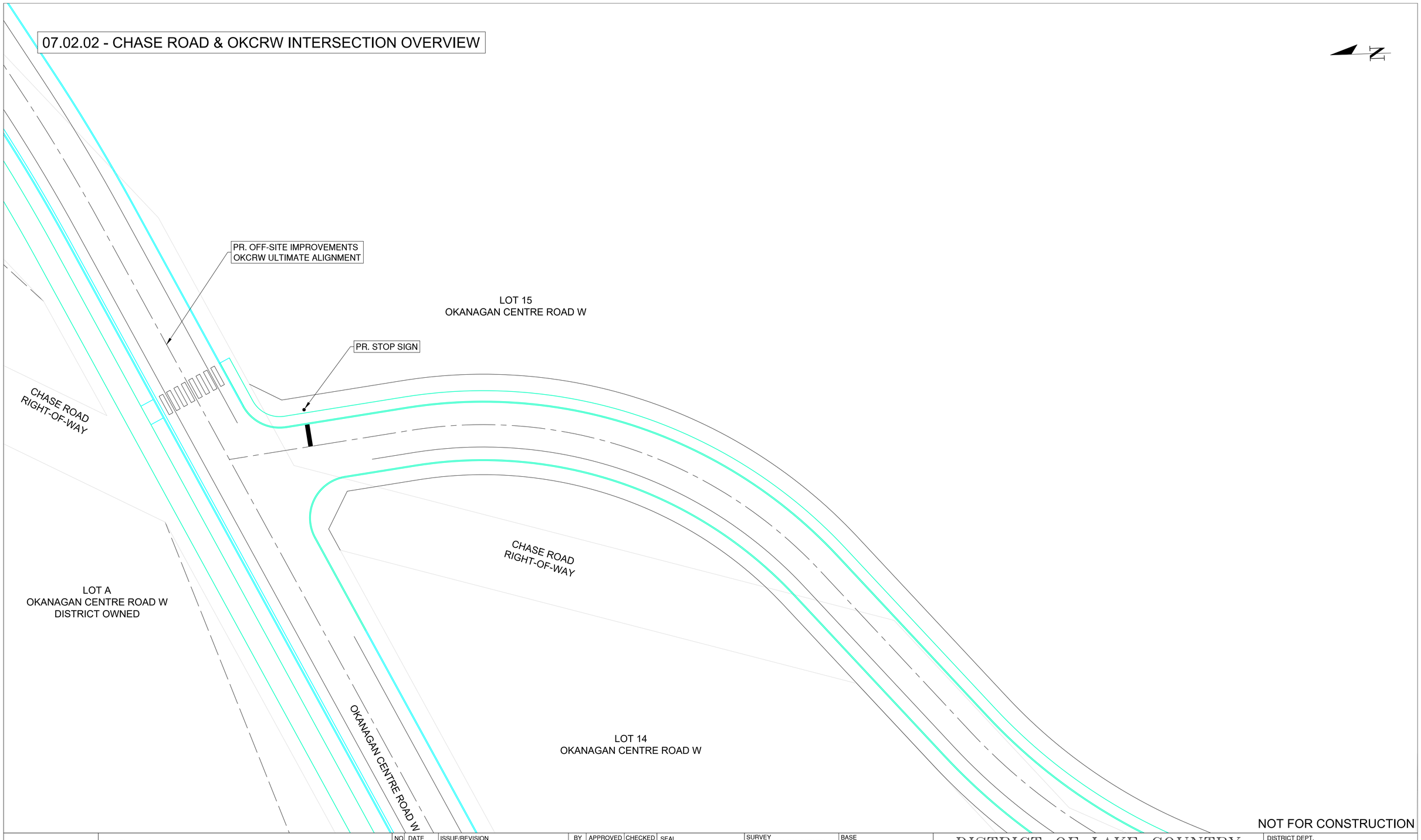
DISTRICT OF LAKE COUNTRY

OKCRW ALIGNMENT
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.02.01	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 12 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-ROADS-OFFSITE.dwg

07.02.02 - CHASE ROAD & OKCRW INTERSECTION OVERVIEW



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

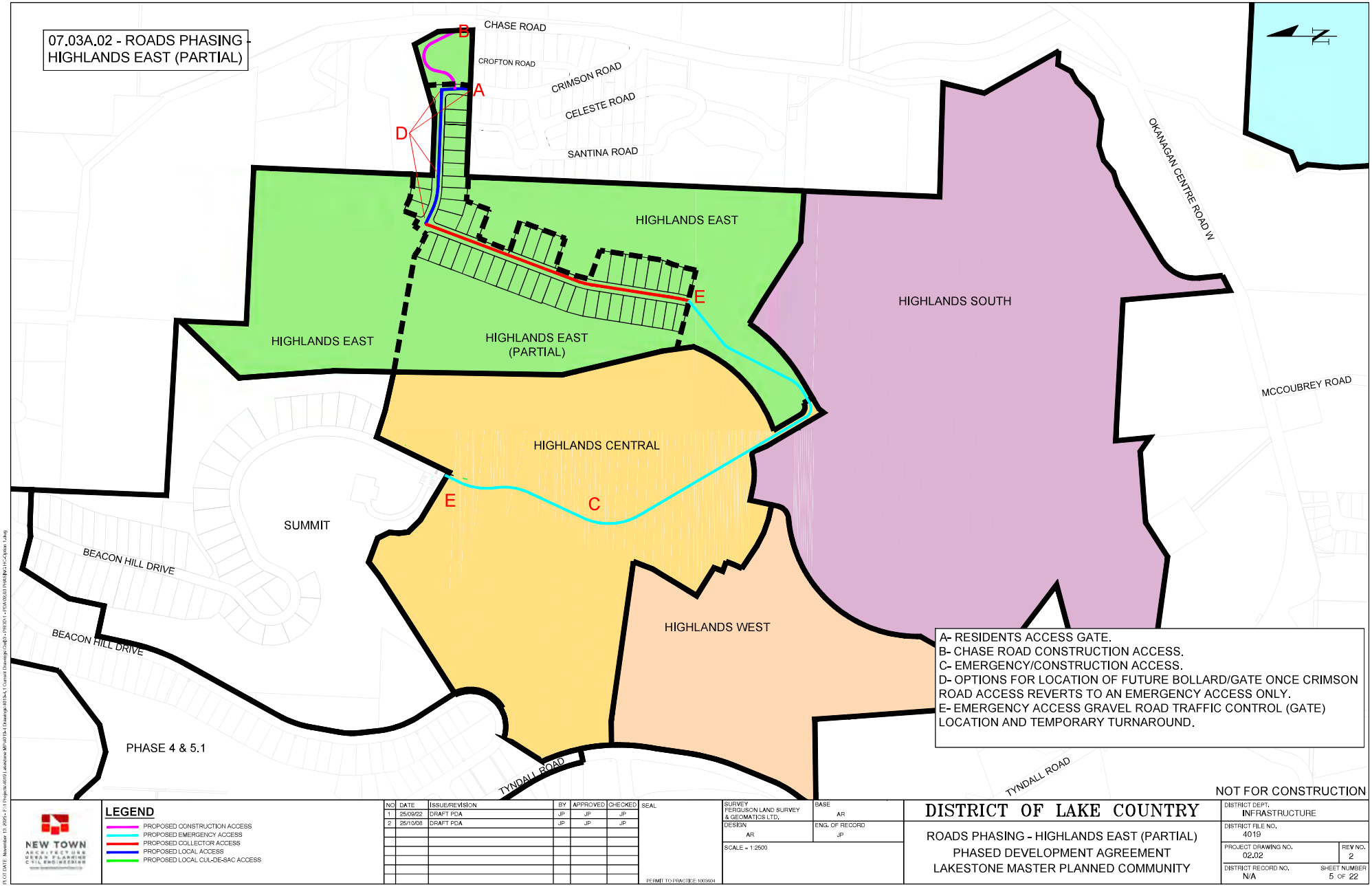
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:250	

DISTRICT OF LAKE COUNTRY

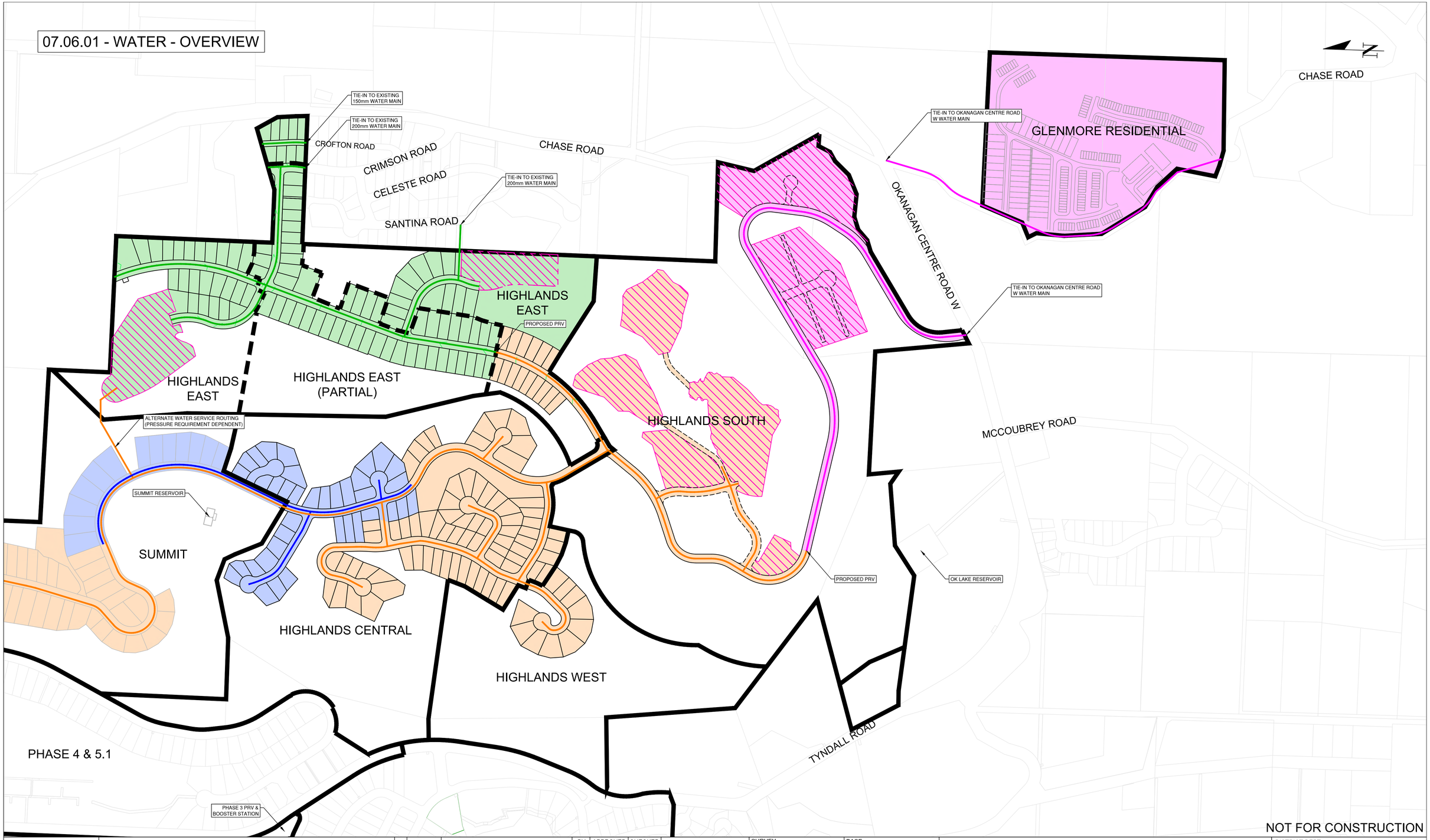
CHASE ROAD & OKCRW INTERSECTION OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.02.02	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 13 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-INTERSECTIONS.dwg


07.03A.02 - ROADS PHASING - HIGHLANDS EAST (PARTIAL)
CHASE ROAD
CROFTON ROAD
CRIMSON ROAD
CELESTE ROAD
SANTINA ROAD
OKANAGAN CENTRE ROAD W
MCCOUBREY ROAD
HIGHLANDS EAST
HIGHLANDS EAST (PARTIAL)
HIGHLANDS SOUTH
HIGHLANDS CENTRAL
HIGHLANDS WEST
SUMMIT
BEACON HILL DRIVE
BEACON HILL DRIVE
PHASE 4 & 5.1
TYNDALL ROAD
TYNDALL ROAD
A
B
C
D
E
E
A- RESIDENTS ACCESS GATE.
B- CHASE ROAD CONSTRUCTION ACCESS.
C- EMERGENCY/CONSTRUCTION ACCESS.
D- OPTIONS FOR LOCATION OF FUTURE BOLLARD/GATE ONCE CRIMSON ROAD ACCESS REVERTS TO AN EMERGENCY ACCESS ONLY.
E- EMERGENCY ACCESS GRAVEL ROAD TRAFFIC CONTROL (GATE) LOCATION AND TEMPORARY TURNAROUND.
NOT FOR CONSTRUCTION
LEGEND
PROPOSED CONSTRUCTION ACCESS
PROPOSED EMERGENCY ACCESS
PROPOSED COLLECTOR ACCESS
PROPOSED LOCAL ACCESS
PROPOSED LOCAL CUL-DE-SAC ACCESS
NEW TOWN ARCHITECTURE URBAN PLANNING CIVIL ENGINEERING
NO. DATE ISSUE/REVISION BY APPROVED CHECKED
1 25/09/22 DRAFT PDA JP JP JP
2 25/10/06 DRAFT PDA JP JP JP
SEAL
PERMIT TO PRACTICE: 1003904
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.
BASE AR
DESIGN AR
ENG. OF RECORD JP
SCALE = 1:2500
DISTRICT OF LAKE COUNTRY
ROADS PHASING - HIGHLANDS EAST (PARTIAL)
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY
DISTRICT DEPT. INFRASTRUCTURE
DISTRICT FILE NO. 4019
PROJECT DRAWING NO. 02.02
REV NO. 2
DISTRICT RECORD NO. N/A
SHEET NUMBER 5 OF 22

07.06.01 - WATER - OVERVIEW



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- PZ 680 - LAKESTONE BOOSTED
- PZ 623 - ELDORADO
- PZ 655 - LAKESTONE SUMMIT
- PZ 600 - MCCOUBREY

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY: FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE: AR
DESIGN: AR	ENG. OF RECORD: JP
SCALE = 1:3000	

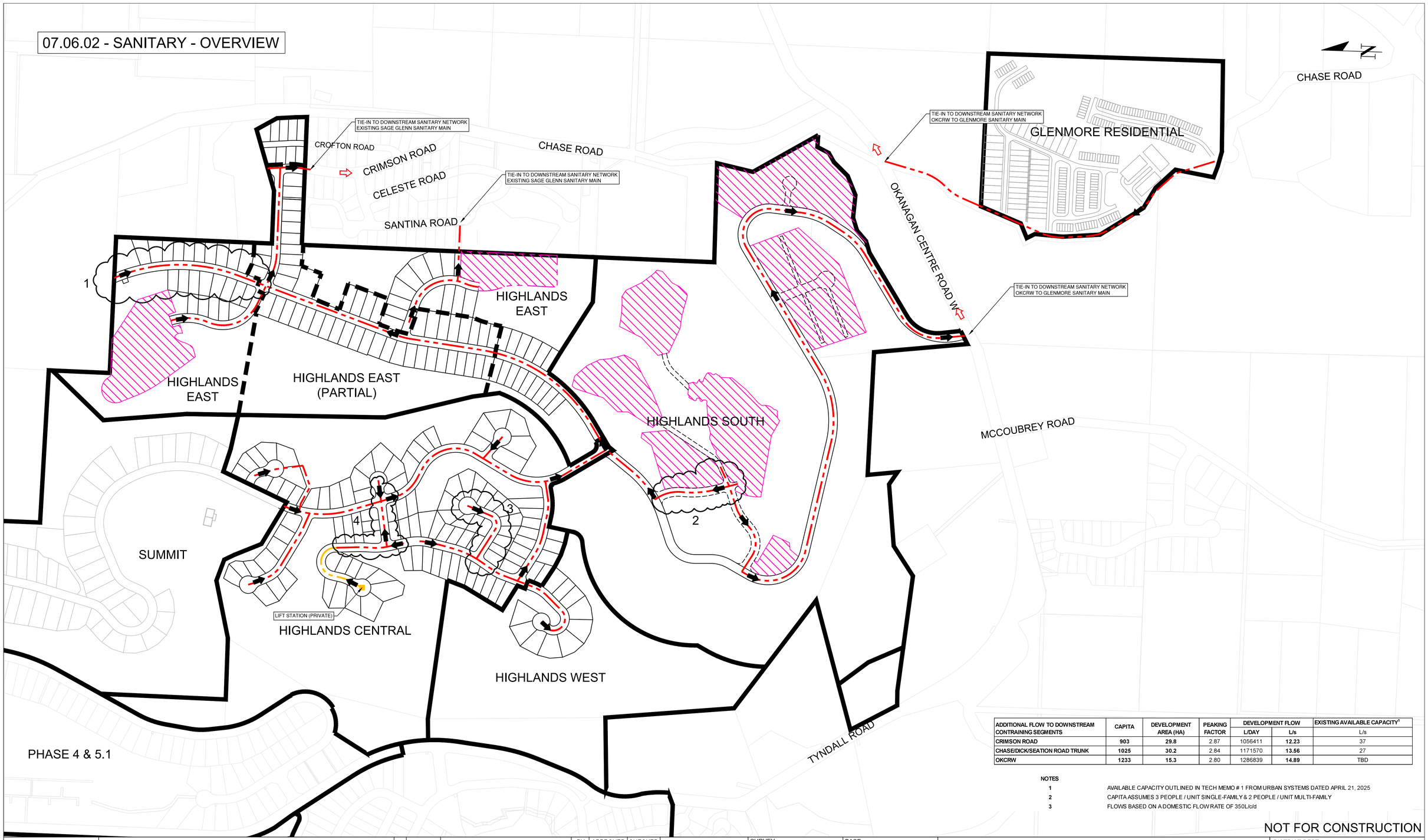
DISTRICT OF LAKE COUNTRY

WATER - OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.	INFRASTRUCTURE
DISTRICT FILE NO.	4019
PROJECT DRAWING NO.	07.06.01
REV NO.	1
DISTRICT RECORD NO.	N/A
SHEET NUMBER	16 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODI 1 - PDA\02.01.02 WATER.dwg

07.06.02 - SANITARY - OVERVIEW



ADDITIONAL FLOW TO DOWNSTREAM CONTRAINING SEGMENTS	CAPITA	DEVELOPMENT AREA (HA)	PEAKING FACTOR	DEVELOPMENT FLOW		EXISTING AVAILABLE CAPACITY[1]
				L/DAY	L/s	L/s
CRIMSON ROAD	903	29.8	2.87	1056411	12.23	37
CHASE/DICK/SEATION ROAD TRUNK	1025	30.2	2.84	1171570	13.56	27
OKCRW	1233	15.3	2.80	1286839	14.89	TBD

NOTES

1. AVAILABLE CAPACITY OUTLINED IN TECH MEMO # 1 FROM URBAN SYSTEMS DATED APRIL 21, 2025
2. CAPITA ASSUMES 3 PEOPLE / UNIT SINGLE-FAMILY & 2 PEOPLE / UNIT MULTI-FAMILY
3. FLOWS BASED ON A DOMESTIC FLOW RATE OF 350L/c/d

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- SANITARY MAIN ROUTING
- FORCE MAIN ROUTING (PRIVATE)
- PROPOSED DIRECTION OF FLOW
- EXISTING DIRECTION OF FLOW
- SANITARY DEPTH OF COVER VARIANCE

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:3000	

DISTRICT OF LAKE COUNTRY

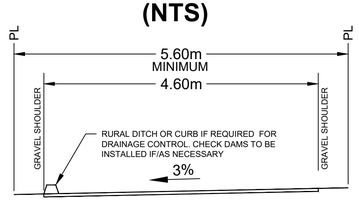
SANITARY - OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.06.02	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 17 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODU1 - PDA\PROD-SAN.dwg

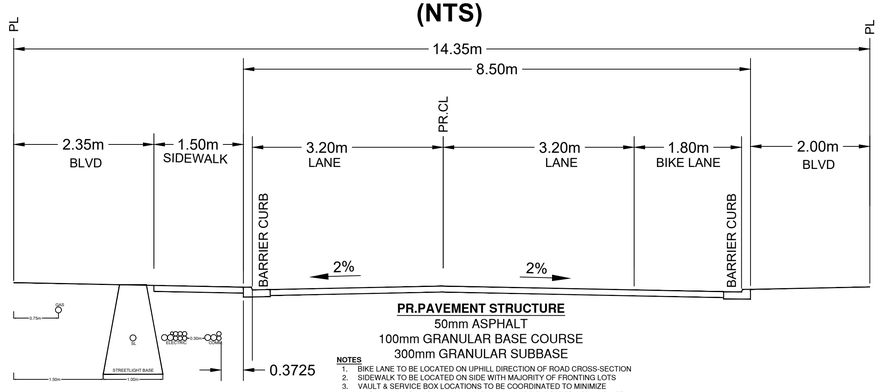
07.07.01 - ROADS PHASING - GLENMORE RESIDENTIAL

HILLSIDE EMERGENCY VEHICLE ACCESS ROAD X-SEC (NTS)



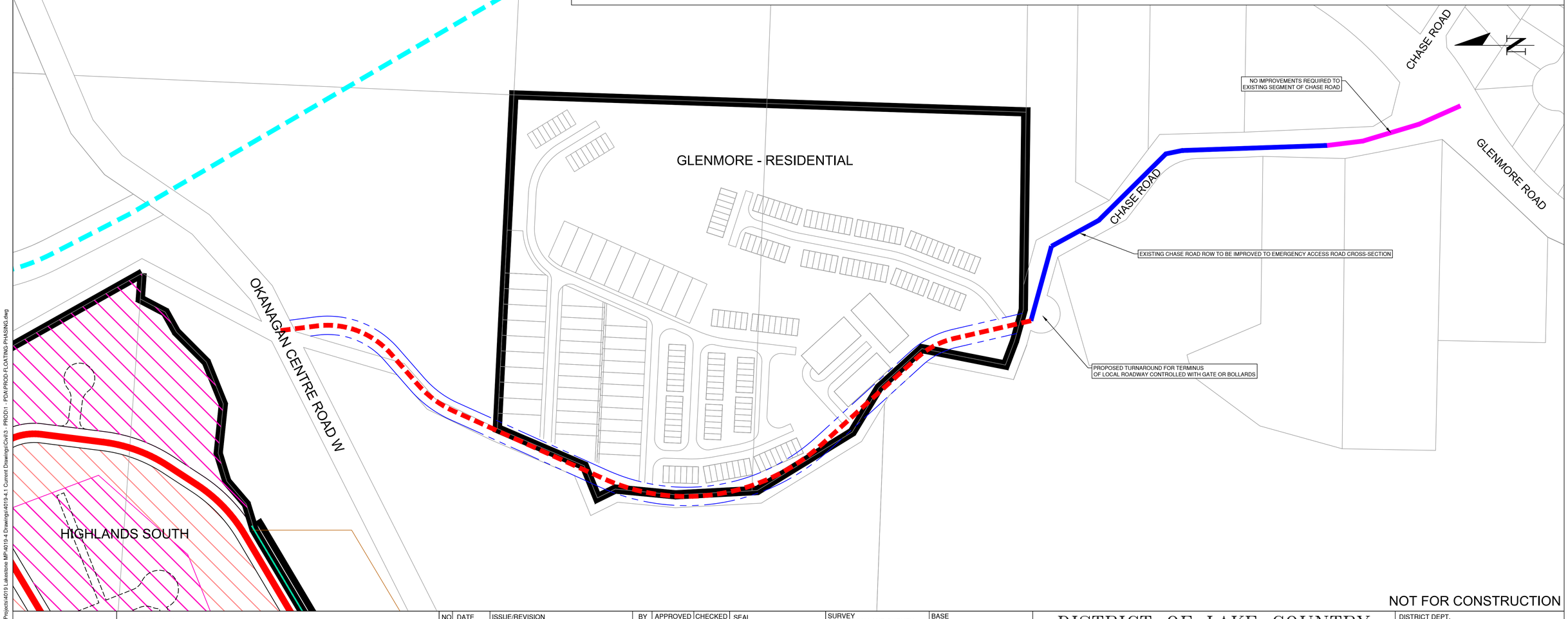
PR.PAVEMENT STRUCTURE
50mm ASPHALT
50mm GRANULAR BASE COURSE
150mm GRANULAR SUBBASE

CHASE LOCAL ROAD X-SEC (NTS)



PR.PAVEMENT STRUCTURE
50mm ASPHALT
100mm GRANULAR BASE COURSE
300mm GRANULAR SUBBASE

NOTES
1. BIKE LANE TO BE LOCATED ON UPHILL DIRECTION OF ROAD CROSS-SECTION
2. SIDEWALK TO BE LOCATED ON SIDE WITH MAJORITY OF FRONTING LOTS
3. VAULT & SERVICE BOX LOCATIONS TO BE COORDINATED TO MINIMIZE LIKELIHOOD OF SIDEWALK DAMAGES & MAXIMIZE EXPECTED SERVICE LIFE



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND
- PROPOSED LOCAL ACCESS
- FUTURE COLLECTOR ACCESS
- PROPOSED EMERGENCY ACCESS
- EXISTING LOCAL ROADWAY

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY: FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE: AR
DESIGN: AR	ENG. OF RECORD: JP
SCALE = 1:1500	

DISTRICT OF LAKE COUNTRY

ROADS PHASING - GLENMORE RESIDENTIAL
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.	INFRASTRUCTURE
DISTRICT FILE NO.	4019
PROJECT DRAWING NO.	07.07.01
REV NO.	1
DISTRICT RECORD NO.	N/A
SHEET NUMBER	18 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-FLOATING-PHASING.dwg

07.07.02 - CHASE ROAD ROW - EXISTING & PROPOSED

LOT 15
OKANAGAN CENTRE RD

8555 OKANAGAN CENTRE RD W

CHASE RD RIGHT-OF-WAY

LOT 138
GLENMORE RD

LOT 137
GLENMORE RD

6494 CHASE RD

4430 GLENMORE RD

REM LOT 4
OKANAGAN CENTRE RD

OKANAGAN CENTRE RD W

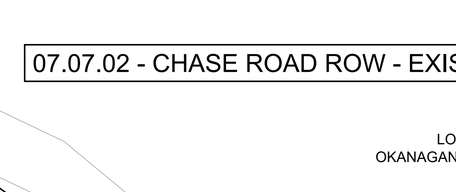
CHASE RD RIGHT-OF-WAY

LOT A
OKANAGAN CENTRE RD

LOT 14
OKANAGAN CENTRE RD

EMERGENCY ACCESS CONNECTION TO EXISTING CHASE ROAD
REFER TO HILLSIDE EMERGENCY VEHICLE ACCESS

CHASE LOCAL ROAD X-SEC
(NTS)



PR.PAVEMENT STRUCTURE
50mm ASPHALT
100mm GRANULAR BASE COURSE
300mm GRANULAR SUBBASE

NOTES
1. REFER UNDER SEPARATE CONTRACT FOR ROAD CROSS-SECTION
2. SIDEWALK TO BE LOCATED ON SIDE WITH MAJORITY OF FRONTING LOTS
3. VAULT & SERVICE BOX LOCATIONS TO BE COORDINATED TO MINIMIZE LIKELIHOOD OF SIDEWALK DAMAGES & MAXIMIZE EXPECTED SERVICE LIFE

LOT 15
OKANAGAN CENTRE RD

CHASE RD RIGHT-OF-WAY

LOT 138
GLENMORE RD

LOT 137
GLENMORE RD

6494 CHASE RD

4430 GLENMORE RD

REM LOT 4
OKANAGAN CENTRE RD

OKANAGAN CENTRE RD W

LOT A
OKANAGAN CENTRE RD

LOT 14
OKANAGAN CENTRE RD

TERMINUS OF CHASE ROAD X-SEC
TURNAROUND TO BE PROVIDED

APPROXIMATE ALIGNMENT OF
PROPOSED ROAD RIGHT-OF-WAY
REFER TO CHASE ROAD X-SEC

NOTES

① PRIVATE PROPERTY REQUIRED TO ACCOMMODATE REQUIRED ROAD RIGHT-OF-WAY WIDTH

NOT FOR CONSTRUCTION

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1000	

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

DISTRICT OF LAKE COUNTRY

CHASE ROAD ROW - EXISTING & PROPOSED
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.07.02	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 19 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-ROADS-OFFSITE.dwg

08.04.04 - Highlands South - Walls - Private

N

6
7
8
9
10
11
12
13
14
15
16

OKANAGAN CENTRE ROAD W

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
0	25/03/28	LAKESTONE MASTER PLAN PDA	AR	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

BASE
FERGUSON LAND SURVEY & GEOMATICS LTD.

DESIGN
AR

ENGINEER OF RECORD

SCALE
HORIZ.1:1500
VERT.

NOT FOR CONSTRUCTION

DISTRICT OF LAKE COUNTRY

HLS - WALLS - PRIVATE
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

CITY DEPT.
INFRASTRUCTURE

PROJECT DRAWING NO.
HLS W-000

REV NO.
01

SHEET NUMBER
1 OF 23

PLOT DATE: April 16, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\5.1 - HIGHLAND'S SOUTH\PROD\-HLS WALLS.dwg

09.08.02 - Lakestone Conceptual Trail Plan Difficulty

Lakestone Conceptual Trail Plan - Trail Difficulty

Project Location Map



Legend

Trails
- Black Existing
- Black Summit Phase
- Black Conceptual
- Blue Existing
- Blue Summit Phase
- Blue Conceptual
- Green Existing
- Green Summit Phase
- Green Conceptual

Lakestone Dev.
- C-PROP/FUTR
- Parks
- Property
- Road
- Water

DLC Bike Park
- Green
- Blue
- Black

N W E S

1:8,000

0 50 100 200 300 400

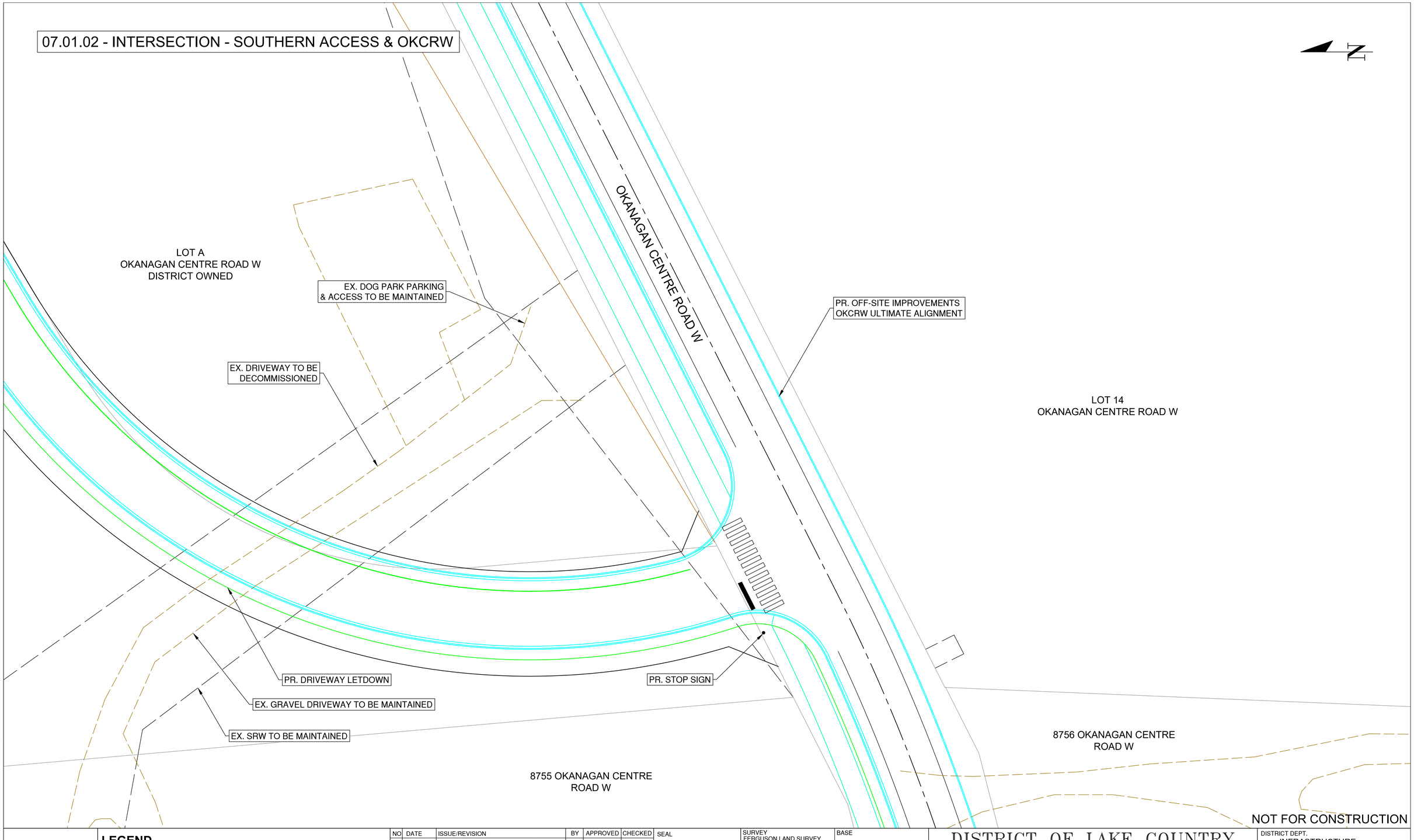
Meters

NAD 1983 CSRS UTM Zone 11N

Prepared For: MacDonald Development Corp.
Map Created: 2023-12-18
Data Sources: Esri, DLC, Macdonald, DataBC

CABIN

07.01.02 - INTERSECTION - SOUTHERN ACCESS & OKCRW



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:250	

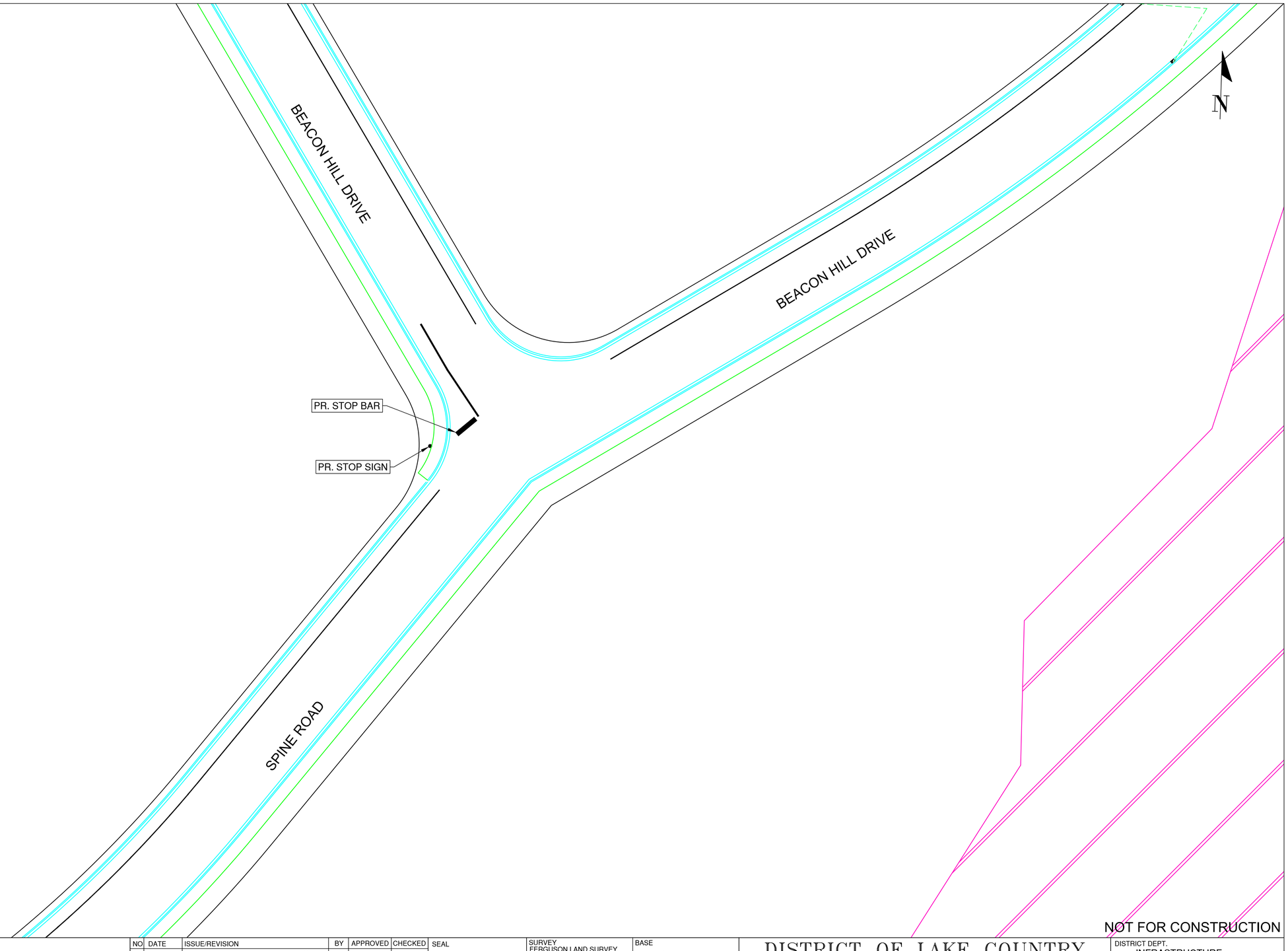
DISTRICT OF LAKE COUNTRY

INTERSECTION - SOUTHERN ACCESS & OKCRW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.01.02	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 8 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRO\0\1 - PDA\PROD-INTERSECTIONS.dwg

07.01.03 - INTERSECTION
BEACON HILL SPINE ROAD



NOT FOR CONSTRUCTION

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-INTERSECTIONS.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

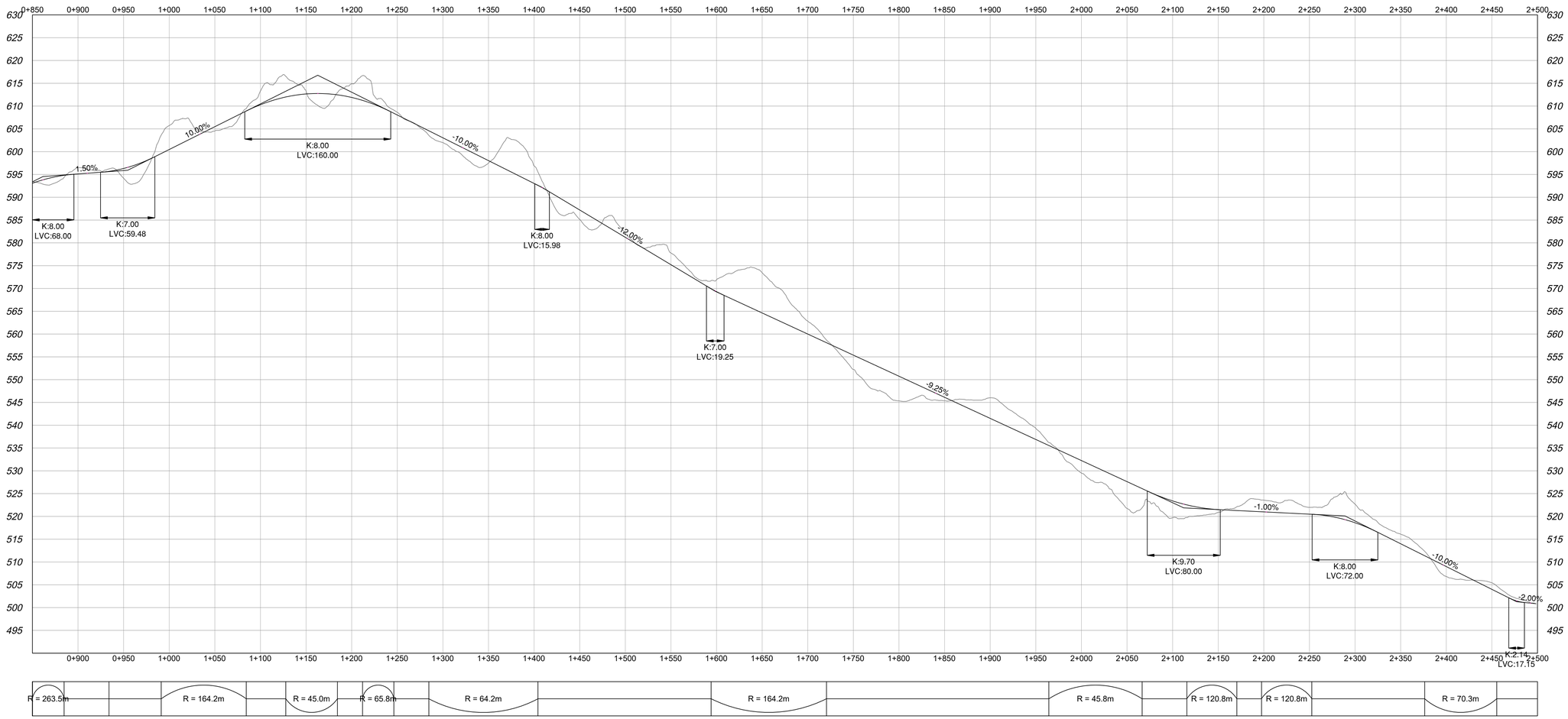
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:250	

DISTRICT OF LAKE COUNTRY

INTERSECTION BEACON HILL SPINE ROAD
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.01.03	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 9 OF 22

07.01.04 - ROADS - SPINE PROFILE VIEW



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = H -1:2500 V -1:500	

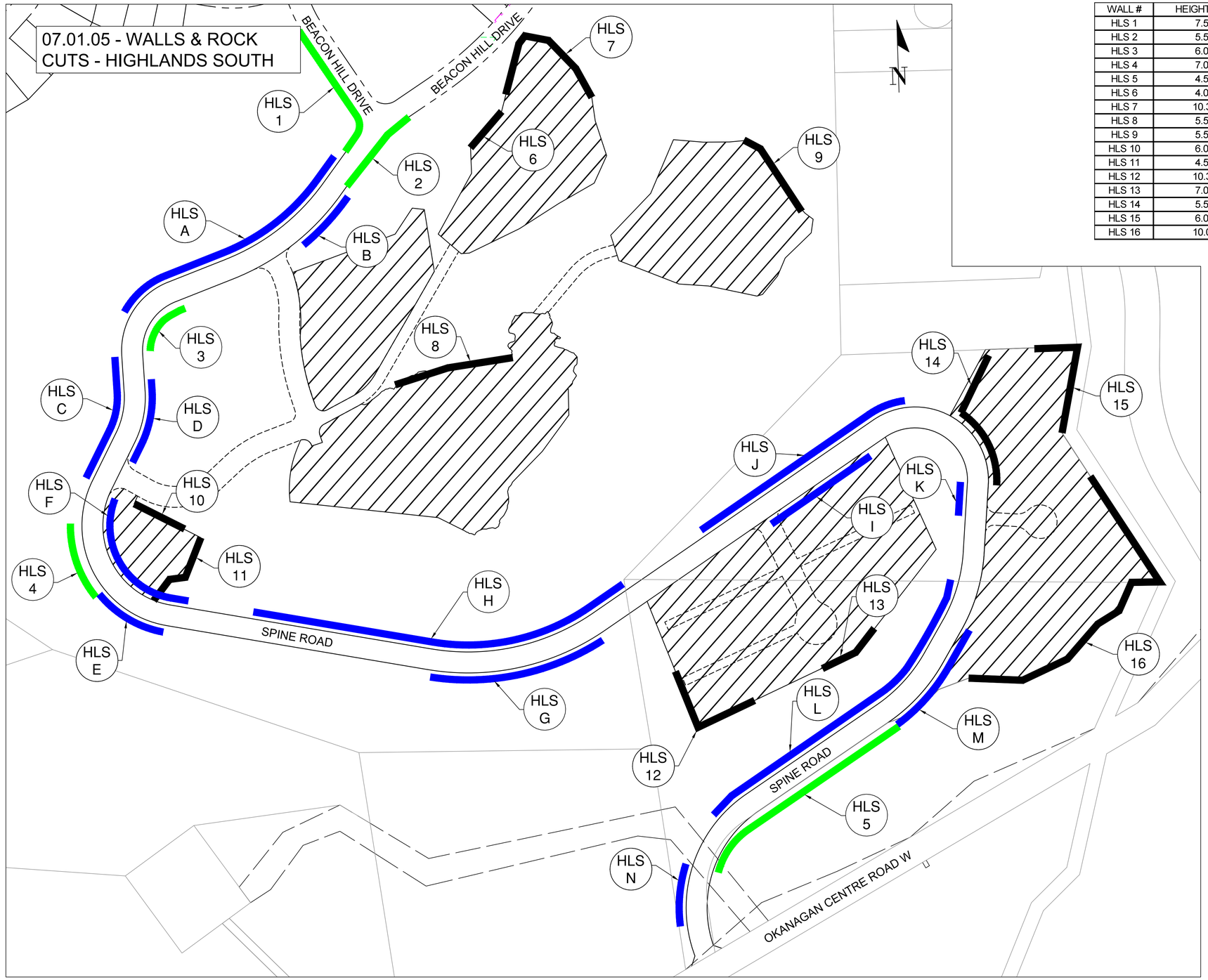
DISTRICT OF LAKE COUNTRY

ROADS - SPINE PROFILE VIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.01.04	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 10 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PRODI1 - PDA\PROD-SPINE ROAD.dwg

07.01.05 - WALLS & ROCK CUTS - HIGHLANDS SOUTH



WALL #	HEIGHT (m)	PHASE	WALL TYPE	LOT TYPE
HLS 1	7.5	HIGHLANDS SOUTH	PUBLIC	-
HLS 2	5.5	HIGHLANDS SOUTH	PUBLIC	-
HLS 3	6.0	HIGHLANDS SOUTH	PUBLIC	-
HLS 4	7.0	HIGHLANDS SOUTH	PUBLIC	-
HLS 5	4.5	HIGHLANDS SOUTH	PUBLIC	-
HLS 6	4.0	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 7	10.3	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 8	5.5	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 9	5.5	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 10	6.0	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 11	4.5	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 12	10.3	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 13	7.0	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 14	5.5	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 15	6.0	HIGHLANDS SOUTH	PRIVATE	STRATA
HLS 16	10.0	HIGHLANDS SOUTH	PRIVATE	STRATA

NOTE:
RETAINING WALL LENGTHS, HEIGHTS, AND LOCATIONS DERIVED FROM PRELIMINARY DESIGN AND ARE PROVIDED FOR GENERAL INFORMATION. NO WALL WILL EXCEED THE MAXIMUM HEIGHT OF 10.3m AS OUTLINED IN THE PDA.

PROPOSED PRIVATE RETAINING WALL

PROPOSED PUBLIC RETAINING WALL

PROPOSED PUBLIC ROCK CUT LOCATION

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4-1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-HLS WALLS.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

BASE FERGUSON LAND SURVEY & GEOMATICS LTD.	DESIGN AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1500	

DISTRICT OF LAKE COUNTRY

WALLS & ROCK CUTS - HIGHLANDS SOUTH
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.01.05	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 11 OF 22

07.01.06 - 10080 CHASE ROAD NETWORK

LAKESTONE LANDS

10180 CHASE ROAD

CHASE ROAD

FUTURE LAKESTONE TO CHASE CONNECTION

10080 CHASE ROAD

9850 CHASE ROAD

9890 CHASE ROAD

9950 CHASE ROAD

9970 CHASE ROAD

9990 CHASE ROAD

CRIMSON ROAD

CROFTON ROAD

CHASE ROAD

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED

SEAL

SURVEY | BASE

DESIGN | ENG. OF RECORD

SCALE = 1:3500

DISTRICT OF LAKE COUNTRY

CHASE - CONCEPTUAL ROAD NETWORK
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.: INFRASTRUCTURE

DISTRICT FILE NO.: 4019

PROJECT DRAWING NO. | REV NO.: -

DISTRICT RECORD NO.: N/A | SHEET NUMBER OF

PLOT DATE: November 14, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\MISC\251114_PROD-CRIMSON EXT..dwg

07.02.03 - Intersection - Spine and OKCRW

PR. DOG PARK PARKING
& ACCESS REVISION

EX. DOG PARK PARKING
& ACCESS

LOT A
OKANAGAN CENTRE ROAD W
DISTRICT OWNED

OKANAGAN CENTRE ROAD W

49.5m

60.31m

PR. OFF-SITE IMPROVEMENTS
OKCRW ULTIMATE ALIGNMENT

EX. DRIVEWAY TO BE REMOVED

EX. SRW TO BE DISCHARGED

PROPOSED SIGNALIZED
INTERSECTION

PR. DRIVEWAY LETDOWN

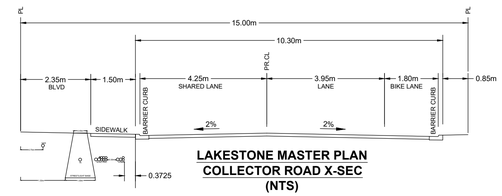
EX. GRAVEL DRIVEWAY TO BE MAINTAINED

EX. SRW TO BE MAINTAINED

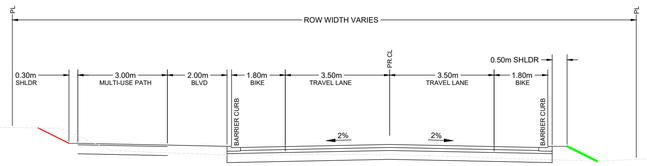
8755 OKANAGAN CENTRE
ROAD W

8756 OKANAGAN CENTRE
ROAD W

LOT 14
OKANAGAN CENTRE ROAD W



LAKESTONE MASTER PLAN
COLLECTOR ROAD X-SEC
(NTS)



OKANAGAN CENTRE ROAD WEST TYPICAL SECTION
LAKE COUNTRY BUSINESS PARK
(NTS)

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
0	25/05/05	LAKESTONE MASTER PLAN PDA	AR	JP	JP

SEAL

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE 1:250	

DISTRICT OF LAKE COUNTRY

INTERSECTION - SOUTNERN ACCESS & OKCRW
PHASED DEVELOPMENT AGREEMENT
LAKESHORE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. -	REV NO. 0
DISTRICT RECORD NO. N/A	SHEET NUMBER - OF -

PLOT DATE: May 5, 2025 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\4 - PDA\PROD-INTERSECTIONS.dwg

NEW TOWN

January 16, 2026

District of Lake Country
10150 Bottom Wood Lake Road
Lake Country, BC, L4V 2M1

Attention: **Mr. Matthew Salmon, P.Eng.**
Director of Infrastructure and Development Engineering

Dear Sir,

Re: Stormwater Management Plan – Chase Road to Seaton Road
Lakestone – Phased Development Agreement
Macdonald Lakeshore Properties Ltd.

New Town Architecture & Engineering Inc. is pleased to provide you with our Stormwater Management Plan (SWMP) for the overland flow route extending from the Chase Road stormwater outlet (existing from Sage Glenn) to the intersection of Seaton Road and Knopf Brook. The SWMP has been compiled in support of the Phased Development Agreement for the Lakestone Development site and details the existing flow route and the proposed improvements to this flow route to address existing deficiencies and accommodate upstream development.

The SWMP has been compiled based on a combination of the following documents:

- District of Lake Country Subdivision and Servicing Bylaw 1121, 2020 (Includes amendments as of May 21, 2024).
- Lakestone Area Stormwater Servicing Plan March 25, 2025 compiled by Urban Systems.
- Best Engineering Practices.

Our team would like to submit the design calculations and rationale for the SWMP to the District of Lake Country for review and approval, in support of the Phased Development Agreement. A large portion of the undeveloped (future phases) of Lakestone lands contribute to downstream stormwater overland flow routes; including Knopf Brook and ultimately Middle Vernon Creek. The catchment area in question is outlined in the Lakestone Area Stormwater Servicing Plan as MVC KP. Table 2 of the Stormwater Servicing Plan recommends a Unit Runoff Rate (URR) of 1.5 Lps/Ha for the Knopf Brook catchment. This URR has been used as a basis for the preceding calculations.

The total catchment area for the Sage Glenn Outlet bordering Chase Road is 86.5 Hectares and includes both Lakestone Lands & contributing District parcels. The total catchment area can be seen detailed in Appendix 1 = Existing Catchment Area.

www.newtownservices.ca
300-1650 Bertram Street
Kelowna BC V1Y 2G4
Phone: 250-860-8185

It is assumed that development upstream of the Chase Road outlet have/will be designed in accordance with the Subdivision and Servicing Bylaw, capturing and controlling stormwater with release rates limited to URR. As such, the URR has been used as a foundational element of the calculation.

$Q_T = A \times URR_T$ where Q_T = pre-development runoff rate for the return period "T" [m^3/s]
A = drainage area [ha]
URR_T = Unit Runoff Rate for the return period "T"

Q_T = 86.5 Ha x 1.5 L/s/HA
Q_T = 129.75 L/s

The overland flow segment extending from the Chase Road outlet to the intersection of Knopf Brook and Seaton Road is currently undeveloped and as a result has been the source of complaint from the impacted property owners (9751 Chase Road & 9750 Seaton Road). Lakestone is proposing the improvement and formalization of this overland flow segment through the introduction of stormwater storage & infiltration (limiting flows conveyed downstream) and the construction of an overland flow ditch (directed any flows). The two-part design proposed is further detailed below.

1. Outlet Storage & Infiltration. A rock pit is proposed at the Sage Glenn outlet, within the Chase Road right-of-way, to minimize flows conveyed downstream. Percolation testing was completed by Valley Geotechnical, a factor of safety (FoS) of 2 has been applied to the field values for design purposes. The geotechnical report can be found attached as Appendix B.
    - $Q_{Infiltration}$ = Infiltration Rate (m/s) x Infiltration Area (m2)
      $Q_{infiltration}$ = $1.2 \times 10^{-4} \times (1/2) \times 350\ m^2$
      $Q_{infiltration}$ = $0.021\ m^3/s$ = 21 L/s
    - $V_{storage} = A_{storage} \times H_{storage} \times$ Storage Void Ratio
      $V_{storage} = 350m^2 \times 1.2m \times 0.33 = 139\ m^3$
2. Overland Flow Ditch. An overland flow ditch is proposed to extend from the Sage Glenn outlet to the intersection of Knopf Brook with Seaton Road. This will convey any flows that overwhelm the proposed rock pit, and will minimize the negative impacts currently being experience by the surrounding properties, due to no formal flow route existing. The overland flow ditch has been designed to ensure that the expected flows can be conveyed while minimizing the impact to the lands they encumber. As such, a shallow V-ditch has been selected as the best-fit mechanism for conveyance. The segment in question has been further segmented to reflect the longitudinal grades. The first segment has an approximate grade of 5% whereas the second segment has an approximate grade of 0.15%. Approximate grades are based on the LiDAR information provided by the District for the area in question. Sizing and flow calculations for the two segments of V-ditch can be found below.
    - $Q_{outlet} = Q_T - Q_{infiltration}$
      Q_{outlet} = 129.75 L/s – 21 L/s
      Q_{outlet} = 108.75 L/s
    - $Q_{D1} = VA = (1.00/n)\ AR^{2/3}\ S^{1/2}$

$Q_{D1} = (1.00/0.02)(0.3)(0.09926)^{2/3}(0.05)^{0.5}$
$Q_{D1} = 0.719\ m^3/s = 719\ L/s$

- $Q_{D2} = VA = (1.00/n)\ AR^{2/3}S^{1/2}$
  $Q_{D2} = (1.00/0.02)(0.8)(0.25364)^{2/3}(0.0015)^{0.5}$
  $Q_{D2} = 0.6208\ m^3/s = 621\ L/s$

From review of the calculations above it can be seen that the flow capacity of both segments of the proposed ditch (719L/s & 621L/s respectively) well exceed the outlet flow rate (108.75 L/s). The combination of the drain rock storage volume and the additional flow capacities of the ditches provide additional ability for the infrastructure to convey flows exceeding the expected outlet flow rates.

The proposed improvements result in a formalized overland flow route for flows outletting from the Chase Road stormwater outlet and provide conveyance downstream to the intersection of Seaton Road and Knopf Brook. The simple nature of the design (shallow vegetated ditch) looks to minimize the impact to the bisected properties, while also allowing for the ability to further improve and increase capacities if ever deemed necessary.

It is our understanding that the District will be working to coordinate with the impacted landowners to secure the necessary rights to complete both the construction and to operate and maintain the infrastructure moving forwards.

The improvements outlined above are the responsibility of the developer, and address both the existing deficient infrastructure and the expected upstream development. The improvements outlined are the expected extent of off-site improvements necessary for Lakestone East stormwater management. Flows further downstream from the outlined segment are being addressed by the District.

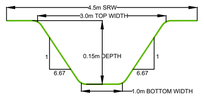
We trust that the above provides the District with the required design and calculation information necessary to approve the proposed design solutions. If there are any questions regarding the design, please do not hesitate to reach out.

Sincerely,
NEW TOWN ARCHITECTURE & ENGINEERING INC.

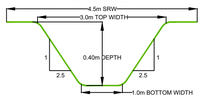
Jacob Paul, P.Eng.
Project Engineer / CA

07.04.02 - STORM - EAST

VEGETATED DITCH
CROSS-SECTION 1



VEGETATED DITCH
CROSS-SECTION 2



EX. 300mm CULVERT

DLC
MLP

SEATON ROAD

PR. OUTLET TO
EX. DITCH

EX. DRAINAGE PATH TO BE
IMPROVED & FORMALIZED
REFER TO CROSS-SECTION 2

KNOPF BROOK

9750 SEATON
ROAD

9660 SEATON
ROAD

9590 SEATON
ROAD

9790 SEATON
ROAD

EX. DRAINAGE PATH TO BE
IMPROVED & FORMALIZED
REFER TO CROSS-SECTION 1

9751 CHASE ROAD

2550 DICK ROAD

9891 CHASE
ROAD

PR. DRAIN ROCK INFILTRATION GALLERY
1.2m DEPTH

EX. SAGE GLENN
STORMWATER OUTLET
(375mmØ)

CHASE ROAD

MLP

NOT FOR CONSTRUCTION

PLOT DATE: November 17, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-ER Storm Routing.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

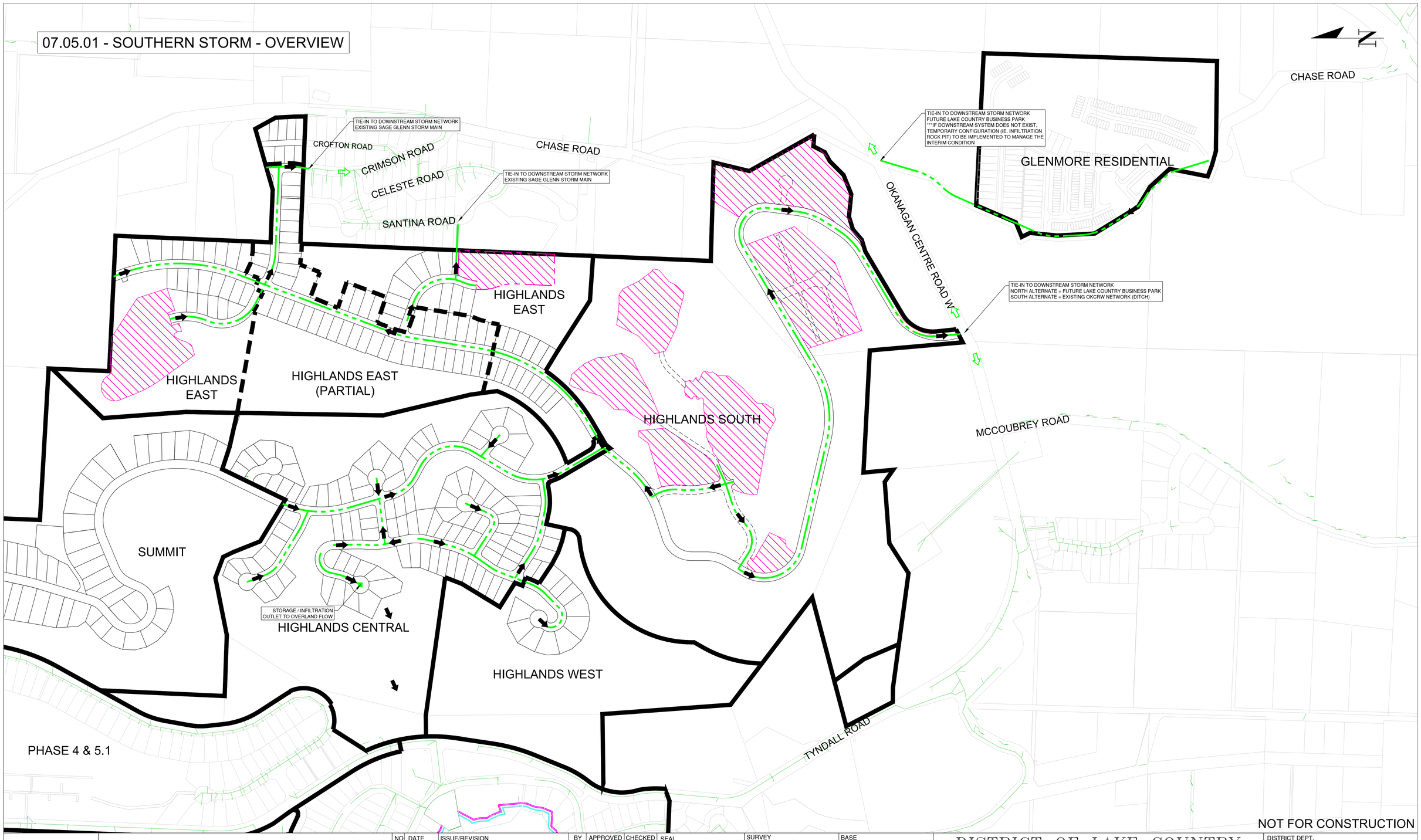
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1000	

DISTRICT OF LAKE COUNTRY

STORM - EAST
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.04.02	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 14 OF 22

07.05.01 - SOUTHERN STORM - OVERVIEW



NOT FOR CONSTRUCTION

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-STM.dwg

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- STORM MAIN ROUTING
- FLOW DIRECTION (ONSITE)
- FLOW DIRECTION (OFFSITE)

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

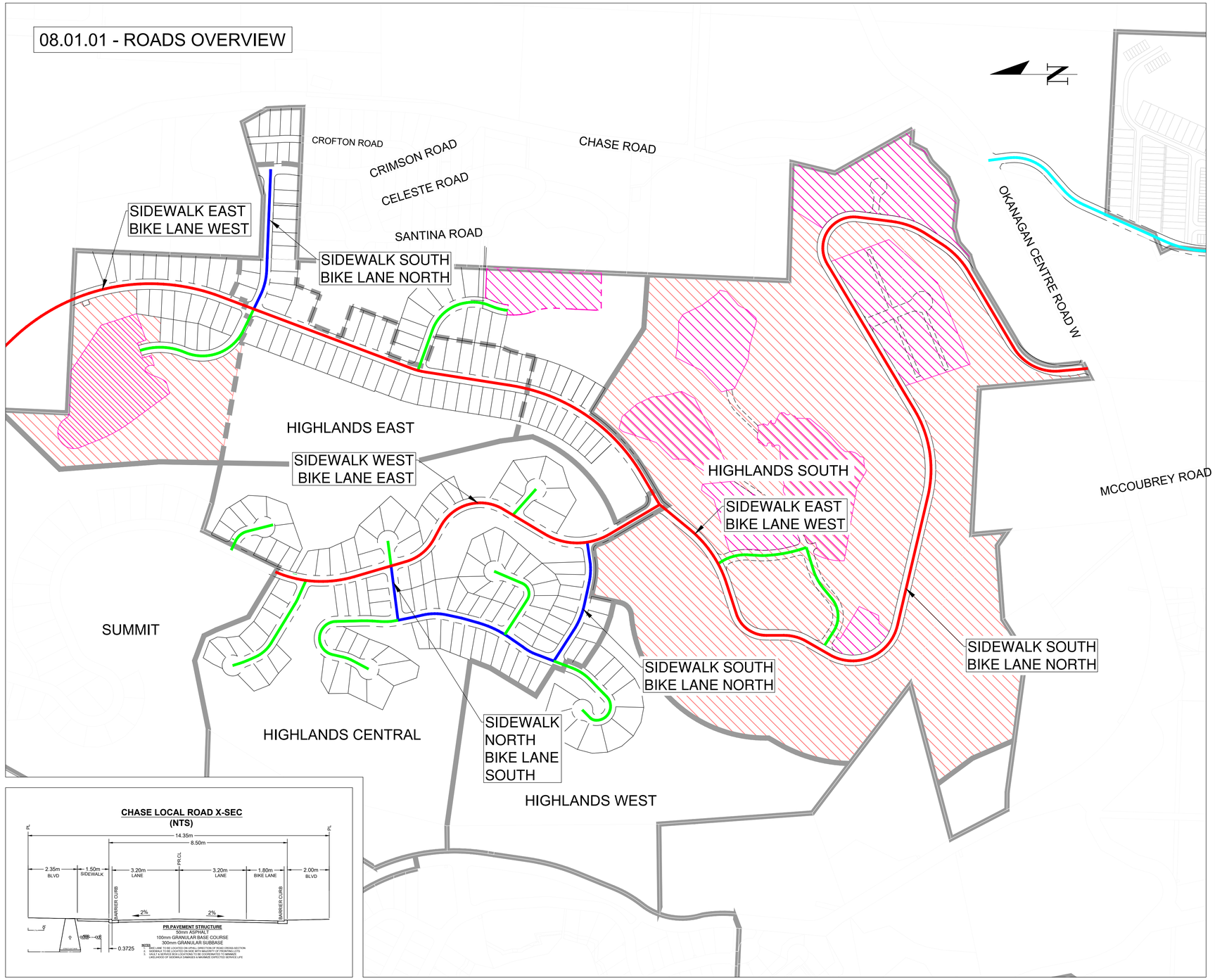
SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:3000	

DISTRICT OF LAKE COUNTRY

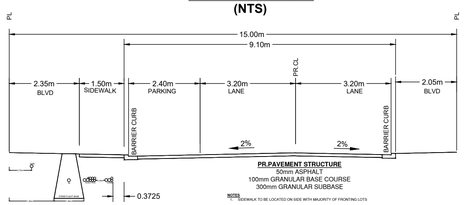
SOUTHERN STORM - OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 07.05.01	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 15 OF 22

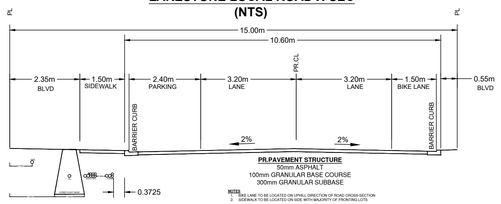
08.01.01 - ROADS OVERVIEW



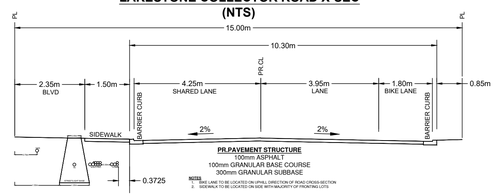
LAKESTONE CUL-DE-SAC
LOCAL ROAD X-SEC
(NTS)

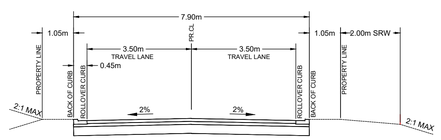


LAKESTONE LOCAL ROAD X-SEC
(NTS)

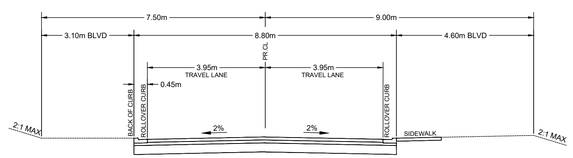


LAKESTONE COLLECTOR ROAD X-SEC
(NTS)





CROFTON RD. TYPICAL ROAD CROSS-SECTION
(NTS)



CRIMSON RD. TYPICAL ROAD CROSS-SECTION
(NTS)

CHASE LOCAL ROAD X-SEC
(NTS)

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- COLLECTOR ROAD
- LOCAL ROAD
- LOCAL ROAD - CUL DE SAC (NO BIKE LANE)
- CHASE LOCAL ROAD
- PHASE BOUNDARY

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:3000	

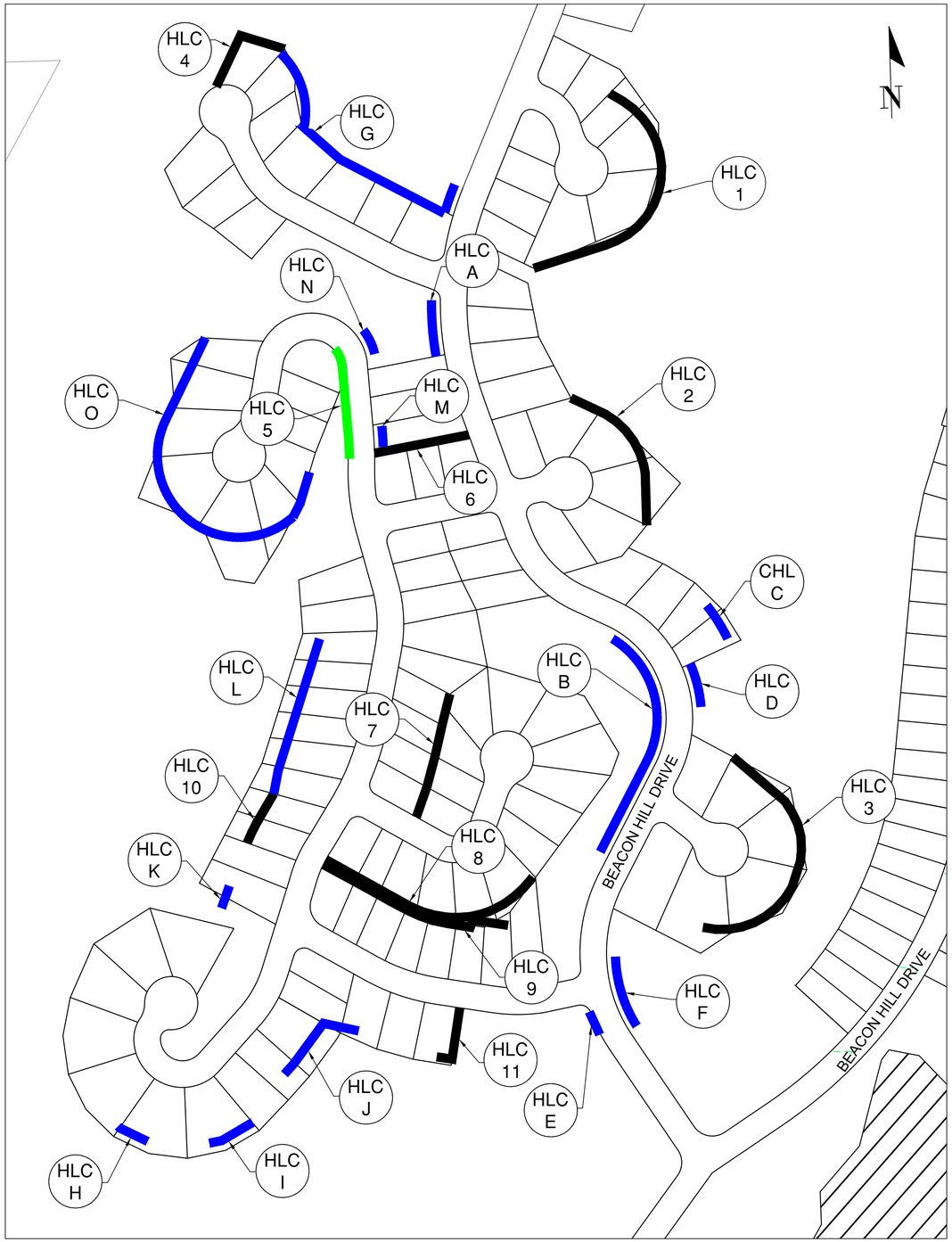
DISTRICT OF LAKE COUNTRY

ROADS OVERVIEW
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.	INFRASTRUCTURE
DISTRICT FILE NO.	4019
PROJECT DRAWING NO.	08.01.01
REV NO.	1
DISTRICT RECORD NO.	N/A
SHEET NUMBER	20 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP-4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-ROADS-OVERVIEW.dwg

08.04.01 - WALLS & ROCK CUTS - HIGHLANDS CENTRAL



WALL #	HEIGHT (m)	PHASE	WALL TYPE	LOT TYPE
1	2.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
2	7.5	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
3	9.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
4	4.5	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
5	6.5	HIGHLANDS CENTRAL	PUBLIC	-
6	3.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
7	4.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
8	9.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
9	8.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
10	3.5	HIGHLANDS CENTRAL	PRIVATE	PRIVATE
11	6.0	HIGHLANDS CENTRAL	PRIVATE	PRIVATE

NOTE:
RETAINING WALL LENGTHS, HEIGHTS, AND LOCATIONS DERIVED FROM PRELIMINARY DESIGN AND ARE PROVIDED FOR GENERAL INFORMATION. NO WALL WILL EXCEED THE MAXIMUM HEIGHT OF 10.3m AS OUTLINED IN THE PDA.

PROPOSED PRIVATE RETAINING WALL

PROPOSED PUBLIC RETAINING WALL

PROPOSED PUBLIC ROCK CUT LOCATION

NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

BASE FERGUSON LAND SURVEY & GEOMATICS LTD.	DESIGN AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1500	

DISTRICT OF LAKE COUNTRY

WALLS & ROCK CUTS - HIGHLANDS CENTRAL
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 08.04.01	REV NO. 1
DISTRICT RECORD NO.	SHEET NUMBER 21 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-HLC WALLS.dwg

08.04.02 - WALLS & ROCK CUTS - HIGHLANDS EAST

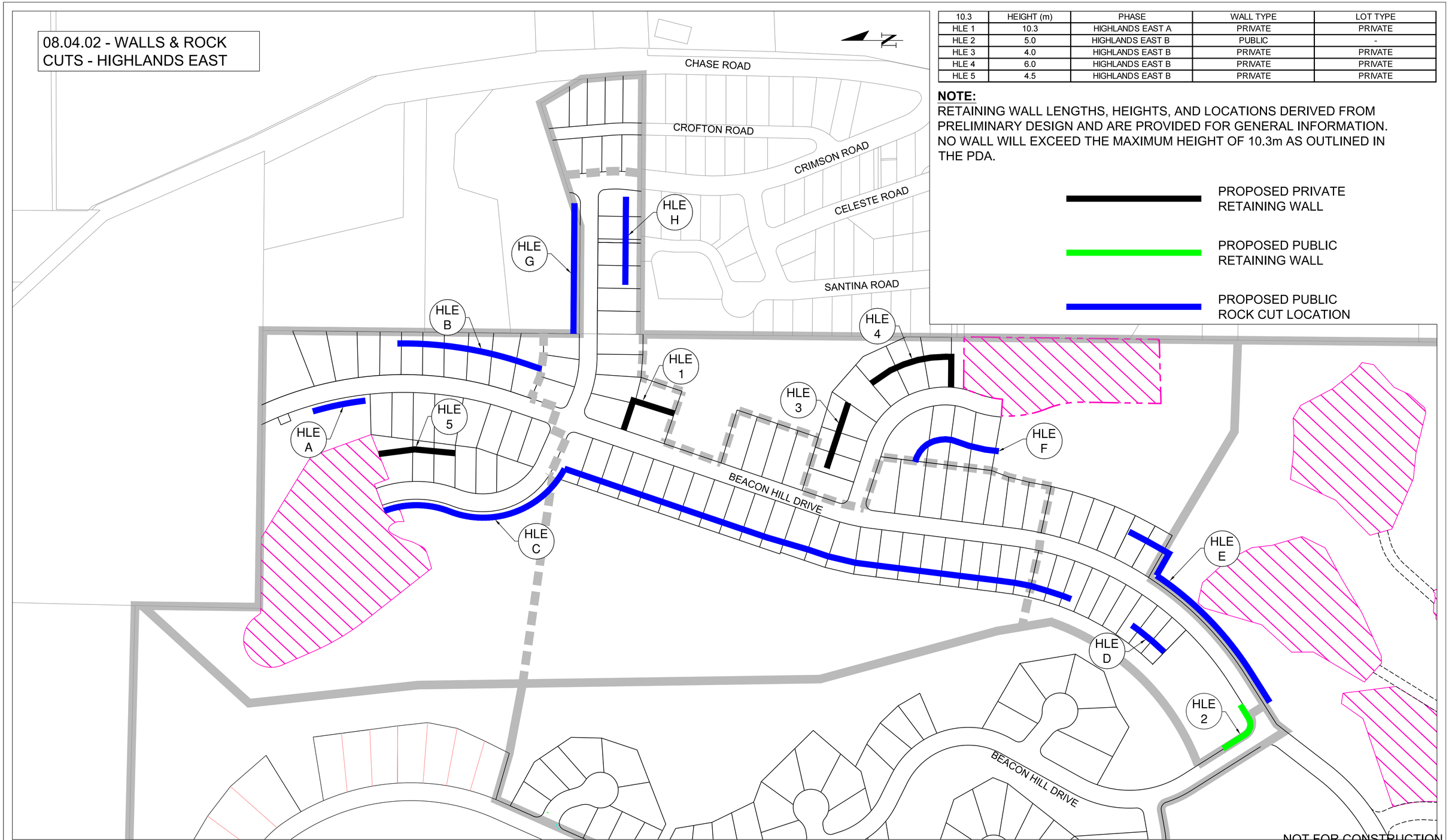
10.3	HEIGHT (m)	PHASE	WALL TYPE	LOT TYPE
HLE 1	10.3	HIGHLANDS EAST A	PRIVATE	PRIVATE
HLE 2	5.0	HIGHLANDS EAST B	PUBLIC	-
HLE 3	4.0	HIGHLANDS EAST B	PRIVATE	PRIVATE
HLE 4	6.0	HIGHLANDS EAST B	PRIVATE	PRIVATE
HLE 5	4.5	HIGHLANDS EAST B	PRIVATE	PRIVATE

NOTE:
RETAINING WALL LENGTHS, HEIGHTS, AND LOCATIONS DERIVED FROM PRELIMINARY DESIGN AND ARE PROVIDED FOR GENERAL INFORMATION. NO WALL WILL EXCEED THE MAXIMUM HEIGHT OF 10.3m AS OUTLINED IN THE PDA.

PROPOSED PRIVATE RETAINING WALL

PROPOSED PUBLIC RETAINING WALL

PROPOSED PUBLIC ROCK CUT LOCATION



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

BASE FERGUSON LAND SURVEY & GEOMATICS LTD.	DESIGN AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:1500	

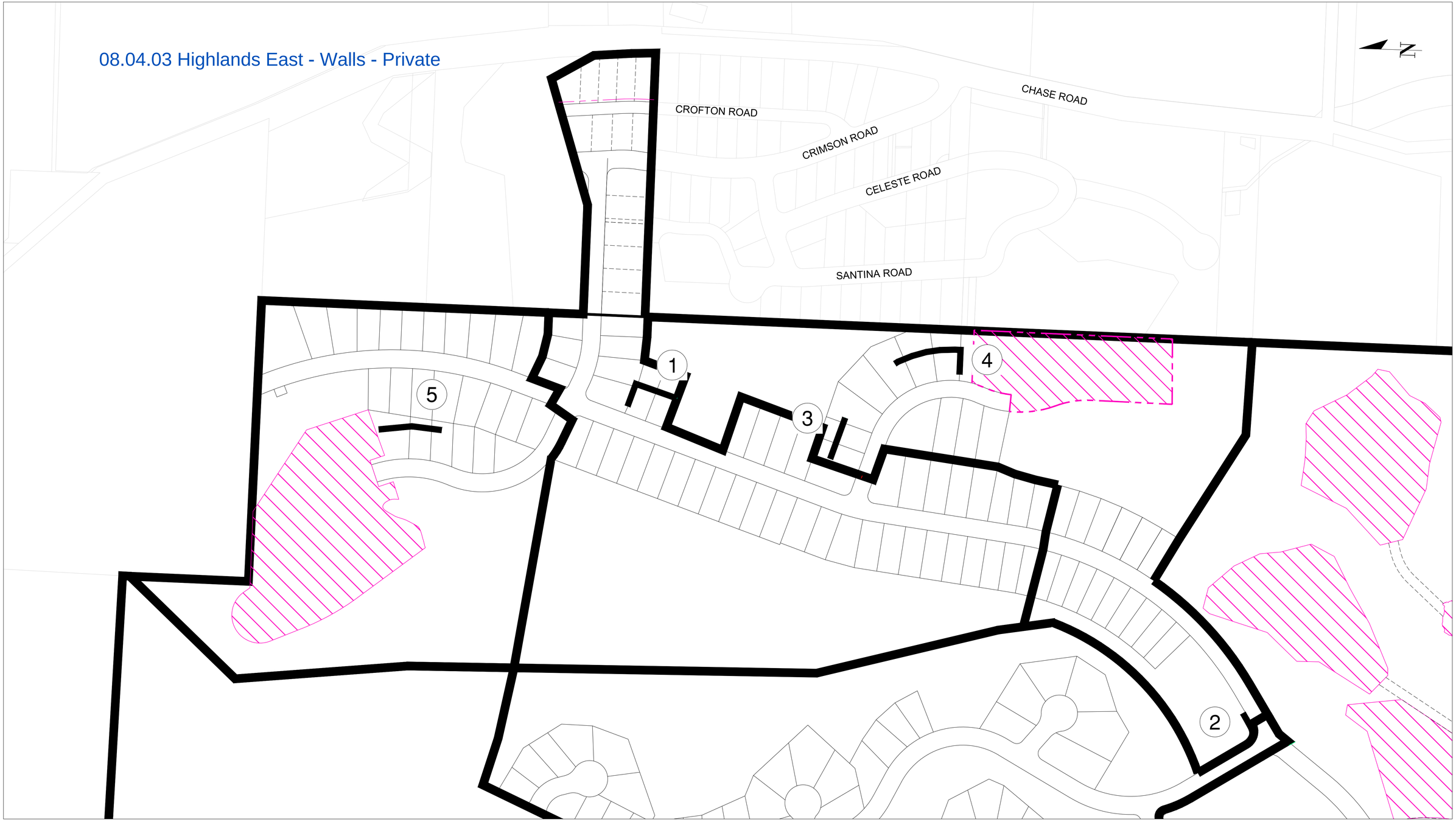
DISTRICT OF LAKE COUNTRY

WALLS & ROCK CUTS - HIGHLANDS EAST
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 08.04.02	REV NO. 1
DISTRICT RECORD NO.	SHEET NUMBER 22 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4-1 Current Drawings\Civil\3 - PROD\1 - PDA\PROD-HLE WALLS.dwg

08.04.03 Highlands East - Walls - Private



NOT FOR CONSTRUCTION

LEGEND

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
0	25/04/16	LAKESTONE MASTER PLAN PDA	AR	JP	JP

SEAL

SURVEY: FERGUSON LAND SURVEY & GEOMATICS LTD.
BASE: AR
DESIGN: JR
ENG. OF RECORD: JP
SCALE = 1:1500

DISTRICT OF LAKE COUNTRY

HLE - WALLS - PRIVATE
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

DISTRICT DEPT.
DISTRICT FILE NO. 4019
PROJECT DRAWING NO. XXX
REV NO. 0
DISTRICT RECORD NO. N/A
SHEET NUMBER 1 OF 1

PLOT DATE: April 16, 2025 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\4 - PDA\PROD-HLE WALLS.dwg

09.03.01 - PARKS & OPEN SPACE



NOT FOR CONSTRUCTION

NEW TOWN
ARCHITECTURE
URBAN PLANNING
CIVIL ENGINEERING
www.newtownservices.ca

LEGEND

- OPEN SPACE
- PARK SPACE
- STRATA DEVELOPMENT POD

NO	DATE	ISSUE/REVISION	BY	APPROVED	CHECKED
1	26/01/16	PDA-PRESENTATION TO MAYOR & COUNCIL	JP	JP	JP

SEAL

PERMIT TO PRACTICE:1003604

SURVEY FERGUSON LAND SURVEY & GEOMATICS LTD.	BASE AR
DESIGN AR	ENG. OF RECORD JP
SCALE = 1:3000	

DISTRICT OF LAKE COUNTRY

PARKS & OPEN SPACE
PHASED DEVELOPMENT AGREEMENT
LAKESTONE MASTER PLANNED COMMUNITY

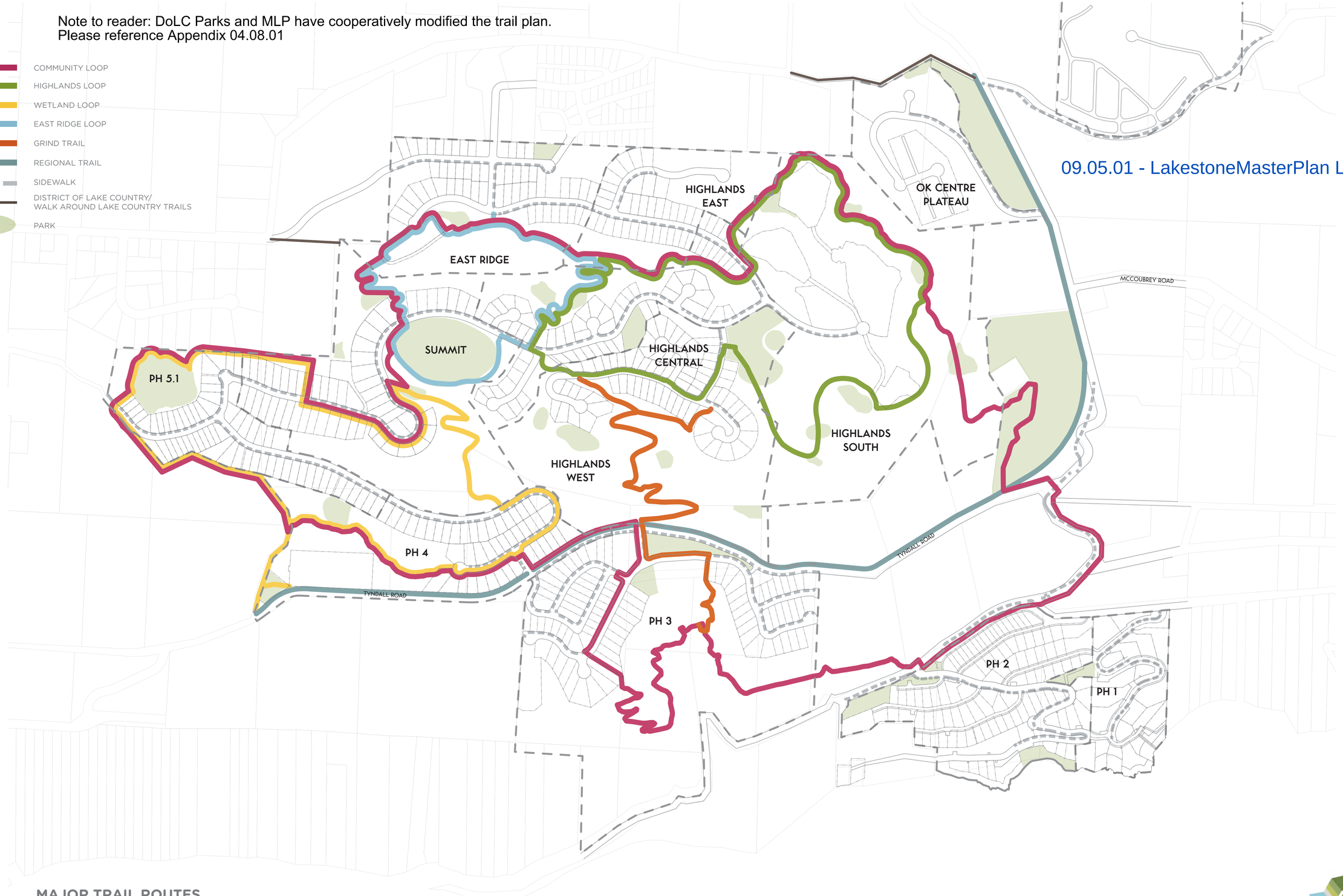
DISTRICT DEPT. INFRASTRUCTURE	
DISTRICT FILE NO. 4019	
PROJECT DRAWING NO. 04.03.01	REV NO. 1
DISTRICT RECORD NO. N/A	SHEET NUMBER 4 OF 22

PLOT DATE: January 16, 2026 - F:\1 Projects\4019 Lakestone MP\4019-4 Drawings\4019-4.1 Current Drawings\Civil\3 - PROD\1 - PDA\02.01 PHASING PLAN.dwg

Note to reader: DoLC Parks and MLP have cooperatively modified the trail plan.
Please reference Appendix 04.08.01

LEGEND:

- COMMUNITY LOOP
- HIGHLANDS LOOP
- WETLAND LOOP
- EAST RIDGE LOOP
- GRIND TRAIL
- REGIONAL TRAIL
- SIDEWALK
- DISTRICT OF LAKE COUNTRY/ WALK AROUND LAKE COUNTRY TRAILS
- PARK



09.05.01 - LakestoneMasterPlan L1-L9

L1

MAJOR TRAIL ROUTES

LAKESTONE DEVELOPMENT | LAKE COUNTRY, BC | LAKESTONE MASTER PLAN

REISSUED FOR MASTER PLAN UPDATE - January 4, 2021

SCALE 1:4000

BENCH SITE DESIGN

LEGEND:

- REGIONAL TRAIL (2.8 km)
- ROADSIDE TRAIL (11.1 km)
- MAJOR TRAIL (1.1 km)
- RIGHT-OF-WAY/RESIDENTIAL CONNECTIONS (0.9 km)
- NATURE TRAIL (11.9 km)

TOTAL DISTANCE OF LAKESTONE TRAILS = 27.8 km

- DISTRICT OF LAKE COUNTRY/ WALK AROUND LAKE COUNTRY TRAILS
- PARK

HIGHLANDS EAST

OK CENTRE PLATEAU

EAST RIDGE

MCCOUBREY ROAD

SUMMIT

HIGHLANDS CENTRAL

PH 5.1

HIGHLANDS SOUTH

HIGHLANDS WEST

PH 4

TYNDALL ROAD

TYNDALL ROAD

PH 3

PH 2

PH 1

L2

TRAIL TYPES

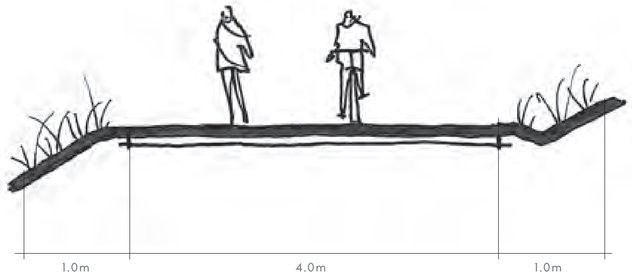
LAKESTONE DEVELOPMENT | LAKE COUNTRY, BC | LAKESTONE MASTER PLAN

REISSUED FOR MASTER PLAN UPDATE - January 4, 2021

SCALE 1:4000

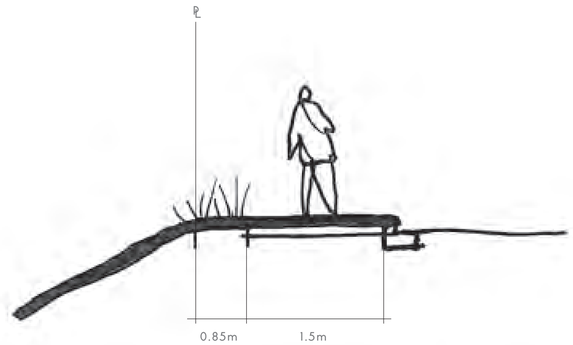
BENCH SITE DESIGN

REGIONAL TRAIL



Regional trails will be 4.0m wide with asphalt paved surfacing and minimal slopes to maintain accessibility. Users will include a range such as walkers/hikers, and commuter and recreational cyclists. It will accommodate moderate to high levels of use, and should be barrier-free.

ROADSIDE TRAIL



Roadside trails will be 1.5m wide with concrete surfacing. Users will include walkers and hikers. It will accommodate moderate to high levels of use, and should be barrier-free.

RIGHT-OF-WAY/NEIGHBOURHOOD CONNECTIONS



Right-of-way/neighbourhood connections will be 3.0m wide with either compacted granular surfacing or stairs to meet back property elevation. Users will include walkers and hikers. It will accommodate moderate to high levels of use, and should be barrier-free.

MAJOR TRAIL

The primary function of the Major trail is for recreation. These trails may serve as primary routes into parks of all types, or provide circulation in parks. While generally accessible, Major trails may have limited accessibility in sections due to steeper slopes. They will be between 1.2m and 1.8m wide with compacted granular surfacing. Users will include walkers, recreational cyclists, and hikers.

NATURE TRAIL

Nature trails are recreational hiking trails that may be a combination of newly constructed or improved trails. Their primary function is to provide hiking routes throughout the development. These trails have varying levels of difficulty and are not accessible to all users. They will be either hand or machine built between 0.9m and 1.2m wide with native material surfacing. In areas where the slope in unsafe, stairs or earth may be required.

LEGEND:

- COMMUNITY PARK (3.7 ha)
- NATURAL PARK (3.2 ha)
- DEVELOPED PARK (0.4 ha)
- PASSIVE PARK (0.8 ha)
- HIKE RESTING AREA (3.4 ha)
- DISTRICT OF LAKE COUNTRY PARK (9.0 ha)
- TRAILS AND SIDEWALKS

TOTAL HECTARES OF LAKESTONE PARKS = 20.5 ha



L4

PARK TYPES

LAKESTONE DEVELOPMENT | LAKE COUNTRY, BC | LAKESTONE MASTER PLAN

REISSUED FOR MASTER PLAN UPDATE - January 4, 2021

SCALE 1:4000

BENCH SITE DESIGN

LEGEND:

- PROJECT ENTRY SIGN
- KIOSK
- TRAILHEAD SIGN
- DIRECTIONAL SIGN
- INTERPRETIVE SIGN
- CROSSWALK
- TRAILS AND SIDEWALKS

HIGHLANDS EAST

OK CENTRE PLATEAU

EAST RIDGE

MCCOUBREY ROAD

SUMMIT

HIGHLANDS CENTRAL

PH 5.1

HIGHLANDS SOUTH

HIGHLANDS WEST

PH 4

TYNDALL ROAD

TYNDALL ROAD

PH 3

PH 2

PH 1

L5 SITE FEATURES PLAN

LAKESTONE DEVELOPMENT | LAKE COUNTRY, BC | LAKESTONE MASTER PLAN

REISSUED FOR MASTER PLAN UPDATE - January 4, 2021

SCALE 1:4000

BENCH SITE DESIGN

COMMUNITY PARK:

Community parks are large developed areas within Lakestone with public amenities. These include:

SUMMIT PARK: located in the Highlands, Summit Park will be a peaceful space atop the highest point of land at Lakestone. A natural amphitheatre will provide space for special events and small performances. Summit Park will be a primary hiking destination.

MULTI-SPORT PARK: located in the Benchlands, the Multi-Sport Park will feature tennis and multi-sport courts and open space for recreational activities (See Figure 1).

LAKESTONE BEACH PARK: located in Waterside, Lakestone Beach Park offers picnic tables and loungers, kayak and paddleboard storage, and space to swim.

NATURAL PARK:

Natural parks at Lakestone encompass wetland areas. These areas are ecologically significant and provide valuable habitat for native species. Interpretive infrastructure and signage provides users with a connection to these unique natural environments.

DEVELOPED PARK:

Developed parks provide open space and natural play opportunities for children. These areas will have minimal impact to the native landscape. Deadfall will be removed and selective planting and reforestation will occur. Features of these parks include benches, shade structures, and natural play elements.

FIGURE 2: BENCHLANDS DEVELOPED PARK

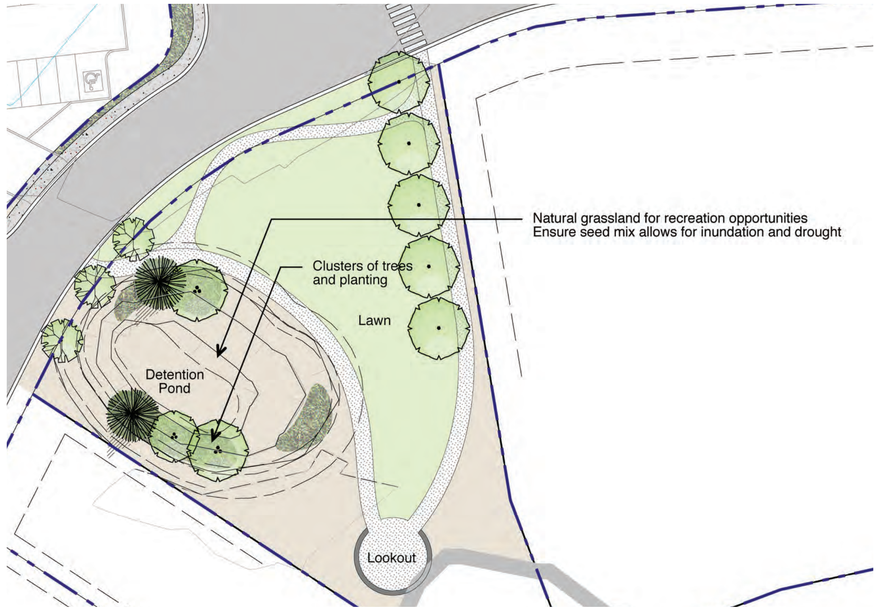


FIGURE 1: MULTI-SPORT COMMUNITY PARK



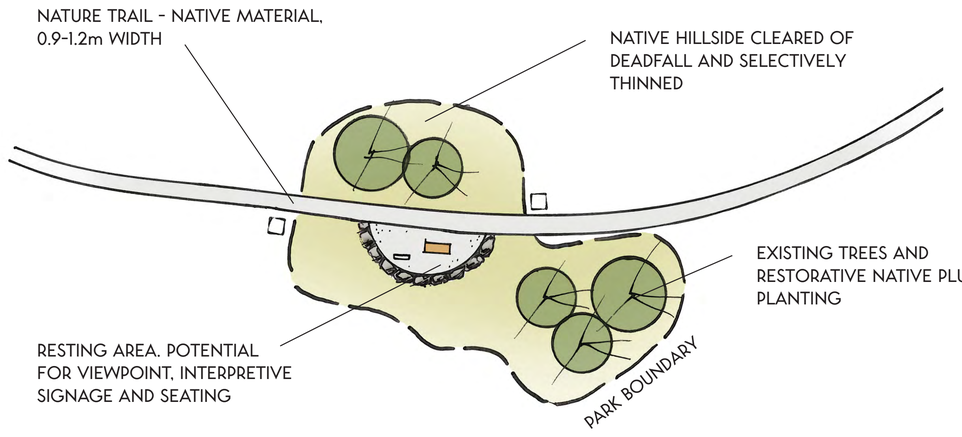
PASSIVE PARK:

Passive parks retain much of the vegetation of the native hillside environment, with selective thinning at view corridors and cleanup of deadfall. Passive parks feature compacted granular clearings with picnic tables or benches, providing places to rest, gather, or eat along the hiking routes (See Figure 4).

HIKE RESTING AREA:

Hike resting areas retain much of the vegetation of the native hillside environment, with selective thinning at view corridors and cleanup of deadfall. Hike resting areas can be found along the trail network and may feature a bench and/or interpretive signage (See Figure 3).

FIGURE 3: HIKE RESTING AREA



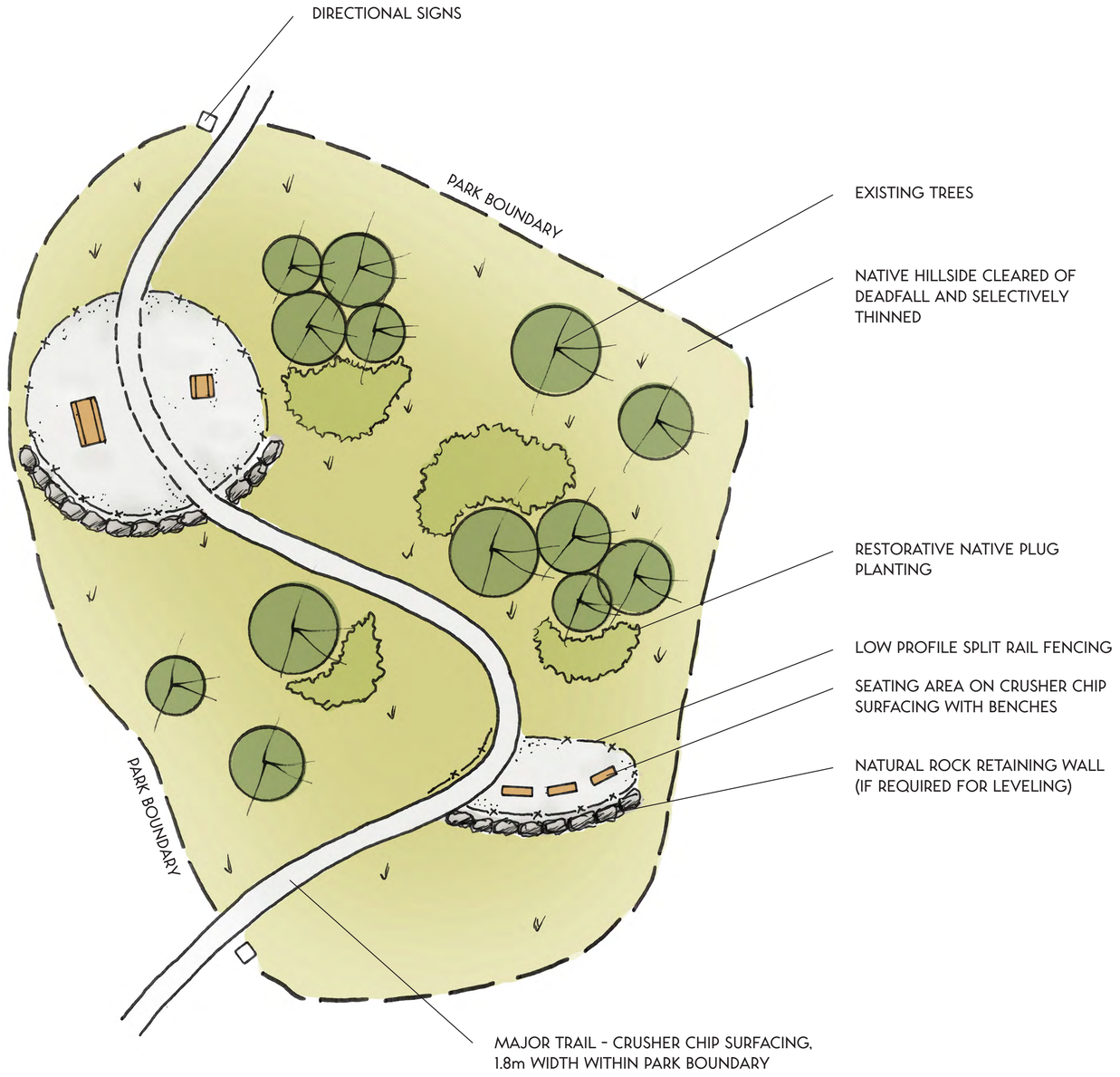


RESTING AREA



PASSIVE PARK AREA

FIGURE 4: PASSIVE PARK



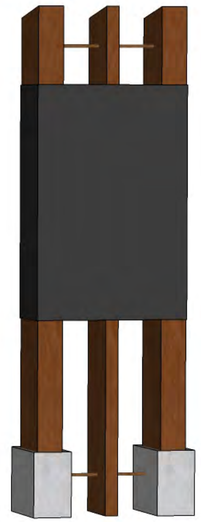
SIGNAGE STRUCTURES



PARK SIGN



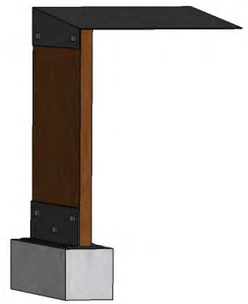
KIOSK



TRAILHEAD SIGN



DIRECTIONAL SIGNPOST



INTERPRETIVE SIGN

SIGNAGE GRAPHICS

KIOSK

- Map of overall development, including:
  - Focus on neighbourhood in which kiosk is located
  - Parks (with descriptions)
  - Trails (with descriptions)
  - Roads
  - You are here symbol
  - North arrow
  - Special features
  - Regulatory symbols and descriptions
  - Phase boundaries

TRAILHEAD SIGN

- Map of overall trail network, including:
  - Trail names and locations
  - Roads
  - You are here symbol
  - North arrow
  - Special features
  - Regulatory symbols
  - Phase boundaries

DIRECTIONAL SIGNPOST

- Wayfinding Signage
  - Trail symbol
  - Directional arrow
  - Amenity symbols (where applicable)

INTERPRETIVE SIGN

- Description of site feature
- Image
- Regulatory symbols

SAMPLE WAYFINDING SIGNAGE



LOOP TRAIL



LOOKOUT



DIRECTIONAL ARROW



DIRECTIONAL ARROW

COMMUNITY & DEVELOPED PARK FURNISHINGS:



PICNIC TABLE



BENCH



WASTE RECEPTACLE

NATURAL, PASSIVE & HIKE REST AREA FURNISHINGS:



PICNIC TABLE



BENCH



WASTE RECEPTACLE

SPLIT RAIL FENCING:



NATURAL ROCK RETAINING WALL:

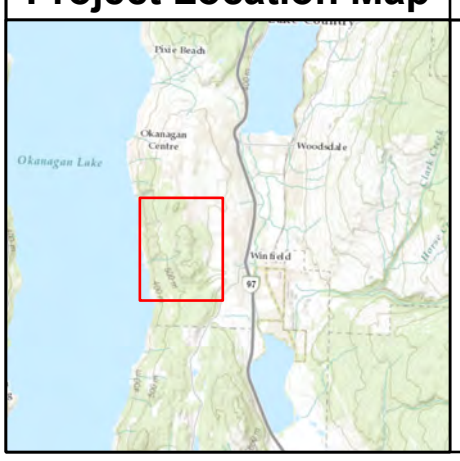


09.08.01 - Lakestone Conceptual Trail Plan 2024

620 m
Okanagan Centre Rd W
Nighthawk Rd
Tyndall Rd
Long Rd
Wetland Loop
Wetland Loop
Wetland Connector
Chase Rd
Seaton Rd
Access
Access
Long Trail
Highland Trail Access
Highland Trail
Access
Tyndall Road Multi-Use Trail
Beacon Hill Dr
Tyndall Rd
Park Loop
Summit Park Trail
Summit Trail
Lakestone Climb Trail
Access
Main Ridge Trail
Santina Rd Access
Access
Chase Rd
Benchlands Trail Access
Beacon Hill Connector
Summit Trail
Wetland Loop
Lakestone Downhill
Santina Rd
Crimson Rd
Grind Trail Access
Grind Trail
Chase Road Loop
Chase Rd
Benchlands Trail
Rock Slabs
Southern
Dick Rd
Okanagan Centre Rd W
Tyndall Rd
Tyndall Road Multi-Use Trail
Tyndall Downhill
Chase Trail Connector
Chase Trail
Okanagan Centre Rd
Chase Road Trail
Lakestone Dr
Okanagan Centre Rd W

Lakestone Conceptual Trail Plan

Project Location Map



Legend

Trails
- Existing Paved
- Proposed Paved Trail
- Existing Major Trail
- Proposed Major Trail
- Existing Nature Trail
- Proposed Nature Trail
- Existing,Access
- Proposed,Access
- Existing WALC Trail

Lakestone Dev.
- C-PROP/FUTR
- Parks
- Property
- Road
- Water

DLC Bike Park
- Green
- Blue
- Black

N
W E
S

1:8,000

0 50 100 200 300 400
Meters

NAD 1983 CSRS UTM Zone 11N

Prepared For: MacDonald Development Corp.
Map Created: 2023-12-18
Data Sources: Esri, DLC, Macdonald, DataBC

CABIN