Crossings Guideline for Valley and Stream Corridors

September 2015

Toronto and Region Conservation for The Living City

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How to Read this Document

The “Crossings Guideline for Valley and Stream Corridors” outlines TRCA’s study requirements and recommendations for the planning and design of valley and stream corridor crossings. This document consists of the following sections:

Section 1: **Introduction** provides an overview of the context, rationale, and role of TRCA in crossing planning and design, which sets the premise for the rest of the guideline.

Section 2: **TRCA objectives for crossings** establish the key natural hazard and natural heritage objectives that TRCA strives to meet through crossing structure planning and design.

Section 3: **TRCA study requirements for crossings** set outs a list of TRCA’s study requirements, and where appropriate, refers readers to supporting Appendices.

Appendices that describe the specific technical details needed to guide the required studies.

The purpose of the guideline is best understood if readers acquaint themselves with the document in its entirety. However, recognizing that the level and type of information required may vary depending on the unique needs of a given user, TRCA recommends that readers direct their focus accordingly based on the following:

Readers	Relevant Sections
Planning level decision makers (e.g. Municipal land use and infrastructure planners, development industry proponents and their planners)	Section 1 and Table 2
Project level decision makers (e.g. municipal and development project managers)	Section 1, Section 2, and parts of Section 3
Municipal and CA review staff , technical consultants	Section 1, Section 2, Section 3, and Appendices

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1. INTRODUCTION

Urban growth in the Toronto region will continue to require the development of new road and rail infrastructure as well as upgrades to existing infrastructure. Most of this infrastructure crosses, or will cross one or more of the region's valley and stream corridors, requiring the construction of bridges and culverts at crossing points. There are currently over 3,500 bridges and culvert crossings within the nine watersheds that comprise the Toronto and Region Conservation Authority's (TRCA) jurisdiction. In coming years many crossings will be added, upgraded and reconstructed to accommodate population growth and associated transportation needs, as well as necessary replacement of deteriorated infrastructure.

a. **b.**

Figure 1: (a) a valley corridor and (b) a stream corridor in TRCA's jurisdiction

Given the tremendous urban growth in southern Ontario over the past several decades, TRCA and other conservation authorities (CAs) have become engaged in providing input to their partner municipalities and private proponents on crossing infrastructure location and design. CAs use their expertise in natural hazard management and natural heritage protection and restoration to comment to other approval authorities, and to issue their own permits, for the siting and the design of valley and stream corridor crossings.

This *Crossings Guideline for Valley and Stream Corridors* (the Guideline) is therefore intended to support TRCA partner municipalities and other agencies and proponents in the management of natural hazards and natural heritage issues associated with crossings. In particular, the Guideline supports the infrastructure and transportation infrastructure sections of *The Living City Policies for Planning and Development in the Watersheds of the Toronto and Region Conservation Authority* (2014).

1.1 Rationale

Evidence indicates that crossings can have substantial impacts on valley and stream corridors (see Box 1). From a natural hazard perspective, crossing structures that do not provide a sufficiently large opening can (i) cause increases in upstream flooding during high flows or (ii) can be overtopped by floodwaters, creating major risks to the safety of vehicles and pedestrians. In addition, rivers and streams are dynamic systems and their channels naturally migrate across the floodplain over time. Migrating rivers and streams that come into contact with crossing infrastructure can cause significant damage, and in some cases, catastrophic infrastructure failure. Likewise, construction of crossing infrastructure can affect slope stability in the valleys, necessitating consideration of current and future slope stability. Figure 2 a, b, and c illustrates some of the natural hazard impacts associated with existing crossing infrastructure. Natural hazard issues related to crossings are of increasing concern, as impacts are exacerbated by the changing climate, including an increased frequency of flood events and changing freeze-thaw and wetting-drying cycles. Carefully sited, sufficiently sized, and appropriately designed crossings can avoid expensive repairs, channel realignment, or early replacement caused by migrating channels.

a. b. c.

Figure 2: Impacts of crossing infrastructure on natural hazards (a) impacts on flooding, (b) impacts on channel migration, and (c) impacts on erosion

Natural heritage functions include existing and potential high quality aquatic and terrestrial habitat and connectivity for fish and wildlife passage (LCP, Section 7.4.4.1.2). These functions have become increasingly important in the location and design of valley and stream corridor crossings in recent years. The value of protecting and restoring terrestrial and aquatic natural heritage functions in urban and near urban landscapes is now widely recognized and enshrined in provincial policy, municipal official plans and sustainability strategies. Through establishment of various natural heritage systems in land use planning documents, many municipalities have invested in defining, protecting, and restoring natural heritage functions. The impacts that road and rail crossings can have on these natural heritage functions may undermine the commitment and investments made by municipalities. Protecting these investments is particularly significant in the Toronto region where valley and stream corridors comprise the bulk of the remaining natural system, and are already highly stressed due to continual habitat loss, degradation, and fragmentation. In such settings, road and rail crossings, in particular, can lead to further habitat loss during construction, wildlife-vehicle collisions due to increased traffic, road mortality of wildlife, and/or restrict movement of sensitive wildlife to key habitats for feeding and reproduction. These direct and indirect impacts of road crossings can have a substantial impact on the *habitat and wildlife connectivity* in the watershed, which ultimately affects the overall natural heritage function. Figure 3 a, b, and c illustrates some of these impacts; Box 1 further outlines potential impacts on the natural heritage functions. Appropriately sited, sufficiently sized, and carefully designed crossings can mitigate most of the impacts on terrestrial and aquatic natural heritage functions within valley and stream corridors as well as the broader landscape. Various road ecology studies conducted by TRCA and elsewhere provide further direction on this, the guiding principles of which inform the Guideline as well (further information is available from TRCA staff upon request).

a. **b.** **c.**

Figure 3: Impacts of crossing infrastructure on natural heritage functions (a) terrestrial barriers and wildlife-vehicle collisions, (b) road mortality, and (c) aquatic barriers

The Guideline outlines a balanced approach to planning and design of valley and stream corridor crossings as a means of achieving TRCA's natural hazard and natural heritage objectives described in Section 2 many of which are aligned with the objectives of partner municipalities. Reflecting recognition by TRCA that social, economic and ecological issues need to be considered together in planning and designing valley and stream corridor crossings, this Guideline provides a context-sensitive approach to crossing siting and design, rather than providing a standard set of requirements or recommendations to be applied everywhere. Thus, the Guideline aims to direct appropriate resources and effort to those locations where larger structures will most effectively achieve the natural hazard and natural heritage objectives. For example, smaller and less expensive structures may be acceptable for small and stable watercourses with lower priorities for natural heritage functions, provided that flood hazard objectives can also be met. Further, in some cases, the study requirements in support of submissions to TRCA for these types of crossing locations are significantly reduced. Nevertheless, it is important that the municipality, as the ultimate owner and operator of the infrastructure, understands the implications associated with different options so that approval authorities can make informed decisions on appropriate crossing location and design.

The Guideline also supports the goals of other agencies in protecting the natural heritage system and protecting people and property from harm and risk due to natural hazards. The directions provided in the Guideline are consistent with the guidance provided in various provincial and other agency documents (listed in the Reference section) and will be updated as needed.

1.2 Guideline Scope

The Guideline is intended to describe for proponents the information that TRCA requires in order to review road and rail crossing structures and proposed modifications to existing structures in the context of planning, environmental assessment and TRCA permit processes.

There are numerous other requirements that the crossing proponent must satisfy that relate to municipal standards and objectives and provincial and federal legislation (Figure 4). These are referenced in the Guideline in Section 3.3. In this regard, it is the responsibility of the crossing proponent to consult appropriate agencies for detailed guidance on their specific requirements and to ensure that all considerations are integrated into the crossing siting and design.

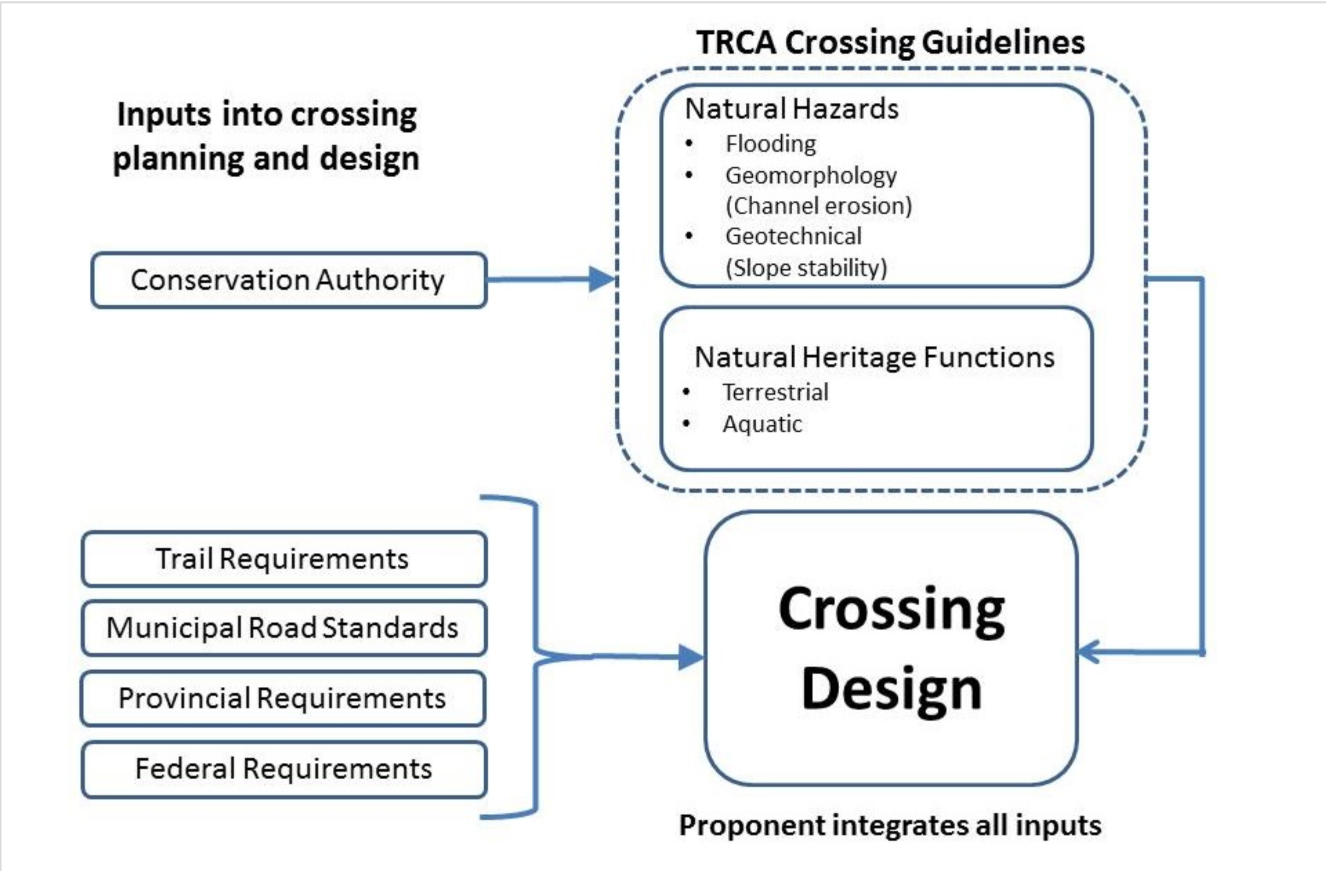


Figure 4: TRCA's Crossings Guideline for Valley and Stream Corridors addresses natural hazard (flooding, geomorphology, and geotechnical), and natural heritage function (terrestrial and aquatic) considerations in the siting and design of crossings

1.3 TRCA Roles in Planning and Design of Crossings

TRCA reviews crossings in multiple capacities: as a public commenting body and service provider to approval authorities under the *Planning Act* and *Environmental Assessment Act*, and as a regulator that issues permits under section 28 of the *Conservation Authorities Act*. Under the *Planning Act*, TRCA also represents the provincial interest in natural hazards as delegated by the Province to all conservation authorities. In both the advisory capacity as well as in the delegated role, TRCA endeavours to make proponents aware of the requirements of the section 28 regulation in order to avoid duplication, conflict or delay within the review and approvals processes. All of these roles are depicted in Figure 5 of the Guideline and are described in more detail in Section 3 of *The Living City Policies* (TRCA, 2014), and in TRCA's Planning and Development Procedural Manual.

The Guideline is a technical support component of the Planning and Development Procedural Manual (Figure 5) that supports The Living City Policies (TRCA 2014). Most of the other technical guidelines referred to herein are also components of the Procedural Manual, which can be found on the TRCA website: http://www.trca.on.ca/planning-services-permits/developers-and-consultants-information/planning-and-development-procedural-manual.dot.

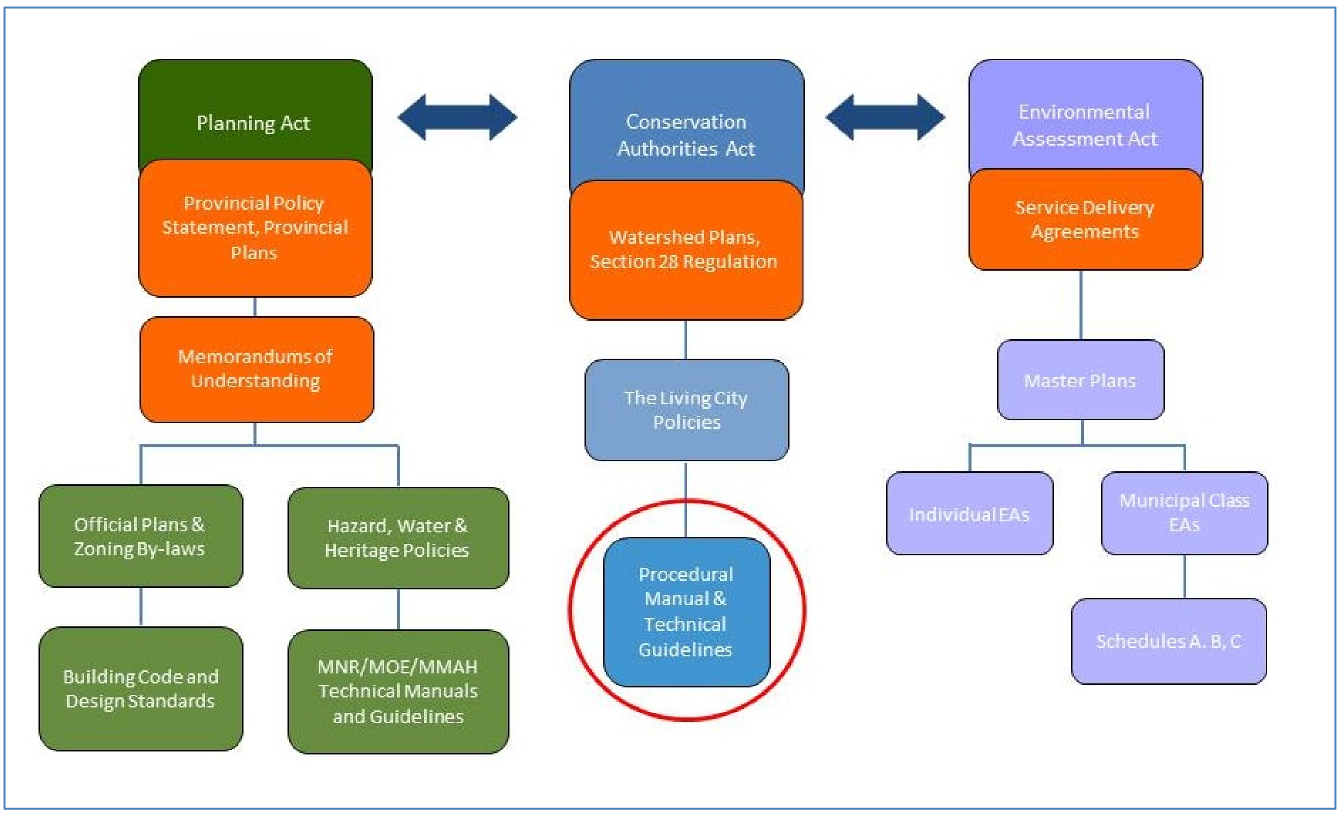


Figure 5: Legislation, Policies and Processes for TRCA's roles in the planning and development process

Certain proponents are exempt from TRCA's permit process (e.g., Ontario Ministry of Transportation, Metrolinx, Canadian National Rail and Canadian Pacific Rail) but may still undergo the TRCA review process on a voluntary basis. TRCA typically provides comments to these proponents throughout their planning and design process for new crossings or the upgrade of existing crossings.

TRCA's roles, specific to the review of crossings, in the *Planning Act* and *Environmental Assessment Act* processes are outlined in Figure 6. Ideally, both processes are informed by watershed or subwatershed studies that set land use targets and objectives at the watershed or subwatershed scale in accordance with The Living City Policies. TRCA and its partners rely on these studies to subsequently inform other planning and design processes.

The TRCA submission requirements for crossing infrastructure works outlined within the Guideline are organized based on three planning stages: early, intermediate and late, which align with both the land-use and infrastructure planning processes. The terminology used to describe the planning stages varies from municipality to municipality and between planning and environmental assessment processes. TRCA has selected the terms early, intermediate and late stages to generalize them and accommodate all of these processes (Figure 6).

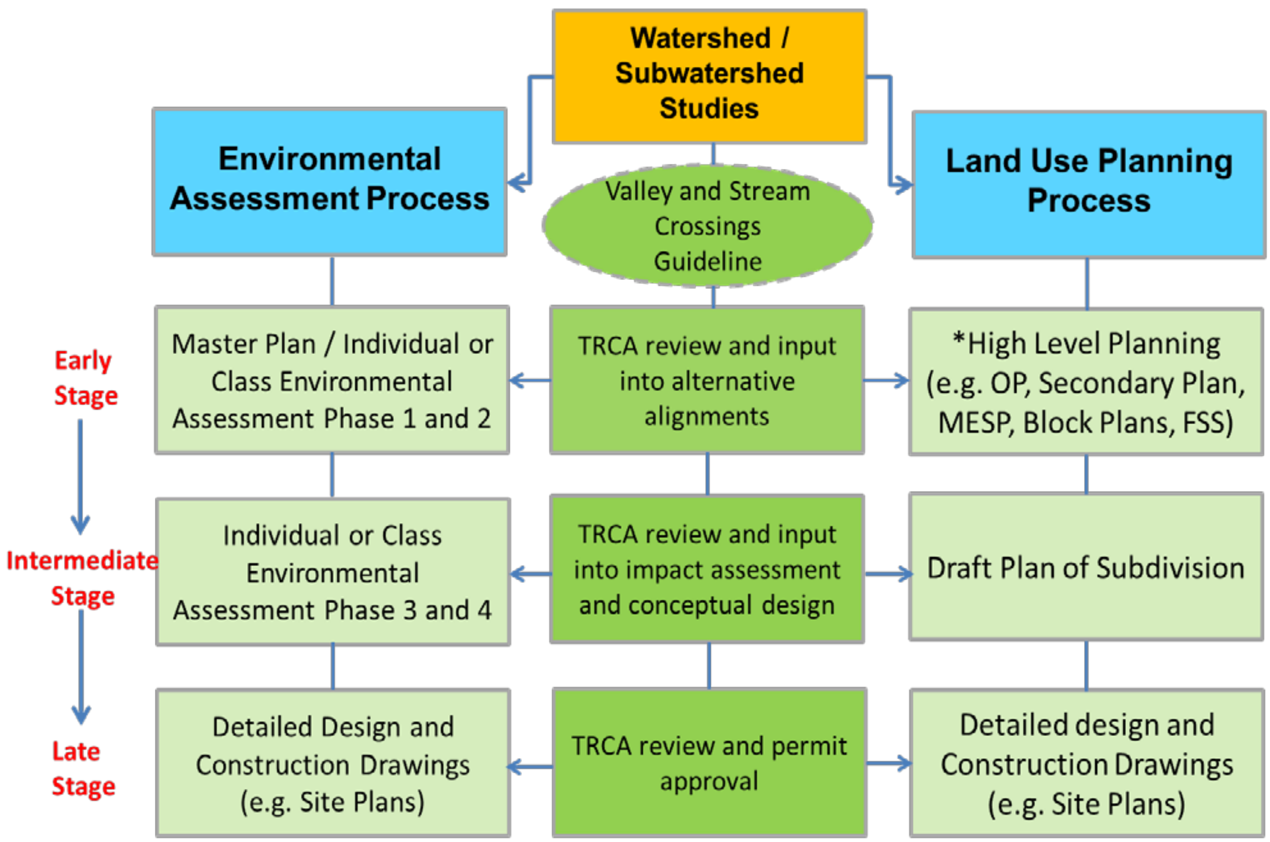
Although these requirements are presented separately according to each stage, they build on each other, ensuring the required level of analysis is completed at the appropriate time to progressively inform planning and design. It is therefore important to understand the requirements within each stage to ensure a coordinated approach. The three stages are outlined below:

1. The **early stages** of planning refer to those activities in the environmental assessment and planning processes related to establishing the need for the crossing infrastructure and assessing alternative road or rail routing and alignments (Figure 6). The specific planning instruments adopted to undertake this stage, and the level of detail of the information provided varies by municipal jurisdiction. For example, for the planning process, the Master Planning stage may provide input into the official plan, which is then further articulated in the secondary plan or official plan amendment stages. Master Environmental Servicing Plans, Block Plans, or Functional Servicing Studies may also be prepared at this stage. However, in some cases, impact assessment and conceptual design (intermediate stage) will also be undertaken through these studies. For the environmental assessment process, the early stage covers Phases 1 and 2 of the process relating to the identification of the problem / opportunity and the evaluation of alternative solutions.

   TRCA reviews and provides input at the early stage of crossing proposals to ensure that the preferred location and alignment adequately avoids natural hazards and maintains natural heritage functions. It is important that preliminary crossing sizing be established at the early planning stage in order to ensure that the appropriate costing for the required infrastructure is considered.

2. Once the need for the infrastructure has been established, and the preferred route determined, the activities in the **intermediate stages** of planning further refine the early stage planning decisions related to crossings, including impact assessment and development of alternative conceptual designs of the crossing. For example, the draft plan of subdivision phase and the Individual or Class Environmental Assessment Phases 3 and 4 represent intermediate stage planning activities. TRCA reviews and provides input at this stage to ensure that appropriate impact assessments on natural hazard and natural heritage function have been completed, conceptual design addresses TRCA objectives, and that any future issues that may arise at the late or detailed design stage are flagged.

3. The activities in the **late stages** of planning further refine the conceptual designs completed during the intermediate stages including development of the detailed design of the crossing. TRCA reviews and approves final designs, including construction drawings, through the permitting process.



Note: The planning instrument used to determine alternative alignments and the scale and level of detail of information provided for the early planning stages may vary by municipality.
OP = Official Plan, MESP = Master Environmental Servicing Plan, and FSS = Functional Servicing Study

Figure 6: TRCA's plan review and permitting roles for crossings at various stages in the planning and environmental assessment processes

Box 1: Overview of Valley and Stream Corridor Crossing Impacts

The natural physical and ecological processes, including water moving through valley and stream corridors, provide critical functions for local and regional ecosystems. These functions include shaping valleys to provide habitat and movement pathways for terrestrial and aquatic wildlife, the transport of energy and nutrients and the conveyance of runoff and melt water, and the transport of sediment eroded from the land surface. These natural processes are intensified as land use changes occur within our watersheds, such as urbanization and the construction of infrastructure within valley corridors. These natural processes may pose hazards to adjacent tablelands and infrastructure associated with flooding, valley slope instability and stream erosion. The extent of natural hazards can be greatly exacerbated by undersized road / rail crossings of corridors that result in both adverse economic / social impacts and ecological impacts.

In terms of economic / social issues, the constriction of flows and localized increases in sediment transport capacity at undersized crossings may cause physical erosion impacts, such as scour holes and channel down-cutting. Undersized crossing structures can also be problematic in flood vulnerable areas, as they may restrict flow conveyance during a flood event and increase the vulnerability of communities and infrastructure to flooding (Figure 2).

In the long term, undersized openings may result in the migration of the watercourse channel into crossing and road or rail infrastructure including footings, piers or embankments, thereby requiring maintenance and added costs (Figure 2). Structure maintenance is typically accompanied by the installation of erosion protection works to prevent additional erosion impacts. However, such erosion protection works typically involve hardening the bed or banks of the watercourse channel with stone, concrete, or other inflexible materials, which further restrict and alter channel movement and increase the magnitude and extent of erosion problems downstream. Additionally, this leads to alteration of natural stream function and degradation of terrestrial and aquatic habitats within TRCA watersheds.

For aquatic functions, increased flow velocities through crossing structure openings restricts fish passage, as do the physical barriers of perched conditions created by scour holes (Figure 3). Channel down cutting and failed erosion protection beneath the structure can also be problematic for aquatic systems. The long-term impacts of these barriers on fish populations, community assemblages, and genetic diversity have been well documented. For terrestrial wildlife, the crossing footprint and fragmentation of the remaining habitat results in direct habitat loss within valley and stream corridors. Undersized crossing structures, and noise, lighting and vegetation impacts associated with road or rail, create degraded habitat and barriers to wildlife movement that can partially or completely isolate wildlife populations. For species that are able and willing to cross roads, this often leads to high wildlife mortality and dangerous driving conditions due to wildlife-vehicle collisions (Figure 3). This is in addition to the indirect impacts that roads or rails have on ecological functions resulting from edge effects and loss of interior forest that can further affect sensitive wildlife.

2. TRCA OBJECTIVES FOR CROSSINGS

TRCA's objectives for valley and stream corridor crossings related to natural hazards (flooding, geomorphology, geotechnical) and natural heritage functions (terrestrial and aquatic) are outlined in the Section 2.1 and 2.2 and illustrated in Figure 7. These objectives are consistent with the goals and objectives of The Living City Policies (TRCA, 2014) and are aligned with many of TRCA's municipal partners' objectives for natural hazards and natural heritage.

For new road and rail crossings, many aspects of natural hazards and natural heritage objectives can best be accomplished through proper siting of infrastructure in the early planning stages. Proper siting may also reduce the number or scope of studies required and potential delays in approval at late planning stages. For example, crossings that are perpendicular to valley and stream corridors and crossing at the narrowest point along the corridor will help to reduce impacts and construction costs. In addition, proposals for aligning infrastructure parallel to the watercourse are not supported and should be avoided.

Further, minimizing the total number of infrastructure crossings of valleys is important to minimize cumulative impacts, and proponents are encouraged to co-locate infrastructure (including roads, rails, trails, water mains, pipelines, and other utilities etc.) wherever possible.

Figure 7 provides a conceptual illustration of how TRCA objectives for crossings can be met.

For upgrades or replacement of existing crossing structures, TRCA recognizes that both the location of the crossing and the vertical profile of the road or railway are already established and often cannot be modified to any significant degree. In these instances, it may be difficult to achieve all natural hazard and natural heritage objectives and TRCA will work with proponents to achieve the best practical outcome.

2.1 Natural Hazard Objectives

TRCA's objectives for natural hazards pertain to the avoidance and mitigation of flood risk, geotechnical risk from slope instability, and geomorphic risk from channel migration over time. Overall, valley and stream corridor crossings should be sited and designed to avoid the exacerbation of natural hazard risks and to minimize risks of natural hazards to the infrastructure and to the users of the crossing. In particular, a proposed crossing must not increase flood risk for design storm events up to, and including, the Regulatory event. In the case of geotechnical risk, appropriate studies must be completed to confirm that there is no outstanding slope stability or structural protection issues. For geomorphic risks, TRCA assists the infrastructure owner who holds responsibility in understanding and addressing risks through crossing location and design. Crossings should be located away from geomorphically active and unstable areas, and be designed to span the zone of potential future channel migration, as defined by the meander belt or the 100-year erosion limit, to reduce risks from channel migration over time. However, it is recognized that in some instances this may not be practical, particularly for modifications to existing crossings or for new crossings of small, stable watercourses. In these cases, alternative designs supported by geomorphic studies may be acceptable in consultation with TRCA and the municipality. It is important to note that where there are risks associated with these options that they are taken into consideration by the municipality as the ultimate owners and operators of the infrastructure. A description of study and submission requirements for natural hazards for existing and new crossings is provided in Section 3 and Appendices 1A through 1C.

2.1.1 Flood Hazards

- Ensure that flood risk does not increase as a result of the proposed crossing for all design storm events up to, and including, the Regulatory event.
- Safely convey the applicable design storm as per municipal, regional, and/or Ministry of Transportation guidelines considering implications of future land use on flooding.
- Establish the requirements for crossing size (i.e., overtopping of the Regulatory event) while considering ingress/egress within the surrounding area in consultation with local municipal emergency managers.

2.1.2 Geomorphic Hazards

- Minimize the risks of damage to the crossing infrastructure from watercourse channel migration, erosion and scour through proper crossing siting and design.
- Avoid the need for future channel realignment or hardening by minimizing the probability of channel contact with the crossing infrastructure.
- Improve existing crossing structures, where possible, to reduce erosion hazards.

2.1.3 Geotechnical Hazards

- Minimize risk to crossing infrastructure by avoiding sites of active erosion and locations with risk of slope instability (i.e. over-steepened slopes and locations where the watercourse is coincident with the toe of slope).
- Ensure that the construction of the crossing structure does not aggravate valley slope instability.
- Avoid siting crossing infrastructure where there is a need for permanent dewatering.
- Ensure appropriate restoration of valley slopes where slope treatments are necessary.

2.2 Natural Heritage Function Objectives

TRCA's natural heritage function objectives relate to terrestrial and aquatic habitat and connectivity functions. Valley and stream corridor crossings should be sited and designed to avoid or minimize the physical footprint impact to habitats and on terrestrial and aquatic connectivity. TRCA provides assistance and advice to municipal authorities in understanding and mitigating these impacts, in support of municipal natural heritage strategies, plans and policies. To this end, TRCA strongly recommends larger crossings in deep valleys where there is relatively high priority for terrestrial or aquatic habitat and connectivity. The larger crossing structures will ensure movement of diverse and varied species under the crossing structures. However, where there are higher priority locations in the shallower valleys, it is recognized that the larger structures may not be practical, thus TRCA recommends smaller but appropriately designed structures to achieve habitat and connectivity objectives. Further details on study and submission requirements are provided in Table 2, Section 3 and Appendix 1D. In general, if the crossing is sited to sufficiently avoid impacts on important natural heritage areas, most studies are not required.

2.2.1 Terrestrial Objectives

- Avoid siting infrastructure in locations of existing forests, wetlands, seepage areas, and other sensitive habitats.
- Minimize footprint impacts of crossings on important terrestrial features and their ecological functions through site selection and design.
- Maintain terrestrial habitat and wildlife connectivity functions by avoiding the priority areas for habitat and wildlife connectivity or by siting and designing crossings to structurally connect habitat patches and to permit wildlife movement.

2.2.2 Aquatic Objectives

- Avoid sensitive aquatic habitat features (e.g. critical spawning areas, important feeding or refuge areas for sensitive/locally rare/indicator species).
- Avoid channel realignment, hardening, or other modifications.
- Minimize footprint impacts of crossings on important aquatic features and their ecological functions (e.g. groundwater upwellings and discharge areas, maintaining natural sediment transport) through site selection and design.
- Maintain aquatic habitat and fish passage functions by avoiding the priority areas or by siting and designing crossings to permit fish passage.

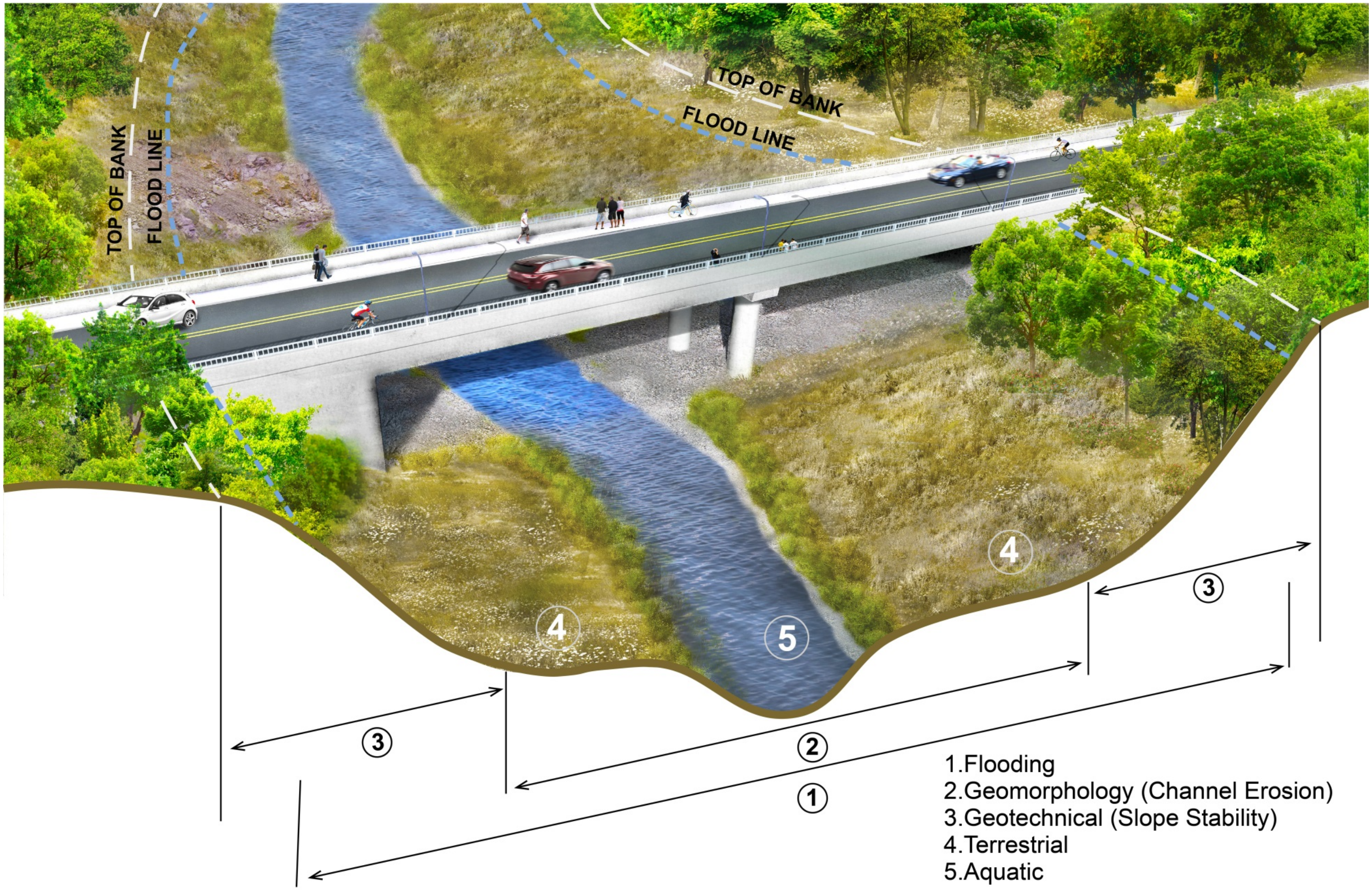
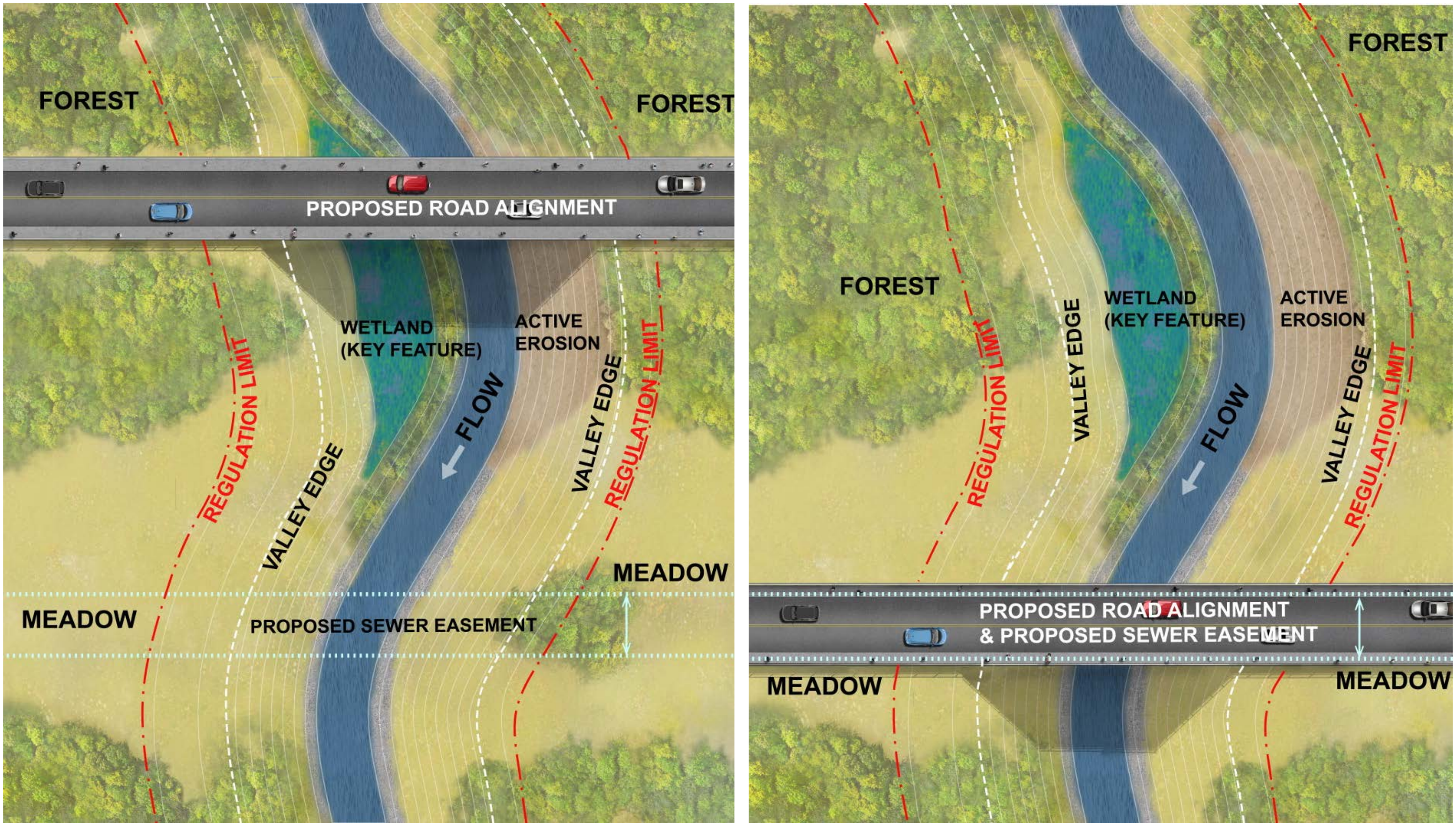


Figure 7: TRCA natural hazard and natural heritage objectives for crossings



a. b.

Figure 8: Illustration of how a number of TRCA objectives for crossings can be satisfied through proper siting of infrastructure. Situate the crossing at an appropriate location by avoiding natural hazards, minimizing the total number of crossings, and avoiding high ecological function areas. a. This is not a preferred alignment as the proposed road is traversing a wetland, forest and active erosion site; b. This is a preferred alignment as the proposed road avoids the wetland, forest and erosion site and is and co-located with a proposed sewer.

3. TRCA STUDY REQUIREMENTS FOR CROSSINGS

The following sections outline TRCA's study requirements for existing (Section 3.1) and new (Section 3.2) road and rail crossings at various *Planning Act, Environmental Assessment Act* and TRCA permit stages as described by Figure 6 and in the planning / policy context in Section 1.3. These stages include early (e.g. Master Plan, Secondary Plans, Official Plan Amendments, etc.), intermediate (Draft Plan of Subdivision, Environmental Assessment, etc.), and late (e.g. detailed design, site plan, permitting) stages. Table 1 provides an overview of the various activities and Table 2 provides an overview of the study requirements at the early, intermediate and late planning stages. It should be noted that many of these requirements may also already be prepared in support of municipal planning applications or the environmental assessment process.

Table 1: Summary of Early, Intermediate, and Late Planning Stages

Planning Stage	Planning Process	Environmental Assessment Process
Early	• Studies/reports submitted in support of secondary plan approval (i.e. Official Plan Amendments, Master Environmental Servicing Plans [MESP], Block Plans, municipal natural heritage strategies, etc.) • Studies/reports submitted prior to draft plan approval (i.e. Functional Servicing Studies [FSS]).	• Master Plan or Individual / Class Environmental Assessment Phases 1 and 2 (i.e. problem identification and alternative solutions)
Intermediate	• Studies/reports submitted in support of draft plan approval (i.e. Functional Servicing Reports [FSR]), Environmental Impact Studies [EIS])	• Individual or Class Environmental Assessment Phases 3 and 4 (i.e. alternative design concepts and Environmental Study Report (ESR))
Late	• Studies/reports/drawings submitted in support of TRCA permit application for a crossing	• Studies/reports/drawings in support of a TRCA permit application for a crossing

It is also important to note that if an area does not have prior planning history at the intermediate or late stages of planning, or if there is prior planning history but the previous submission does not address crossing location and design, the submission requirements for the intermediate or late planning stage will include the requirements listed under the previous planning stages in addition to the submission requirements of that particular stage.

The submission package at all three planning stages (depending on the scope of the studies at each stage) should include a summary checklist in accordance with Table 9 of Appendix 3, which integrates all of TRCA's natural hazard and natural heritage objectives and outlines how they are achieved in the planning stage in question.

Table 2: Summary of the conditions when studies are required at early, intermediate, and late stages of the planning process

Study Criteria	Planning Stage	Conditions when studies are required*	Conditions when studies are not required
Hydraulic Assessment (Flooding)	**Early**	• Studies to determine and review the existing floodline mapping and hydraulic and hydrologic modeling may be required at the proposed crossing location. • High-level hydraulic studies to establish preliminary sizing and flood design criteria may be required.	• Studies are not required for existing crossings if minor changes** are proposed.
	Intermediate	• Detailed studies are always required that provide an update to the hydraulic analysis and associated plans based on the crossing needs of all other natural hazard and natural heritage function constraints.	• Studies are not required for existing crossings if minor changes** are proposed.
	Late	• Studies are always required to refine the hydraulic analysis based on detailed design and update TRCA floodline mapping and provide erosion protection measures.	• Studies are not required for existing crossings if minor changes** are proposed.
Geomorphic Assessment	**Early**	• Historic channel movement and preliminary meander belt width studies are required where crossing locations are being selected or when alternative crossing locations are being evaluated. • Preliminary calculation of 100-year erosion limit is required when preliminary crossing opening dimensions are being examined.	• Geomorphic studies are not required for very small, rural, vegetation-dominated watercourses with drainage area approximately 1 km^2 (100 ha) or smaller. • Studies are not required for existing crossings if minor changes** are proposed.
	Intermediate	• Accurate meander belt width delineation and 100-year erosion limit calculations are required when preliminary crossing opening dimensions are being determined. • Erosion protection locations and specifications are required if a preliminary crossing design is being developed. • Preliminary or detailed channel (as appropriate) realignment design required when realignment is proposed.	• Studies are not required for small, rural, vegetation-dominated watercourses as described above. • Studies are not required for existing crossings if minor changes** are proposed.
	Late	• Accurate meander belt width delineation, 100-year erosion limit calculation, and erosion protection locations and specification are required are required in support of detailed crossing design • Detailed channel realignment design is required when realignment is proposed	• Studies are not required for small, rural, vegetation-dominated watercourses as described above. • New studies are not required when detailed analysis has been conducted at intermediate planning stages and conditions have not changed or the crossing design has not been modified. • Studies are not required for existing crossings if minor changes** are proposed.
Geotechnical Assessment	**Early**	• Geotechnical studies may be required to determine slope stability and structural protection if a slope is steeper than 3:1 and/or >2 m high and/or is coincident with the toe of slope, unstable soils	• Geotechnical studies not required if slope is flatter than 3:1 and < 2 m high, and watercourse is not coincident with toe of slope. • Studies are not required for existing crossings if minor changes** are proposed.
	Intermediate	• Geotechnical studies always required to support the proposed crossing structure based on slope stability assessments and structural protection proposed.	• Geotechnical studies are not required where slope height, steepness, and location criteria listed above are satisfied. • Studies are not required for existing crossings if minor changes** are proposed.
	Late	• Update geotechnical assessments if necessary based on more detailed information.	• New studies are not required when detailed analysis has been conducted at intermediate planning stages and conditions have not changed or the crossing design has not been modified. • Studies are not required for existing crossings if minor changes** are proposed.
Terrestrial Assessment	**Early**	• Desktop analysis and/or field investigation is always required to determine appropriateness of infrastructure siting / routing • Preliminary studies are always required to avoid or minimize impacts of the crossing on terrestrial habitat and connectivity.	• Studies are not required for existing crossings if minor changes** are proposed.
	Intermediate	• If no desktop analysis and/or field investigation was completed at the early stage, it must be completed at this stage • Detailed impact assessment is always required to determine crossing impact if the preferred crossing is within 120 m of a forest or a wetland (footprint impact) <u>or</u> is medium/high priority for terrestrial habitat and wildlife connectivity. • Detailed studies are always required to determine the crossing sizing and design elements to maintain and enhance terrestrial habitat and wildlife connectivity.	• Studies are not required if the crossing location is further than 120 m from a forest or wetland (i.e. no proposed footprint impact) <u>and</u> is low priority from habitat and wildlife connectivity perspectives. • Studies are not required for existing crossings if minor changes** are proposed.
	Late	• Development of plans and drawings are required to satisfy permitting requirements for crossing footprint and related impacts (e.g. erosion and sediment control, lighting, etc.). • Confirmation of sizing and ecological design elements to address terrestrial habitat and wildlife connectivity impacts.	• Studies are not required if the crossing location is further than 120 m from a forest or wetland (i.e. no proposed footprint impact) <u>and</u> is low priority from habitat and wildlife connectivity perspectives. • New studies are not required when detailed analysis has been conducted at intermediate planning stages and conditions have not changed or the crossing design has not been modified. • Studies are not required for existing crossings if minor changes** are proposed.
Aquatic Assessment	**Early**	• Desktop analysis and/or field investigation is always required to determine appropriateness of infrastructure siting / routing • Preliminary studies are always required to determine presence of fish and fish habitat and avoid or minimize impacts of the crossing on aquatic habitat and connectivity.	• Studies are not required for existing crossings if minor changes** are proposed.
	Intermediate	• If no desktop analysis and/or field investigation was completed at the early stage, it must be completed at this stage. • Detailed impact assessment is always required to determine crossing impact where there is direct fish habitat (footprint impact) <u>or</u> is medium/high priority for aquatic habitat and wildlife connectivity. • Detailed studies are always required to determine the crossing sizing and design elements to maintain and enhance aquatic habitat and wildlife connectivity.	• Studies are not required if the aquatic investigation at the early stage determined that there is no fish habitat or indirect fish habitat at the crossing. (i.e. no proposed footprint impact) <u>and</u> is low priority from habitat and wildlife connectivity perspectives. • Studies are not required for existing crossings if minor changes** are proposed.
	Late	• Development of plans and drawings are required to satisfy permitting requirements for crossing footprint and related impacts (e.g. erosion and sediment control, storm water, etc.). • Confirmation of sizing and ecological design elements to address aquatic habitat and wildlife connectivity impacts.	• Further studies are not required if the results of the aquatic investigation determine that there is no fish habitat at the crossing (i.e. headwater drainage feature (HDF) analysis determines that the management outcome for the HDF is "mitigation" [i.e. no proposed footprint impact]) and is low priority from habitat and wildlife connectivity perspectives. • Studies are not required for existing crossings if minor changes** are proposed.

*** Further details on the study requirements and technical methods are provided in other parts of Section 3 and the Appendices. **To be confirmed in consultation with TRCA staff.**

3.1 Existing Crossings

Many of the crossing submissions TRCA receives pertain to modifications, upgrades, or replacement of existing road and rail crossings. In these cases, TRCA recognizes that the location and configuration, including horizontal and vertical profiles, are already set for the existing crossing. Consequently, opportunities to fully achieve TRCA natural hazard and natural heritage objectives are constrained. In such cases, the full suite of studies that is required for new crossings (described in Section 3.2) may not be required for proposals regarding existing crossings. The following sections outline key considerations and study requirements for existing structures, including crossing replacements and extensions, based on the early, intermediate and late planning stages.

Extensions versus Replacement of Crossing Structures Considerations

For extensions of existing structures, such as often occurs when roadways are widened, TRCA strives to achieve its natural hazard and natural heritage objectives to the extent possible. If the extension of an existing crossing structure results in negative natural hazard or natural heritage outcomes, TRCA will recommend that the structure be replaced instead of extended. At a minimum, there should be no increase in flood risk as a result of the proposed extension and existing erosion should not be exacerbated. If this cannot be achieved, the structure must be replaced with one that can safely convey flood flows without increases in flood risk.

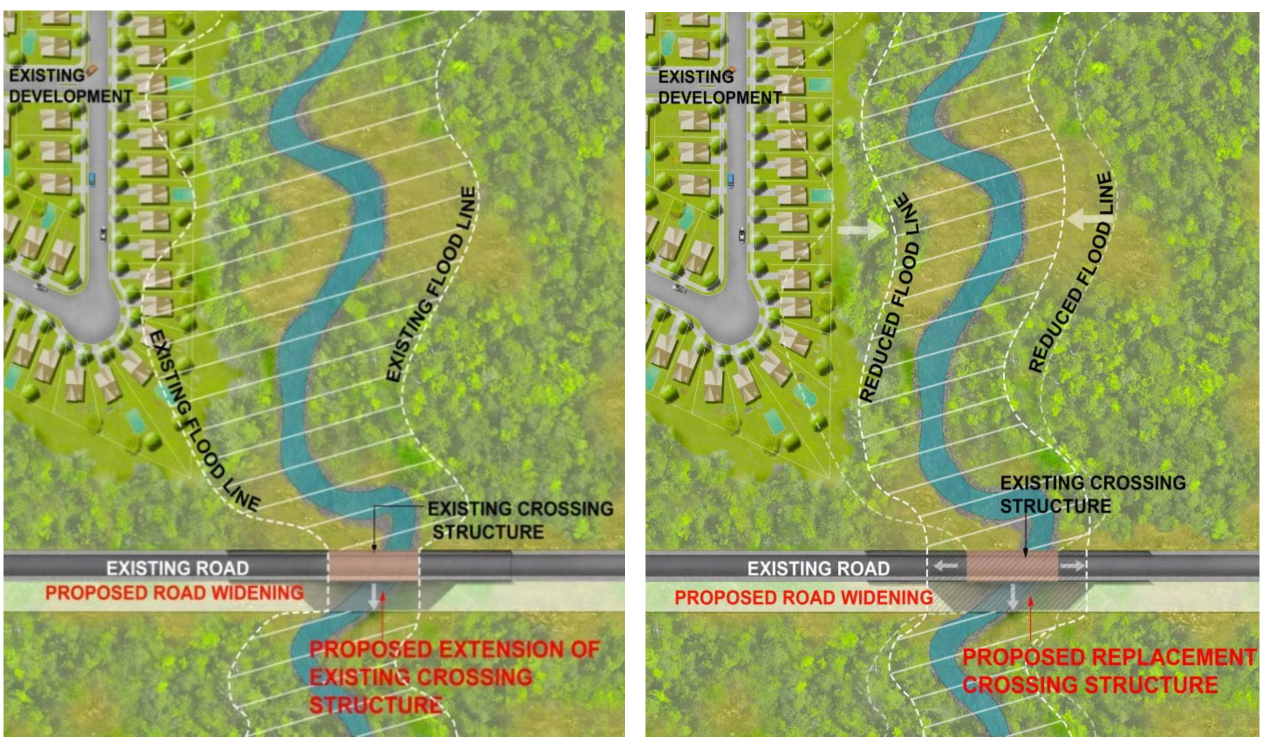


Figure 9: A replacement structure with a larger opening reduces the upstream flood hazard.

TRCA strongly recommends replacement structures where they can alleviate an existing natural hazard concern, or at minimum, recommends impact assessments be completed to identify opportunities to address these concerns (see Figure 9 above). For example, existing crossing structures may create constrictions that artificially enlarge the upstream floodplain and create unnecessary risks to property and infrastructure. The configuration of existing structures may also create frequent debris jams, which can cause unnecessary maintenance and create the potential for exacerbated upstream flooding. Channel movement and erosion since the construction of an existing structure may also present significant risks to its long-term integrity. In such cases the cost of replacing the structure may clearly be warranted given the cumulative cost of recurring problems over the long-term, as well as potential risks to life, infrastructure and property.

TRCA may also recommend replacement structures where there are opportunities to address concerns related to terrestrial and aquatic habitat and wildlife connectivity. Consideration for a replacement structure should be given where the existing structure is a barrier to terrestrial or aquatic passage and has been identified as such through existing studies (e.g. Fisheries Management Plan, habitat and wildlife connectivity studies) or through field investigations as described in study requirements sections 3.1.1 to 3.1.3 in consultation with TRCA. This is especially relevant if these issues cannot be mitigated through the crossing extension design. For example, when a crossing extension can exacerbate an existing priority fish passage issue that cannot be mitigated through existing crossing extension design (e.g., a perched culvert; see Figure 10a. below), replacement structures are needed (e.g,. embed the crossing structure below the water level; see Figure 10b.). If the culvert is already embedded, then the extension may be acceptable if mitigation measures are used (e.g., rocky ramp at downstream end; see Figure 10c.).

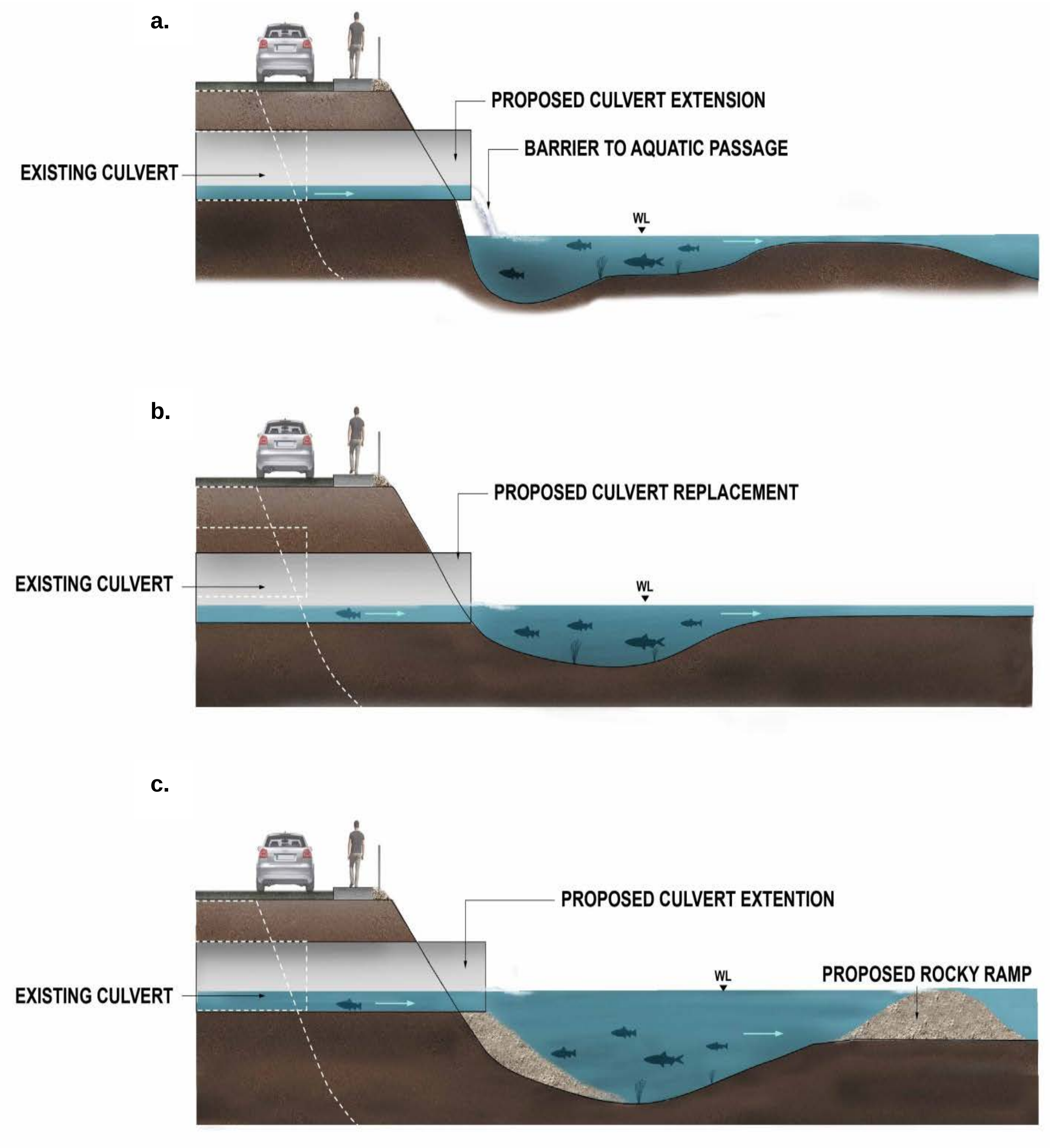


Figure 10: Crossing extensions can exacerbate existing barriers to aquatic passage (a) a perched structure (b) an embedded replacement structure (c) extension with mitigation that improves aquatic passage.

3.1.1 Study Requirements at Early Planning Stages for Existing Crossings

In most cases, submissions for replacement structures or crossing extensions are not expected to address all study requirements under Section 3.2.1 below, which describe the requirements for new crossings at the early planning stages when siting of infrastructure takes place. These are not needed as the location of the existing crossing structure is already set.

However, if major changes to the existing crossing are proposed, including profile changes or major relocation of crossing openings, the study requirements for new crossings as outlined in Section 3.2.1 must be completed in determining the new arrangement.

3.1.2 Study Requirements at Intermediate Planning Stages for Existing Crossings

In general, at intermediate planning stages, the submissions for crossing replacements or extensions will consist of Environmental Study Reports (as per the *Environmental Assessment Act*) and/or permit applications with a design brief and detailed design drawings.

3.1.2 (i) In some situations, the crossing replacement or extension is proposed to have larger or more complex replacement structures or crossing extensions where there are significant issues related to natural hazards or natural heritage functions. These include existing flooding, erosion or slope instability issues, or potential impacts on forests, wetlands, and aquatic habitat, or priority areas for habitat and wildlife connectivity as identified through the early planning stages in consultation with TRCA. In these instances, all relevant study requirements listed in Section 3.2.2 should be submitted for review to TRCA at the intermediate planning stage.

3.1.2 (ii) In other situations, the crossing replacement or extension is proposed to have only a minor change in length and/or opening size when compared to the existing structure, and where natural hazards and natural heritage functions are not likely to be of concern. These instances include where there is no existing flooding, erosion or slope instability issues, no proposed impacts on forests, wetlands, and aquatic habitat or priority areas for habitat and wildlife connectivity as identified through the early planning stages in consultation with TRCA. In these instances, the project can proceed to detailed design (i.e., permitting). Please see the late planning stages for submission requirements.

3.1.3 Study Requirements at Late Planning Stages for Existing Crossings

For existing crossing projects with complex situations as described in 3.1.2(i) above, the relevant study requirements outlined in Section 3.2.3 (for late stage, new crossings) should be followed. For existing crossings where minor changes are proposed, as described in 3.1.2(ii) above, the following information should be followed.

1. Completion of the hydraulic assessment of the existing and proposed structure as per Appendix 1A confirming the proposed structure will not result in increased flood hazards. Hydraulic calculation results, including digital and hard copies of the input and output model files (if applicable), summary table comparing the existing and proposed flood elevations

and flow velocities for the Regulatory storm event, and a technical memo outlining existing and proposed conditions assessment.

2. Confirmation that the proposed crossing footprint impacts as per Appendix 1D have been minimized.

3. Confirmation that aquatic and terrestrial connectivity priorities are considered as per Appendix 1D.

4. Key plan illustrating site location, location of watercourse, regional floodlines, and the location of the crossing.

3.2 New Crossings

The following sections outline TRCA's requirements for new road and rail crossings at the various planning stages as described in Table 1. These stages include early (e.g. Master Plan, Secondary Plans, Official Plan Amendments, etc.), intermediate (Draft Plan of Subdivision, Environmental Assessment, etc.), and late (e.g. detailed design, site plan, permitting).

3.2.1 Study Requirements at Early Planning Stages for New Crossings

This section outlines the information that must be provided to TRCA by crossing proponents at the early stages of the planning and environmental assessment processes for crossing projects. In the early planning stages, TRCA reviews and provides input to the location of crossings and evaluates the appropriateness of the alternative alignments as per natural hazard and natural heritage objectives. Proponents should meet with TRCA staff at key milestones through the existing environmental assessment and/or land use planning consultation processes (e.g. Secondary Plan commencement, terms of reference development, etc.) well in advance of any submission in order to identify pertinent issues and study requirements related to crossings. The level of detail and study required for the submission may be adjusted at this point to reflect the project scope, scale and degree of complexity. Meetings also provide an opportunity for TRCA staff to provide the proponent available data for the study area.

The following activities should be completed and documented for submission to TRCA at early planning stages (refer to Table 2 for further detail about when these studies apply):

1. **Desktop assessment** and review of existing data, to identify natural hazard and natural heritage constraints and to develop preliminary alternative crossing locations that avoid these constraints. The crossing alternatives should be selected in accordance with the objectives outlined in Section 2 and the direction provided in the appendices.

2. Identification of **data gaps**, and completion of required field investigations to gather any missing information.

3. Completion of **field reconnaissance** to determine appropriate preliminary road crossing alternatives.

4. A **preliminary hydraulic assessment** and **preliminary sizing** of the proposed crossing structure for safe flood conveyance as per Appendix 1A in consultation with TRCA and the municipality.

5. A preliminary **geomorphic assessment** determining the preferable locations based on plan form, as well as determining the meander belt width and the 100-year erosion limit as per Appendix 1B and Appendix 2A.

6. A preliminary **geotechnical assessment** to evaluate the long-term slope stability and structural protection either through the MESP or EA process to determine if there is a hazard issue as per Appendix 1C.

7. Review of preliminary ecological data and information from field reconnaissance to determine **ecological features** that constrain the location and should be avoided as per Appendix 1D.

8. A preliminary **ecological impact assessment** of the various crossing alignments on terrestrial and aquatic habitat and connectivity as per TRCA Environmental Impact Statement Guidelines and Appendix 1D. Develop a preliminary mitigation strategy to minimize or eliminate the impacts. Where residual impacts remain, there may be a need to provide compensation, which will need to be further explored at later stages.

9. If appropriate, completion of **site walks** with TRCA and municipal staff to review preliminary crossing locations and discuss preferred alternatives.

10. Completion of a **hydraulic analysis** to determine a preliminary opening size and determine implications to adjacent property owners or hazard limits for proposed developments.

11. **<u>Summarize</u>** all the preliminary assessments completed as per Appendix 1A to 1D and document the crossing locations and preliminary design in the resulting document / report as listed above. In addition, include the following:
    a) Existing flood lines (if applicable) in relation to proposed crossings and updated flood lines.
    b) Preliminary hydraulic calculation results, including digital and hard copies of the input and output model files (if applicable), summary table comparing the existing and proposed flood elevations and flow velocities for the 2-year to regional storm events, and a plan illustrating the hydraulic cross-sections used in the analysis.
    c) Plan showing meander belt width and 100-year erosion limit of watercourse in the vicinity of proposed crossing locations, including all historical watercourse alignments used in the analysis as derived from aerial photography.

d) Results from the preliminary ecological assessments for impacts as per TRCA Environmental Impact Statement Guidelines and Appendix 1D.
e) Key plan with orthophoto base illustrating the location of all natural hazard and natural heritage function constraints.
f) Plan showing identification of any sensitive features.
g) Rationale for proposed crossing locations along the valley feature and discussion of potential natural hazard risks, natural heritage function impacts and potential mitigation / restoration options.
h) Rationale for proposed crossing locations along the valley feature and discussion of potential natural hazard or natural heritage function impacts and potential mitigation/restoration options.
i) Summary of site walk observations, discussions and photos.

3.2.2 Study Requirements at Intermediate Planning Stages for New Crossings

The following outlines the information that must be provided by crossing proponents at intermediate stages of the planning and environmental assessment processes for crossing projects.

The intermediate planning stages are typically the point at which the infrastructure route is selected and alternative design concepts and their corresponding impacts are assessed. Any work done in the intermediate stages should be consistent with the directions established during the early stages. The following studies should be completed and submitted for review to TRCA at the intermediate planning stage (refer to Table 2 for further detail about when these studies apply):

1. Completion of a detailed **hydraulic assessment** as per Appendix 1A.

2. A detailed **geomorphic assessment** determining the preferred crossing locations considering channel plan form, and meander belt width, and the 100-year erosion limit as per Appendix 1B.

3. A detailed **geotechnical assessment** that evaluates the long-term slope stability at the proposed crossing location and structural protection needed as per Appendix 1C

4. A detailed **ecological assessment** of the proposed crossing impacts on terrestrial and aquatic habitat and connectivity as per TRCA *Environmental Impact Statement* Guidelines (TRCA 2007d) and Appendix 1D.

5. Development of the **concept designs** for each crossing specifying the type, length, orientation, and opening size of the crossing structure(s).

6. Ensure that concept designs have addressed TRCA's **natural hazard and natural heritage objectives** as per Section 2.

7. **Summarize** all assessments completed as per Appendix 1A through 1D and document the resulting studies, concept designs, drawing, plans/figures and calculations. In addition, include the following:
   i. Key plan illustrating site location, location of watercourse, regional flood lines, and the location of the proposed crossing.
   ii. Updated hydraulic analysis and associated plans based on the crossing needs of all other natural hazard and natural heritage function constraints, including any changes to the preliminary structure size.
   iii. Geomorphic analysis results, if applicable, including a plan illustrating the delineated meander belt width and/or 100-year erosion limit, and plan(s) summarizing historic information used in 100-year erosion limit analysis.
   iv. Geotechnical report based on borehole data at the crossing location to support the crossing structure size and type, including slope stability analysis, footings and pier foundation and location, where necessary.
   v. More detailed ecological assessment based on the results of the EIS (as per TRCA 2007d) completed during the early stage, (or completion of impact assessment if one was not completed previously), as well as Appendix 1D.
   vi. Confirmation that the crossing structure type, preliminary crossing sizing and design elements are appropriate based on terrestrial and aquatic functions.
   vii. Concept drawings illustrating the proposed preliminary configuration of the structure in plan, profile and cross-section.
   viii. Complete Table 9 of Appendix 3 to integrate the sizing and design criteria that satisfy the various TRCA crossing objectives outlined in Section 2 (including consideration for other agency requirements as per Section 3.3) into an overall conceptual design.

3.2.3 Study Criteria Requirements at Late Planning Stages for New Crossings

The following outlines the information that must be provided by crossing proponents at late planning stages of the planning and environmental assessment processes for crossing projects.

These late planning stages typically entail the review of detailed design drawings that demonstrate adequate avoidance and mitigation of impacts. Any recommendations made at the early and intermediate stages should be carried forward and be addressed at this stage.

If the permit application and supporting documentation are submitted for a land development project without a previously approved draft plan of subdivision, or if there are significant design changes, or if the draft plan of subdivision and supporting material do not adequately address submission requirements listed under Sections 3.2.1 and 3.2.2 above, the items listed in the above sections must be addressed at this stage.

The following should be completed and submitted to TRCA for review at late planning stages:

1. **Refinement of conceptual design** to develop detailed designs for the proposed crossing to address natural hazard and natural heritage considerations, as per Appendix 1A through 1D.

2. How the grades for the new structure(s) will tie in with the existing valley and watercourse upstream and downstream. Construction access, temporary crossings, tree protection, landscaping, restoration and compensation, in-water works, and erosion and sediment control should all be described and finalized at this stage.

3. **Submission package** should include a Design Brief and appropriate plans/drawings that document the detailed design for the crossing and associated works resulting from the detailed design refinement as per Appendix 1A to 1D. Any changes from the concept plan should also be documented and justified. Supporting material and documentation for the submission should include:

   a) Key plan illustrating site location, location of watercourse, and location of the proposed crossing.
   b) Refined final hydraulic analysis results and plan based on detailed design. If changes are made to the configuration of the structure from the concept design, or if additional detail requires modifications to the calculations or modelling, these must be documented and reflected in the results.
   c) Upstream and downstream erosion protection measures and associated details and calculations based on the outcome of all natural hazard assessments.
   d) Detailed design and construction drawings showing the configuration of the structure in plan, profile and cross-section, indicating the crossing structure type, length, orientation, and opening size.
   e) Drawings should show the alignment of the channel, flood lines, and toe and top of valley slope. Meander belt width and/or 100-year erosion limit, should be shown if a geomorphic analysis has been conducted.
   f) Erosion and sediment control plan and report, showing location of control measures, detailed drawings for control measures, construction access, dewatering requirements (as necessary), notes on construction procedure and phasing, and notes on maintenance of control measures. Details for in-water works and "working in the dry" should also be included if applicable.
   g) Geotechnical assessment results should include the following to be submitted for review for crossings located within the TRCA Regulated Areas
      - Cross-sections of existing condition valley wall at the location of the crossing;
      - Existing and proposed grading drawings;
      - Subsurface investigation report, including level of compaction discussion, if required;
      - Hydrogeological analyses outlining groundwater issues for design and construction, including dewatering, if required;
      - Structural Drawing stamped by a Structural Engineer;
      - Slope protection and restoration measures, where necessary;
      - Slope stability assessment.
   h) Detailed plan for crossing design consistent with the recommendations outlined as per the environmental impact statement completed during earlier phases and

Appendix 1D to address crossing impacts on terrestrial and aquatic habitat and connectivity. The watershed level natural heritage priorities provided as per Appendix 2B should be referenced in the plan, if appropriate.

i) Restoration plans indicating species and quantities for trees, shrubs and seed mixes, and location, size and condition of plant material; see also TRCA's Post-Construction Restoration Guidelines (as amended from time to time).
j) Tree removal/preservation plan identifying vegetation type within the work area, location of trees to be removed and preserved, and protection measures for the remaining stand as per TRCA's Forest Edge Management Plan Guidelines (TRCA, 2004a).

3.3 Legislation and Other Considerations

In addition to TRCA's natural hazard and natural heritage requirements, there are a number of additional requirements and approvals from other agencies for which crossing decisions should have regard. Some of these legislative requirements as well as other considerations are outlined below; however, this is not an exhaustive list. It is the responsibility of the proponent to ensure that all necessary consultations are figured into the planning and design of a crossing project and that approvals are completed prior to construction.

3.3.1 Legislation

3.3.1.1 Navigation Protection Act

As per the federal *Navigation Protection Act*, crossings must maintain navigability of designated rivers/streams and may require Transport Canada approval in this regard.

3.3.1.2 Endangered Species Act, Species at Risk Act, and Fisheries Act

The Ontario Ministry of Natural Resources and Forestry (MNRF) enforces regulations of the *Endangered Species Act* that could have implications on the siting, sizing and design of crossing structures. The proponent should contact MNRF Aurora District for further information.

The federal *Species at Risk Act* and *Fisheries Act* have regulations that could also have implications on siting, sizing and design of crossing structures. The proponent should contact Fisheries and Oceans Canada (DFO) for further information.

3.3.1.3 The Greenbelt Act, Oak Ridges Moraine Conservation Act, and the Niagara Escarpment Planning and Development Act

Provincial Plans under the *Greenbelt Act,* the *Oak Ridges Moraine Conservation Act,* and the *Niagara Escarpment Planning and Development Act* may have implications on the siting and design of the crossing structures. The proponent should consult with the municipality and TRCA staff for further information.

3.3.2 Other Considerations

3.3.2.1 Recreation and Trails

Accommodation of multi-use pathways and recreational trails may be required underneath crossings in order to meet the objectives of municipalities or of TRCA (if owned or managed by TRCA). These objectives may be articulated in open space and trail master plans or other trail planning documents. Where trails exist, or are contemplated, the crossing structure should be designed in such a way to ensure the following:

1. Aesthetically pleasing and functional pedestrian and/or bicycle passage.
2. Protection of users from natural hazards.
3. Functional separation of human use areas from those designed for animal passage where target species are sensitive to human presence.

Trails are often routed through valleys to connect neighbourhoods and have to cross perpendicular to the valley and watercourse, thus requiring a crossing structure. Trails are routed through valleys to provide public recreation opportunities. The direct public safety risks and economic consequences associated with the impacts of flooding and erosion on recreational trails are lower than those associated with road and rail crossings. For this reason, TRCA's trail requirements will typically be less stringent than those required for road or rail crossings. However, proponents are encouraged to apply the same principles of natural hazard risk management in trail crossing design as for road and rail crossings.

With respect to the protection of natural heritage function, recreational trails are less likely to be associated with road mortality for terrestrial wildlife. Trails can typically be routed away from sensitive habitats. However, if the trails are of high use, crossings may still act as movement barriers for wildlife species that are sensitive to human presence. In such cases, careful crossing design elements that maintain some form of functional separation (may or may not be physical) between wildlife and human use along with trail maintenance measures need to be considered to maintain terrestrial functions. In support of aquatic systems connectivity, it is critical to address aquatic systems protection in recreational trail crossing design. The specific design criteria for trails and trail crossings will be provided in TRCA's *Trail Strategy* (under development) and/or through design development with municipal trail planners.

3.3.2.2 Driver Safety

Consideration for avoiding wildlife-vehicle collisions for the purposes of driver safety is recommended. The proponent should consult with the municipality or with other relevant organizations to identify known collision hotspots and driver safety concern areas.

3.3.2.3 Utilities

There may be existing utilities that could be affected by crossing construction that should be considered. The proponent should consult with utilities companies as necessary.

REFERENCES

Barrueto, M., A. T. Ford, and A. P. Clevenger. 2014. Anthropogenic effects on activity patterns of wildlife at crossing structures. Ecosphere 5.

Brown, C., A. Hardy, J. Barber, K. Fristrup, K. Crooks, and L. Angeloni. 2012. The effect of human activities and their associated noise on ungulate behavior. PLoS One 7(7):e40505.

Clevenger, A.P. and M.P. Huijser. 2011. Wildlife Crossing Structure handbook Design and Evaluation in North America. Federal Highway Administration Planning, Environment and Reality, Washington D.C.

Hamer, A. J., and M. J. McDonnell. 2008. Amphibian ecology and conservation in the urbanising world: A review. Biological Conservation 141:2432–2449.

Hansen, A. J., N. Piekielek, C. Davis, J. Haas, D. Theobald, J. Gross, W. Monahan, and S. Running. *In press*. Exposure of US National Parks to land use and climate change 1900-2100. Ecological Applications.

Kintsch, J. A., and P. Cramer. 2011. Permeability of Existing Structures for Terrestrial Wildlife: A Passage Assessment System. p.188. Transportation Research.

MassDOT. 2010. Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams, Massachusetts Department of Transportation.

McKinney, M.L., 2006. Urbanization as a major cause of biotic homogenization. Biological Conservation 127, 247–260.

Ministry of Municipal Affairs and Housing. 2014. Provincial Policy Statement 2014.

Ministry of Natural Resources.1998. Geotechnical Principles for Stable Slopes, by Terraprobe.

Ministry of Natural Resources Ontario. 2002. Technical Guide River & Stream Systems: Erosion Hazard Limits.

Ministry of Natural Resources Ontario. 2002. Technical Guide River & Stream Systems: Flooding Hazard Limit

Ministry of Transportation Ontario. 2008. MTO Highway Drainage Design Standards. Available in digital format through the MTO Online Library Catalogue.

Ministry of Natural Resources Ontario. 2010. Natural Heritage Reference Manual for Natural Heritage Policies of the Provincial Policy Statement, 2005. Second Edition. Toronto: Queen’s Printer for Ontario. 248 pp.

Ministry of Transportation Ontario. 1997. MTO Drainage Management Manual. Available in digital format through the MTO Online Library Catalogue.

Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Nilon, C.H., Pouyat, R.V., Zipperer, W.C., Costanza, R., 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. Annual Review of Ecology and Systematics 32, 127–157

Taylor, A., and R. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Eco- logical Applications 13:951–963.

Toronto and Region Conservation Authority. 2004a. Forest Edge Management Plan Guidelines.* (In TRCA Planning and Development Procedural Manual)

Toronto and Region Conservation Authority. 2004b. TRCA Belt Width Delineation Procedures. Prepared by Parish Geomorphic Ltd., September 27, 2001 (revised January 30, 2004). http://sustainabletechnologies.ca/wp/wp-content/uploads/2013/01/Belt-Width-Delineation-Procedures.pdf

Greater Golden Horseshoe Conservation Authorities. 2006. Erosion and Sediment Control Guidelines for Urban Construction. (In TRCA Planning and Development Procedural Manual)

Toronto and Region Conservation Authority. 2007a. Terrestrial Natural Heritage System Strategy.

Toronto and Region Conservation Authority. 2007b. Geotechnical Engineering Design and Submission Requirements.* (In TRCA Planning and Development Procedural Manual)

Toronto and Region Conservation Authority. 2007c. Channel Modification Design and Submission Requirements.* (In TRCA Planning and Development Procedural Manual)

Toronto and Region Conservation Authority. 2007d. TRCA Environmental Impact Statement Guidelines.* (In TRCA Planning and Procedural Manual)

Toronto and Region Conservation Authority. 2014. The Living City Policies for Planning and Development in the Watersheds of the Toronto and Region Conservation Authority.

Toronto and Region Conservation Authority and Credit Valley Conservation. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guidelines.

Toronto and Region Conservation Authority. 2014. Crossings Guideline for Valley and Stream Corridors: Natural Heritage Functions Requirements, A Technical Summary.

Toronto and Region Conservation Authority. Post-Construction Restoration Guidelines.* (In TRCA Planning and Development Procedural Manual)

Van der Ree and Van der Grift. 2015. Recreational co-use of wildlife crossing structures. In Handbook of Road Ecology. Eds R. van der Ree and D.J. Smith and C. Grilo. Wiley Blackwell.

*as amended from time to time

Appendix 1: Detailed Study Requirements at Early, Intermediate, and Late Planning Stages

Appendix 1.A: Flooding Hazards

For all new and existing valley and stream corridor crossings, hydraulic analysis is required to ensure that all flood hazard objectives are met as per Section 2.1.1.

The proponent must complete a hydraulic analysis to determine the appropriate design storm and peak flow rate associated with the watercourse at the proposed crossing location based on proposed development conditions. The analysis should be accompanied by discussions with TRCA, the local or regional municipality, or the Ministry of Transportation where applicable. The proposed crossing must be sized to convey the appropriate peak flow rate without increasing flood elevations for the 2 to 100 and Regional storm events in the vicinity of the crossing. All hydraulic analyses must be prepared by a professional engineer or professional geoscientist qualified to practice in the area of hydraulic analysis.

There are various techniques including spreadsheets and computer models to complete a hydraulic analysis. For all defined watercourses (floodplains), TRCA requires that a HEC-RAS analysis be completed and floodline mapping be updated to TRCA's standards. Where available, an original copy of the existing conditions hydrologic and hydraulic models and floodline mapping can be obtained from TRCA staff. Where an existing HEC-RAS model exists, the existing modeling should be updated to the more detailed base mapping used as part of the study. If a model does not exist, HEC-RAS model should be prepared for the watercourse to an appropriate distance for any changes in the proposed condition.

<u>Study Components for Early Planning Stages</u>

1. Determination of existing floodline mapping and hydrologic and hydraulic modeling for the proposed crossing. Note that flow information should be obtained from TRCA, which should be based on current and future land uses.
2. Review of existing hydraulic models and development of new hydraulic models, as required in consultation with TRCA and the municipality.
3. Identification of flood hazards at the preferred crossing location using existing floodplain mapping and modeling. Update the models, as necessary to reflect more detailed topographical and flow data.
4. Establishment of flood design criteria required for each new crossings in consultation with TRCA and the municipality.
5. If preliminary sizing is necessary at this stage then completion of a high-level hydraulic modeling exercise using the HEC-RAS model to determine flood impacts and preliminary structure sizes.

<u>Study Components for Intermediate Planning Stages</u>

1. For all defined watercourses (floodplains), completion of detailed hydraulic assessments using the HEC-RAS model. Update floodline mapping to TRCA's standards to determine appropriate design storm and peak flow rate associated with the watercourse at the proposed crossing location based on future land use conditions.

2. Determination of sizing for the proposed crossing to convey the appropriate peak flow rate without increasing flood elevations for the 2 to 100 and Regional storm events.
3. Confirmation of flood hazard at the preferred crossing location using existing floodplain mapping and modeling, and update the models, as necessary to reflect more detailed topographical and flow data.

Study Components for Late Planning Stages

1. Refinement of the hydraulic analyses based on the detailed design to ensure flooding objectives is met with regard to future land use changes.
2. Update of the TRCA floodline mapping based on the detailed design.

Appendix 1.B: Geomorphic Hazards

For all new valley and stream corridor crossings or for significant modifications to existing crossings, a geomorphic study is required to confirm that all geomorphic hazard management objectives are adequately addressed as per Section 2.1.2. In these cases, proponents must conduct meander belt and erosion rate analyses to assess the risk associated with migration of the watercourse channel across the floodplain and the potential for future destructive contact between the channel and road infrastructure. Crossings of very small rural watercourses that are vegetation controlled and are not subject to cross-corridor migration (typically those with less than one square kilometer (100 hectares) of upstream drainage area) are exempt from this requirement. All geomorphic analyses must be prepared by a professional engineer or professional geoscientist qualified to practice in the area of fluvial geomorphology.

The results of geomorphic analyses should be used by the proponent in the selection of locations for crossings and in the design of both new and replacement crossings in order to address channel migration risks. The determination of acceptable risk is the responsibility of the proponent and the municipal infrastructure owner, and should be made in consultation with qualified consultants and discussion with public agencies. However, TRCA strongly recommends that proponents consider the additional risk associated with large, rapidly eroding or unstable watercourses and apply a more precautionary approach to crossing siting and design (refer to Table 3). In particular, it is recommended that crossing structure openings in these circumstances span the watercourse meander belt (Figure 11a), where possible, and at a minimum, span the 100-year erosion limit of the watercourse (Figure 11b) in order to minimize the risk of channel contact with abutments, footings and fill slopes.

For small and stable watercourses, other alternatives exist for proponents to manage these risks including a combination of crossing opening configuration and erosion protection in anticipation of channel migration (Figure 11c, “geomorphic design” in Table 3). Alternatively, the channel could be realigned to create a stable, naturalized alignment that will not result in contact between the channel and road infrastructure over the life of the crossing (Figure 11d).

In all cases, scour and erosion protection should be provided for structural components as described in the following section on geotechnical hazards, taking into account the insights provided by the geomorphic analysis on the likelihood of contact between the channel and infrastructure over time. Scour and erosion protection is particularly important where structural components are located within the meander belt of the watercourse.

Table 3: Summary of geomorphic recommendations for existing and new crossings

	Geomorphic Preference	Existing Crossings	New Crossings
Large, rapidly eroding, or unstable watercourses*	*Most Preferred*	Meander belt	Meander belt
	Preferred	100-year erosion limit	100-year erosion limit
	Less Preferred	Geomorphic design**	---
	Not Recommended	Realignment**	Geomorphic design** or Realignment**
Small, stable watercourses*	*Most Preferred*	Meander belt	Meander belt
	Preferred	100-year erosion limit	100-year erosion limit
	Less Preferred	Geomorphic design** or Realignment**	Geomorphic design** or Realignment**
	Not Recommended	---	---

* "Large" watercourses are those with drainage areas greater than 25 km^2; "small" watercourses are those with drainage areas between 1 km^2 to 25 km^2
"Rapidly eroding" watercourses are those with annual rates of lateral erosion greater than 5% of their channel width
"Unstable" watercourses are those with a catchment area greater than 5 km^2 with more than 25% urban land uses, either current or as proposed in municipal plans
**These options are less preferred as they increase the risk that the channel will come into contact with the infrastructure, increase the likelihood of maintenance, decrease the long-term structural stability of the crossing, and can lead to aquatic habitat degradation. In all cases, erosion protection should be provided for abutments, footings and piers.

Study Components for Early Planning Stages

1. Analysis of historic and potential future channel movement to assist in identifying crossing locations with lower channel migration risk (for new crossings):
    a. Assessment of historic migration rates through analysis of air photos and other historic information.
    b. Field assessment of current watercourse channel and floodplain condition in the vicinity of potential watercourse crossing locations.
2. Preliminary assessment of the meander belt width in the subject reach(es) per *TRCA Belt Width Delineation Procedures* (TRCA, 2004b).
3. Preliminary calculation of the 100-year erosion limit (Appendix 2A) in the vicinity of the existing/preferred crossing location or alternative crossing locations, if this level of detail is appropriate to the planning study.

Study Components for Intermediate Planning Stages

1. Accurate meander belt width delineation for the subject reach per *TRCA Belt Width Delineation Procedures* (TRCA, 2004b).

2. Detailed calculations of the 100-year erosion limit (Appendix 2A) at the proposed or existing crossing location.
3. Determination of crossing opening span and alignment based on the meander belt, 100-year erosion limit and additional information as appropriate to the channel and watershed context per Table 3, if appropriate to the planning study.
4. Location and specification of erosion protection measures for structural components of the crossing infrastructure, if appropriate to the planning study.
5. Channel realignment design, if proposed and appropriate to the planning study, in accordance with TRCA's *Channel Modification Design and Submission Requirements Checklist* (as amended from time to time)

Study Components for Late Planning Stages

1. Accurate meander belt width delineation for the subject reach(es), if not previously completed at intermediate planning stages.
2. Detailed calculation of the 100-year erosion limit, if not previously completed at intermediate planning stages.
3. Details of crossing span and alignment, if modified from intermediate planning stages
4. Location and specification of erosion protection measures, if modified or refined from intermediate planning stages.
5. Channel realignment design, if modified or refined from intermediate planning stages

Additional Requirements

1. All comparative analysis of air photos and maps should be performed using GIS or CAD software. All air photos, maps and surveys should be registered to a common base map and corrected for distortion if necessary.
2. Proponents should consult with TRCA prior to submission of reports and permit applications to present the results of geomorphic analyses and to demonstrate how the crossing design is appropriate given the risks associated with channel migration and erosion.
3. For crossings with an opening span smaller than the meander belt, submission documents should clearly acknowledge that the proponent understands and accepts potential risks associated with channel migration and erosion.
4. In instances where an intermediary is constructing crossing infrastructure on behalf of the ultimate owner, the ultimate owner must participate in consultations and be signatory to documents acknowledging acceptance of risk.

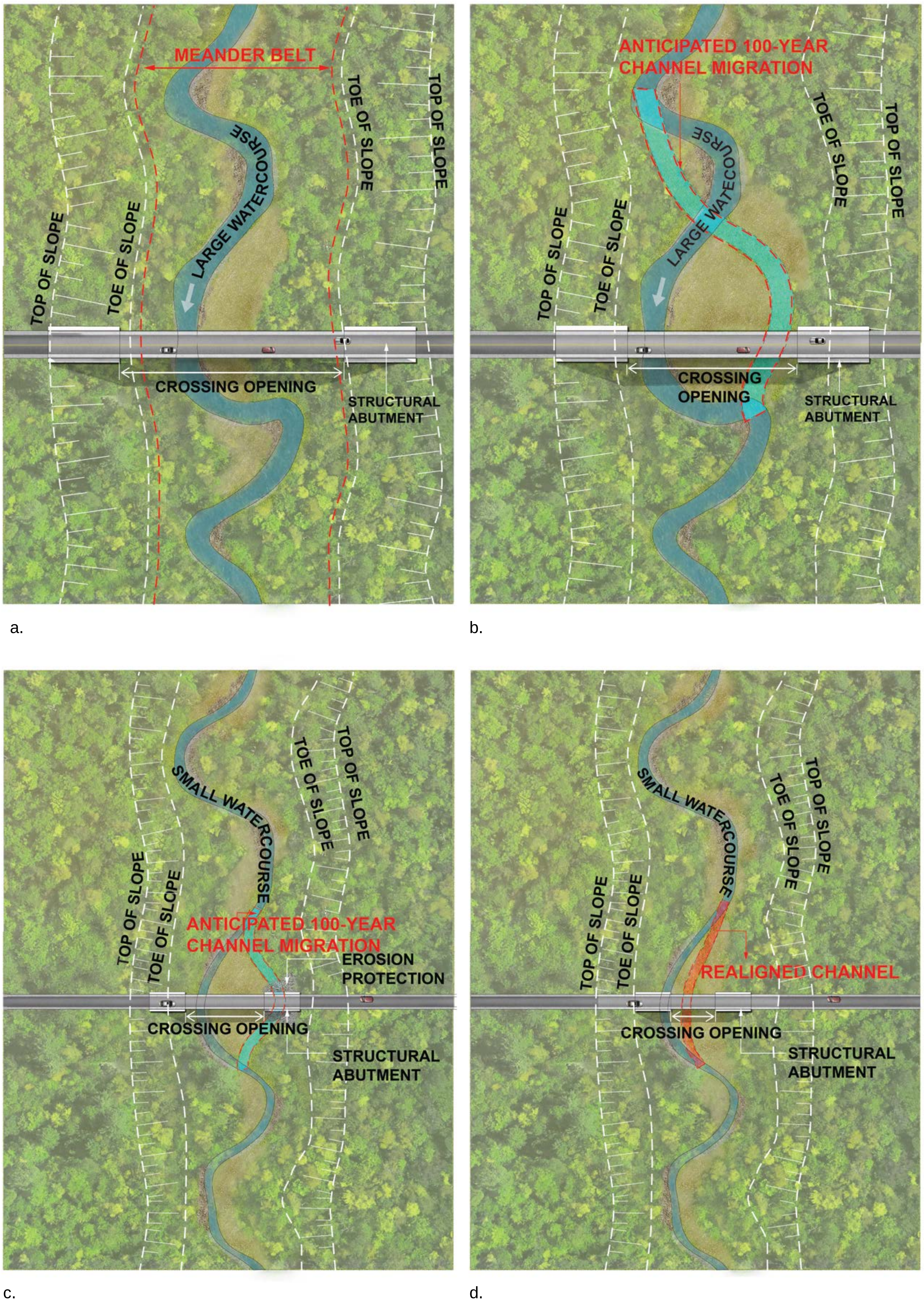


Figure 11: The four potential options* to address the geomorphic hazard ; (a) Meander belt involves locating infrastructure outside of the meander belt and protecting it from erosion, (b) 100-year erosion limit involves locating infrastructure outside the 100-year erosion limit and protecting it from erosion, (c) Geomorphic design involves locating infrastructure as far from hazards as possible based on recommendations made in a geomorphic study, and (d) Realignment involves realigning the watercourse to reduce the erosion hazard to infrastructure.

<u>**Note**</u>: These options must be considered in the context of what is described in Table 3 and its notes, and the complete review of natural hazard and natural heritage functions for crossings, in accordance with the entire Guideline as well as other considerations/legislation as per Section 3.3.

Appendix 1.C: Geotechnical Hazards

For all new and existing valley and stream corridor crossings, geotechnical analysis is required to ensure that geotechnical objectives, including slope stability and structural protection, are met as per Section 2.1.1. TRCA requires that any proposed valley and stream corridor crossing structures be certified by a structural engineer for structural integrity during normal loading conditions and for hydrostatic forces during a flood; and further, that a comprehensive Geotechnical Report, prepared by a qualified geotechnical engineer, is submitted to support the proposed crossing design.

Construction of road and rail infrastructure on or near slopes in valleys and watercourse corridors requires careful siting and design as valley walls are often unstable and actively eroding, or will experience instability and erosion at some point in the future. In keeping with its regulatory mandate to ensure that erosion hazards are addressed, TRCA reviews analyses in support of proposed crossings related to slope stability as well as structural protection. TRCA recognizes that structural designs for bridges are guided by several documents, including the Canadian Highway Bridge Design Code. TRCA defers the majority of design review to bridge proponents, and reviews to ensure that appropriate geotechnical analyses have been completed and that issues related to erosion hazards have been addressed.

Prior to selecting a bridge location where abutments are required on valley walls, it must be ensured that the loads applied from abutments into the valley slope do not undermine valley slope stability. It must also be ensured that structural failure or excessive settlements do not occur, causing adverse effect to surrounding slope areas. Where the valley slope is altered due to new crossings, the stable valley slope must be designed with a minimum factor of safety of 1.5. If retaining wall abutments are to be used, bearing capacity and sliding resistance of the foundation materials and overturning stability should be confirmed. For retaining walls close to the slope, the global stability should also be checked to ensure the retaining wall is not undermined by potential deep-seated sliding. Any overburden fill placed on the valley wall or the retaining wall abutment should be analyzed to ensure that the factor of safety for the valley slope remains within the acceptable factor of safety. In general, TRCA further requests that embankment slopes be designed to ensure public safety while minimizing the project's footprint and resultant ecological impact to the valley corridor.

To ensure structural protection, bridge foundations for new bridges should be designed to incorporate erosion measures that can withstand the effects of scour caused by hydraulic conditions from floods. When considering the scour assessment, designers should review the (i) performance of existing or nearby structures on the same watercourse during past floods, if applicable, (ii) results of geomorphic analyses, as discussed in the previous section, (iii) effects of regulation and control of flood discharges by upstream control structures, and (iv) soil susceptibility to erosion through appropriate field and/or laboratory analyses.

For piers and abutments proposed as part of a bridge design, TRCA recommends that in all cases, it is highly desirable to keep them out of the watercourse, as described in the Appendix 1B. If these structures are necessary within the meander belt of the watercourse, their foundations should be designed assuming they will be in contact with the watercourse channel in future, taking into consideration the base elevation of the channel and an allowance for channel downcutting over time. The sound foundation should be designed based on subsurface investigation, confirming that the depth of foundation embedment is sufficient. Piers should be aligned with the direction of flood flows. Further, the hydraulic advantages of circular piers should be considered, particularly where flood patterns are complex and change with flood stage. Piers should be streamlined to decrease scour and minimize potential for buildup of ice and debris. Ice and debris deflectors are recommended to be incorporated where appropriate. Slope remediation should be provided as necessary to ensure restored slope stability and erosion protection.

It should be noted that geotechnical considerations could have implications on natural heritage impacts of crossings, and vice versa. For example, it may be optimum from a geotechnical perspective to reduce slope steepness on embankments and earth fill, but this generally results in a larger project footprint, potentially affecting adjacent natural heritage features and functions. Geotechnical and natural heritage analyses in support of crossings should be integrated to find a balance between the objectives for these two areas of study.

<u>Study Components for Early Planning Stages</u>

1. Determination of physical / valley form constraints (i.e. steep slopes, and where watercourse is coincident with the toe of slope) for crossing locations, based on existing borehole information, existing slope or erosion problem areas, aerial photos and topographical.
2. Completion of preliminary geotechnical assessments if the slope is steeper than 3:1 and/or >2m high and/or is coincident with toe of slope and unstable soils (assessed visually on site)
3. Completion of a long term stable slope assessment to determine if there is a hazard issue as per TRCA's *Geotechnical Engineering Design and Submission Requirements* (TRCA 2007b) and MNR (1998).
4. TRCA review of analyses in support of proposed crossings related to slope stability and structural protection (including erosion, scouring effects, location of piers and abutments).

<u>Study Component for Intermediate Planning Stages</u>

1. Completion of the detailed geotechnical assessments to ensure slope stability and structural protection based on assessment of borehole data and other relevant information at the crossing location.
2. Provision of conceptual slope remediation, as necessary, to ensure restored slope stability and erosion protection.
3. Design the foundations for new bridges to incorporate erosion measures that can withstand the effects of scour caused by hydraulic conditions from floods.
4. Completion of the detailed geotechnical assessment to ensure structural protection from the effects of scouring. For extensive analysis on scouring refer to *MTO Drainage Management*

Manual (MTO, 1997) and the *MTO Highway Drainage Design Standards* (MTO, 2008). In addition, incorporation of the input from professionals with expertise in fluvial geomorphology and water resources engineering to ensure that foundations are protected from scour and channel migration over the life of the crossing.

5. Confirmation that the design of piers and abutments has sufficient depth of foundation embedment and adequate structural protection based on subsurface investigations if the piers and abutments are within the meander belt.

Study Component for Late Planning Stage

1. Update to the geotechnical assessment may be required if modified or refined from the intermediate planning stage.
2. Location and specification of erosion protection measures, if modified or refined from intermediate planning stages.
3. Completion of the detailed slope remediation plans, if applicable, indicating species and quantities for trees, shrubs and seed mixes, and location, size and condition of plant material. Refer to TRCA's *Post-Construction Restoration Guidelines* (as amended from time to time).

Additional Requirements

1. Certification of the proposed crossing structure by a structural engineer for structural integrity during normal loading conditions and for hydrostatic forces during a flood.
2. A comprehensive Geotechnical Report prepared by a qualified geotechnical engineer is submitted to support the crossing design.

Appendix 1.D: Terrestrial and Aquatic

For all new and existing valley and stream corridor crossings, ecological assessments are required to ensure that terrestrial and aquatic objectives are met as per Section 2.1.4 and 2.1.5, respectively. Proponents should complete site level ecological assessments, nested within the context of the watershed or subwatershed, to evaluate the impacts of proposed crossings on terrestrial and aquatic habitat and connectivity. The *preliminary assessment of natural heritage functions* (Appendix 2B) provides a high level watershed or subwatershed context and the *detailed assessment of natural heritage functions* (Appendix 2C) provide guidance on completing the more detailed site-level assessments.

Preliminary assessments and field work are required to identify key features and sensitivities when determining proposed road and rail alignments. If the preliminary assessment determines that the proposed alignment is at a sufficient distance from key habitats to avoid crossings footprint impacts on habitat, and the connectivity priority is relatively low in the proposed crossing location, more ecological assessments are not needed (see Table 2). Also, if the projected impacts of crossings are low such as those on low traffic and gravel/dirt roads with two lanes or less, terrestrial connectivity assessments may not be needed. However, for all other road and rail crossings, qualified ecologists should complete the ecological assessments as per Appendix 2 B and 2 C.

The results of the detailed ecological assessments should be used by the proponent to select appropriate locations for the crossings and design crossings to (i) avoid or minimize crossing footprint impacts on sensitive features as well as (ii) maintain and enhance terrestrial and aquatic habitat and connectivity. TRCA may recommend one or a combination of the three broad crossings types, Option A, B, and C based on the results of the detailed ecological assessment (as per Appendix 2 C).

Option A

TRCA strongly recommends large spanning crossing structures, Option A (e.g. single or multi-span bridges) in deep valleys identified as being high priority for both existing and future habitat and connectivity functions (Figure 12 a). This is to ensure that the habitat patches are connected and all wildlife species, including larger terrestrial species, can move through these locations. This will also ensure that the crossing structures provide the required design elements to facilitate these movements (per Appendix 2C). Finally, this may also minimize crossing footprint impacts to sensitive vegetation communities. In some instances, the vertical profile may be high enough to allow additional vegetation under the structure to be protected through provision of a wider crossing.

Option B

In shallow valleys that are still high priority for existing or potential habitat and connectivity functions, TRCA recognizes that the shallow depth of the valley may limit the connectivity function of large spanning structures as well as pose engineering constraints due to lack of adequate height. In these cases, relatively smaller but appropriately located and designed crossing structures are acceptable, which are classified as Option B. There are two types of structures under Option B. The first type, Option B.1, includes open bottom culverts with dry passage along the watercourse banks (Figure 12b). The second type, Option B.2, has additional dry passage openings elsewhere within the valley as well as dry passage along the watercourse bank, (Figure 12 c). These structures are expected to provide some level of connectivity for wildlife, provided the crossing design includes other important elements such as appropriate spacing between openings, adequate size, substrate, lighting condition, fencing considerations as outlined in Appendix 2C.

Option C
Lastly, structures such as closed bottom culverts, Option C, may be acceptable where existing and future terrestrial and aquatic ecological functionality are expected to be low and crossing design is largely driven by natural hazard and/or other considerations (Figure 12 d).

Study Components for Early Planning Stages

1. Siting of the crossing structure location to avoid or minimize crossing footprint impact on important terrestrial and aquatic natural heritage features, in consultation with TRCA and the municipality.
    a. Review of existing terrestrial and aquatic data such as Ecological Land Classification, flora, and fauna, fish and fish habitat data and priorities (refer to *Aquatic Habitat Management Plans* or *Fisheries Management Plans*, if available), and TRCA's Terrestrial Natural Heritage System Strategy as refined in Watershed Plans or approved in municipal official plans.
    b. Delineation of all watercourses, woodlands, wetlands, fish habitat, Significant Wildlife Habitat and any other natural heritage features on a map with an orthophoto base and topographical contours. Identify point data for L1-L4 flora and fauna species and provide common and scientific names. Indicate where any features are designated as provincially significant or locally significant and any sensitivities, seeps/upwelling areas, or potential restoration opportunities (e.g. barriers).
    c. Identification of the various alternative alignments on the same map, and description of the anticipated impacts associated with each alignment. Provide recommendations on the preferred alignment and justification, and provide a preliminary discussion on potential mitigation, restoration and compensation opportunities (if applicable).
2. If possible, avoid or minimize impacts at crossing locations that have been identified as high and medium priority for connectivity and require natural corridors to facilitate wildlife movement. Determine this using the *preliminary assessment of natural heritage functions* in Appendix 2B.

Study Components for Intermediate Planning Stages

1. Complete detailed crossings footprint impact assessment on terrestrial and aquatic features including a species inventory for the valley and stream corridor. TRCA's *Environmental Impact Statement Guidelines* (TRCA, 2007d) should be referred to for further guidance.
2. Confirmation on whether the following design considerations have been addressed:
   a. The crossing location is appropriate in relation to minimizing impacts to adjacent natural features.
   b. The crossing location is appropriate in relation to existing aquatic habitat features (e.g. critical spawning areas for sensitive/locally rare/indicator species)
   c. Impact mitigation, restoration, and compensation (if applicable).
3. Completion of a detailed habitat and connectivity assessment using the *detailed assessment of natural heritage functions* (Appendix 2C) to identify appropriate type, size, spacing of crossing structure(s), and other key design elements required from terrestrial and aquatic perspectives.
4. Preparation of conceptual design with location adjustments required to avoid key features. Indicate the appropriate opening size and design elements to maintain or enhance terrestrial or aquatic connectivity.

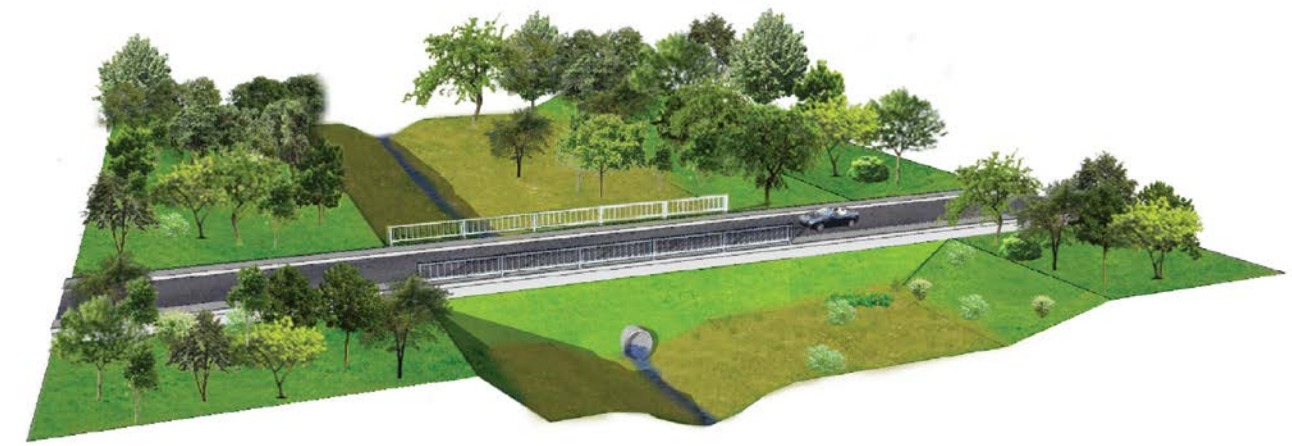
Study Components for Late Planning Stages

1. Confirm that the detailed design of the crossing minimizes the crossing footprint impact and maintains or enhances connectivity functions. Examples to minimize crossing footprint impacts include (but are not limited to) road embankment grade modifications, and co-locating proposed infrastructure and access roads.

a.

b.

c.



d.

Figure 12: Three broad crossing types referenced in the *detailed assessment of natural heritage functions*. (a) Option A: preferred in high priority locations for target natural heritage functions deep enough for large wildlife passage; (b) and (c) are two types of Option B: preferred in high priority locations for target natural heritage functions where the valley depth is shallower and smaller wildlife are targeted; and (d) Option C: acceptable in areas that have been identified as having low priority for target natural heritage functions

<u>**Note**</u>: These options must be considered in the context of the complete review of natural heritage functions <u>**and**</u> natural hazards for crossings, in accordance with the entire Guideline as well as other considerations as per Section 3.3.

Appendix 2: Technical Tools in Support of Study Requirements

Appendix 2.A: Measurement of the Lateral and Down-valley 100-year Erosion Rates

Erosion rates are measured at the two channel bends immediately upstream and two bends immediately downstream of the proposed crossing location, in both the lateral and down-valley direction (Figure 13 and Figure 14).

- Measurements of erosion rates should be based on analysis of a series of maps, air photos and survey information including current data and a minimum of 25 years of historic information.
- Migration rates should be measured at the apex and immediately downstream of the apex of the outside of all meander bends, and all measurements must account for distortion and scaling.
- Where sufficient historic data is not available in the vicinity of the crossing due to vegetation cover or past modifications to the channel, migration rates may be measured at four representative meander bends elsewhere in the watercourse within the subject reach, or like reaches upstream or downstream.
- For watercourses with channel width less than three (3) metres, it is expected that in many cases the scale of historic aerial photographs will not permit accurate delineation of the historic channel plan form. In such instances only, 100-year erosion rates in both lateral and downstream directions can be estimated using criteria outlined in Table 4 from the Ontario Ministry of Natural Resources *Natural Hazards Training Manual* (2003).
- The 100-year migration rates of the watercourse channel in the vicinity of the crossing are assumed to equal the migration rate of the bend immediately upstream of the crossing, or the average rates of the four bends measured in the analysis, whichever is greater.
- In order to assess whether channel migration will affect the proposed structure, migration rates should then be applied to the existing plan form of the watercourse in the vicinity of the crossing, such that the future location of the channel within the anticipated structure lifespan has been accounted for.
- If the planform, when extended and translated according to the calculated erosion rates falls outside of the proposed crossing structure opening, the width of the opening must be increased to accommodate the anticipated future alignment of the watercourse (Figure 8). As noted above, if the projected future planform is narrower than the crossing structure opening, a reduction in the opening size may be considered if all other requirements are met.

Note*:* The 100-year migration risk zone may be reduced if it can be demonstrated that there are topographic or geological controls (e.g. terraces, bedrock outcrops) that would preclude migration of the watercourse channel in certain areas.

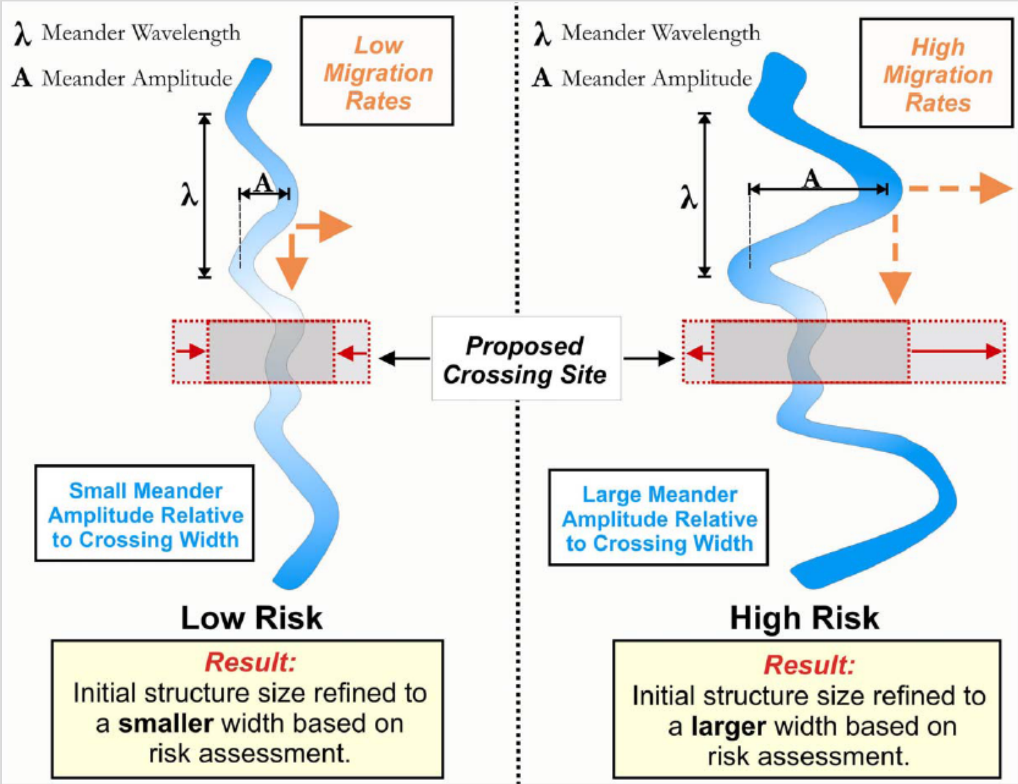


Figure 13: Geomorphic risk associated with meander amplitude and erosion rates

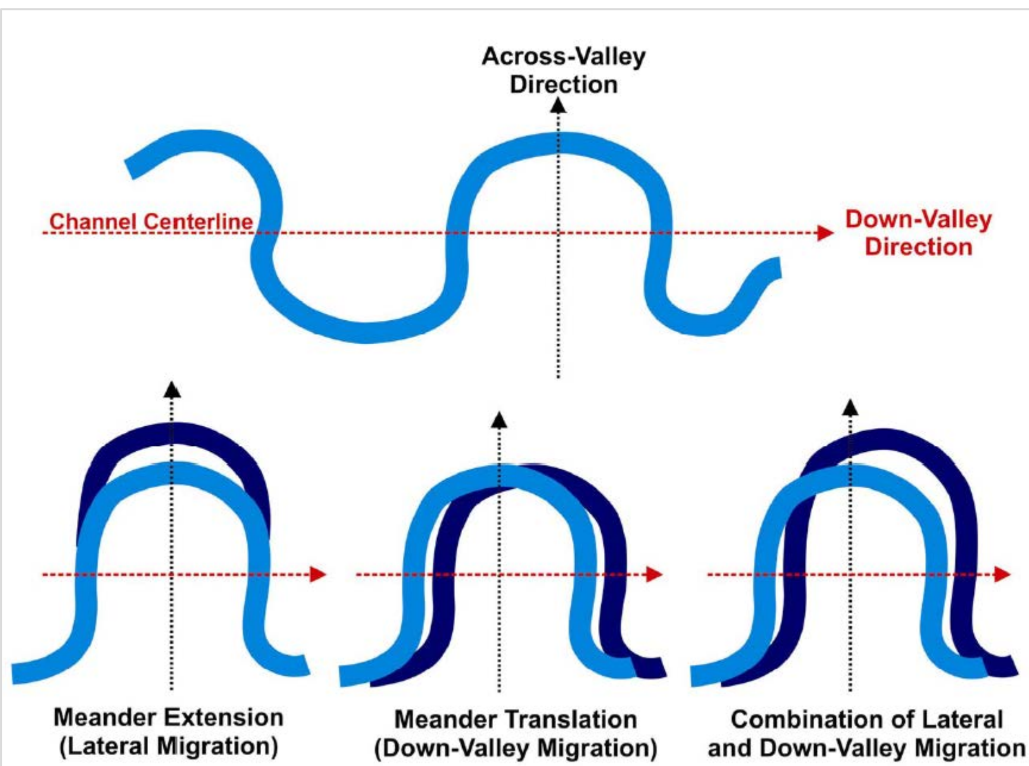


Figure 14: Lateral (extension) and down-valley (translation) channel migration

Table 4: Approximate 100-year toe erosion rates for watercourses <5 meters in width

Type of material OR Native soil OR Structure	Evidence of active erosion* OR where the bankfull flow competence exceeds the erosion threshold	No Evidence of Active Erosion
Hard Rock (e.g. granite)	0 – 2 m	0 m
Soft rock (e.g. shale, limestone), cobbles, boulders.	2 – 5 m	0 m
Clays, clay-silt, gravels	5 – 8 m	1 m
Sand, silt	8 - 15 m	1 – 2 m

**Note that Active Erosion is defined as channel banks exposed directly to stream flow under normal or flood flow conditions and/or where undercutting, oversteepening, slumping of a bank or down stream sediment loading is occurring. It is expected that the majority of watercourses with defined bed and banks will display evidence of active erosion or will have bankfull flow competence in excess of the erosion threshold. Only very small watercourses with heavily vegetated bed and banks are expected to exhibit no evidence of active erosion

Appendix 2.B: Preliminary Assessment of Natural Heritage Function

For crossing projects in the early planning stages, the *preliminary assessment of natural heritage function* is available to provide a watershed scale assessment of terrestrial and aquatic natural heritage functions. This contains a high level mapping tool that was developed using desktop analysis of existing data to highlight valley and stream corridors that are predicted to be of high, medium or low natural heritage/ecological function priority in the consideration of siting and design of crossings within TRCA's jurisdiction. It is intended to assist municipalities and other crossing proponents with understanding TRCA's terrestrial and aquatic concerns, and the associated budgetary implications for crossings, as early in the planning process as possible. It is also intended to provide a systems perspective at the watershed scale for terrestrial and aquatic habitat and connectivity.

The preliminary assessment uses a number of terrestrial and aquatic criteria to reflect the following broad natural heritage functions to be maintained and enhanced, if possible, through crossing structures:

i. Existing and potential habitat quality - avoiding further degradation / fragmentation of high quality habitat,
ii. Regional connectivity - facilitating long-term movements of local wildlife for establishing new home ranges and for gene flow, and
iii. Local connectivity - facilitating short-term movements of local wildlife to satisfy the daily and seasonal life history needs.

More details on each of these criteria are provided in the technical document *Natural Heritage Function Technical Summary* which is available on request from TRCA staff.

Based on the preliminary assessment, the mapping tool (Figure 15) depicts all valley and stream corridors within TRCA's jurisdiction as a gradient of priorities (high, medium, and low) for the crossing structures to maintain and, if possible, enhance natural heritage functions related to habitat and connectivity.

The high priority locations are in red and indicate deep valleys where there is high existing or potential habitat and connectivity functions. In these locations, larger crossing structures are beneficial as the valley depth allows for diverse wildlife species movement (including large mammals) under the structure. The medium priority locations highlighted in green also reflect relatively high habitat and connectivity functions; however, the shallow valley depth may not allow some wildlife species, especially larger mammals, to move under a crossing structure. In these cases smaller, but appropriately designed structures may be acceptable in accommodating wildlife movement. The major design element of these smaller structures is the provision of some form of dry passage as determined through the site level, detailed ecological assessment outlined in Appendix 2 C. The low priority locations in blue reflect where habitat and connectivity functions are low. In these cases, the aquatic and terrestrial concerns are low, so the crossing structure design would be largely driven by natural hazard considerations.

The *preliminary assessment of natural heritage function*s intends to inform and assist municipalities and other crossing proponents with the understanding of TRCA's terrestrial and aquatic ecology criteria, and the associated cost implications as early in the process as possible. The priorities highlighted in this preliminary assessment must be considered in the context of the complete review of natural hazard and natural heritage considerations for crossings, in accordance with this entire Guideline, as well as other considerations that are outside the purview of this Guideline as outlined in Section 3.3.

It should be noted that Figure 15 was developed using desktop information only and more detailed information will need to be collected to refine the data at the intermediate and late planning stages through completion of site level assessments, as further guided by the detailed assessment of natural heritage function in Appendix 2 C.

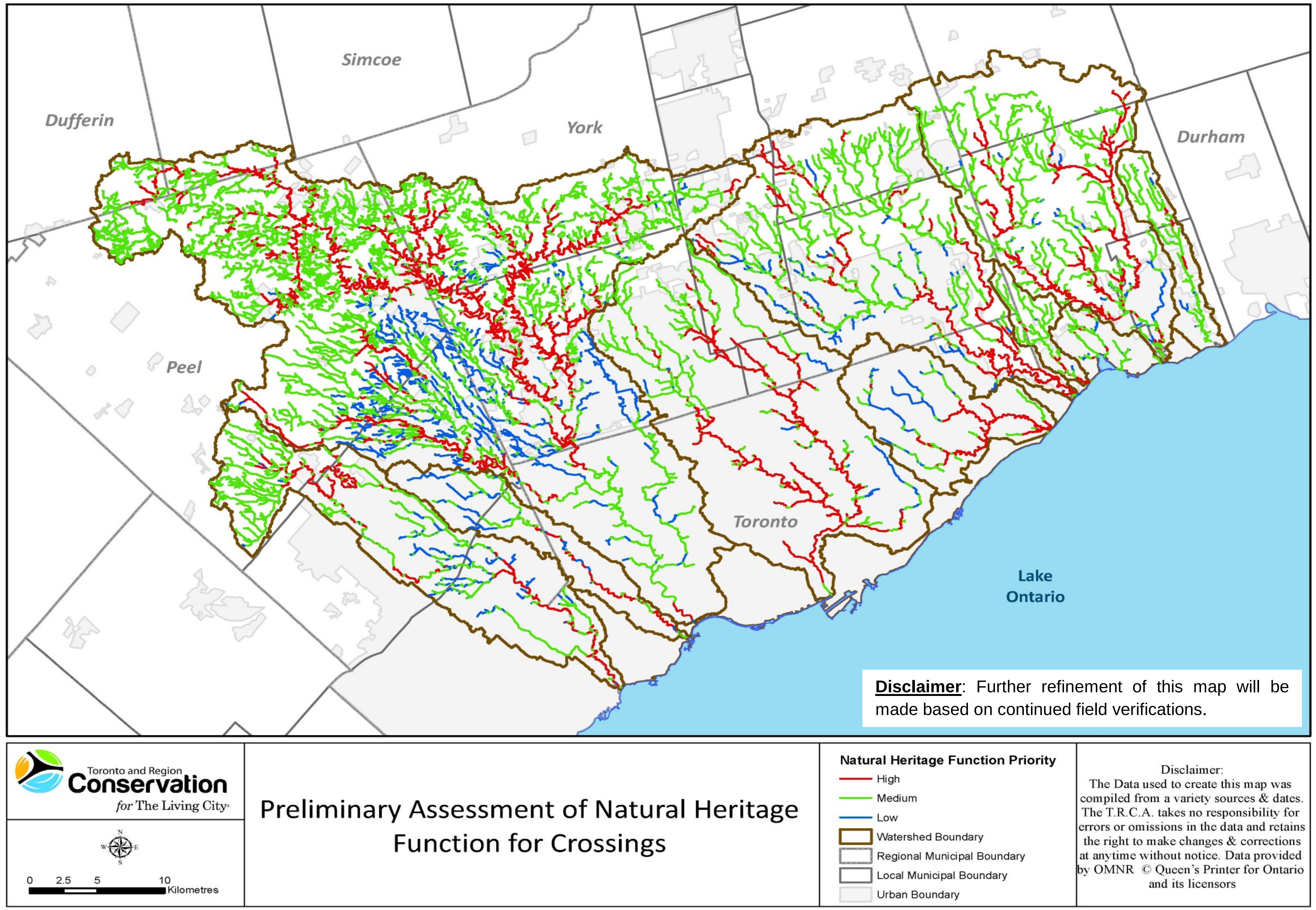


Figure 15: TRCA's *preliminary assessment of natural heritage function*s reflecting a gradient of priority for crossings (i) high (red) are deep valleys with high priority for habitat and connectivity, (ii) medium (green) are shallow valleys with high existing and potential habitat and connectivity potential, and (iii) low (blue) reflects low priority for habitat and connectivity.

__Note__: This assessment must be considered in the context of the complete review of natural hazard and natural heritage functions for crossings, in accordance with this entire Guideline, as well as the other considerations as per Section 3.3

Appendix 2.C: Detailed Assessment of Natural Heritage Function

The natural heritage function assessments at the intermediate and late planning stages are guided by the site level detailed assessment described in this section. The *detailed assessment of natural heritage function* is complemented by the preliminary assessment discussed in Appendix 2 B, which provides a watershed-level systems perspective on habitat and connectivity priorities.

This detailed assessment of natural heritage function provides a clear and consistent approach to data collection / compilation, evaluation, and classification of information. It also identifies the appropriate type, size, and spacing of openings along with other crossing structure design considerations that are important for terrestrial and aquatic ecology. The expected data collection effort recommended in this assessment is similar to what is normally collected in the existing land use planning and environmental assessment process. Also, much of the data is already available from TRCA or other agencies. This data and assessment should be compiled and completed in consultation with TRCA staff.

The guidance on the detailed assessment of natural heritage function was developed using a combination of expert knowledge and literature review of crossing impacts on terrestrial and aquatic functions, the known functions of the valley and stream corridors, and the mitigation success of different types of crossings.

The detailed assessment of natural heritage function involves a four-step process, including screening the projects; data collection/ compilation; evaluation; and classification into the broad crossings types that can maintain and, if possible, enhance terrestrial and aquatic habitat and connectivity functions. TRCA planning ecology staff are available to assist proponents through this process. An example of application of this process is presented in Box 2.

- *Step 1: Screen the types of road projects that require detailed natural heritage function analysis.*
  The first step is to screen out the proposed crossings where specialized crossing structures (e.g., bridge, eco-passage) would not add significant benefit to the ecological function at the site. An example would be where the proposed crossing is on a new or existing local, unpaved (gravel or dirt) road that has two lanes or less indicating that there is and will be a low level of risk from traffic to natural heritage functions.

- *Step 2: Compile field data to understand what is at each site for projects that require detailed analysis.*
  For all projects that are not screened out in Step 1, the next step is to compile or collect data on the presence of terrestrial and aquatic habitat and/or species that are sensitive to the road effects. These data are then evaluated in terms of habitat quality, sensitivity and habitat connectivity. In addition, relevant contextual information, such as the existing and potential upstream and downstream barriers to aquatic and terrestrial movement, the anticipated level of urbanization, the estimated traffic volume (i.e. Annual Average Daily Traffic or other

relevant traffic estimate or number of lanes), and the physical / valley form limitations are also collected and/or compiled. All of this information related to the terrestrial and aquatic functions, potential data sources, and the preferred collection protocol or method that is to be used in the detailed assessment is listed in Table 5.

- *Step 3: Evaluate what the data mean ecologically.*
  The third step involves evaluation of collected / compiled data to understand the gradient of habitat and connectivity significance. This helps to identify those areas that are relatively higher priority for crossing structures to maintain and, if possible, enhance habitat and connectivity functions through appropriate crossing design. Table 6 provides the criteria thresholds that define higher priorities for considering habitat and connectivity in crossing design.

- *Step 4: Classify the information into more specific crossing design options.*
  The final step involves the use of Flowchart 1, which provides a clear decision tree to identify appropriate crossing designs that can maintain the habitat and connectivity functions. The habitat and connectivity priority information along with the contextual information (collected / compiled in the previous steps) are input into the flow charts to determine three broad crossing designs, Options A, B, and C (Figure 14).

  1. Option A includes large spanning structures such as single or multi-span bridges that are required mostly in locations where there is (or there is potential for) high terrestrial or aquatic ecological functionality from habitat and connectivity perspectives, provided that such location has:
     - high estimated traffic volume (high risk to terrestrial movement), and
     - no or mitigable barriers to terrestrial or aquatic movement, and
     - low anticipated urbanization levels (conducive to long term sustenance of habitat and connectivity functions), and
     - valley depths with sufficient height to allow movement of diverse wildlife, including large mammals, under the structure (>4.5 meters that includes 3 meters + 1.5 meter girder height required for bridges).

     It is strongly recommended that the Option A structure design for connectivity should include various relevant measures that determine the willingness of the wildlife to pass through the structure. This includes measure of structure openness for larger mammals (e.g. some form of openness index or ratio), measure of perceived distance to safety, as well as presence of elements that allow for dry passage for wildlife. This generally means that it is important to use crossing structure measurements (length, width, height) with other structural (divided verses undivided roads) and environmental factors (habitat quality, target species etc.) when designing the crossing structures (Clevenger and Huijser 2011).

More comprehensive review of the specific crossings designs elements that should be incorporated into large spanning structures to be effective for enhancing habitat and connectivity are provided in Kintsch and Cramer (2011).

In addition, Option A may be required to minimize the crossing footprint where sensitive vegetation communities are present. Where feasible, the vertical profile should be of sufficient height so that a wider structure would help to minimize impacts to the vegetation communities below and adjacent to the crossing structure.

2. Option B includes structures that may be relatively smaller than the previous option but may achieve similar result in terms of maintaining the habitat and connectivity functions in certain cases. These include structures such as open bottom culverts with dry passage provision either alongside the watercourse or as additional openings. These are required mostly in locations where all of the Option A natural heritage functions are present but the site has either:
    - low estimated/anticipated traffic volume (low risk to terrestrial movement); or
    - existing and unmitigable barriers (to terrestrial or aquatic movement); or
    - high anticipated urbanization level (less conducive for long term sustenance of habitat and connectivity functions)
    - shallow valley depths with insufficient height to allow larger wildlife to move under the structure.

    If Flowchart 1 results in Option B, a number of additional considerations are used (Table 7) to refine the crossing design components based on the compiled data at the site. In general, Option B may be one of two types;

    (i) Option B.1 recommending dry passage only along the watercourse; or
    (ii) Option B.2 recommending dry passage along the watercourse and additional openings within the valley.

    The type of Option B is determined based on the distance between habitat patches (forests and wetlands) and/or species bisected by the road/railway. Data are compiled / collected and evaluated through the previous steps (Step 2 and 3). This information is used to categorize diverse wildlife that could be using the crossing structure into four relative mobility classes based on their movement capacity (in line with Kintsch and Cramer 2011) as shown in Table 5:

Table 5: The four mobility classes of wildlife based on the movement capacity

Mobility class	Movement capacity
Restricted	Up to 50 m
Low	51 – 500 m
Moderate	501 – 1000 m
High	More than 1000 m

If habitat patches are within the specified distance of each other across the road, it is assumed that all wildlife in the most conservative mobility class indicated in Table 5 will be using the crossing structure. For example, if the road bisects habitat patches that are within 50 m of each other, then the restricted mobility class will drive the design of the structure, assuming less restricted mobility classes will also need to be accommodated in the crossing design. If species inventory data are available, then the species specific information provided in Table 8 can be used to complement this assessment in consultation with TRCA staff.

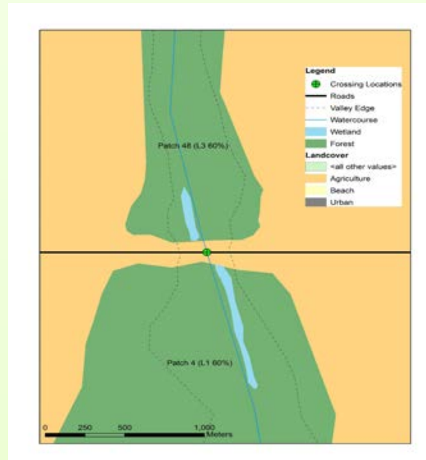
Once the most conservative mobility classes of the wildlife that are likely to be using the crossing structure is identified, this will determine the recommendation for the number and spacing of crossings. If the valley width is narrower than the movement capacity of the identified wildlife, then Option B.1 with dry passage along-side the watercourse is likely sufficient for terrestrial movement. This is because the crossing will be accessible to the wildlife with the most conservative movement capacity. However, if the valley width is wider than the movement capacity of the most restrictive wildlife, then Option B.2 with additional openings for dry passage needs to be considered; otherwise, the only crossing at the watercourse will be inaccessible to the wildlife. The recommended number of crossings and spacing between the additional openings should be based on the movement capacity of the most restrictive wildlife.

In addition, both Option B.1 and B.2 require careful consideration of other crossing design factors such as minimum size, type of substrate, lighting and moisture conditions etc., which may be critical for crossing usage by wildlife. Most of this information is listed in Table 8 (compiled from various sources referenced in Kintsch and Cramer, 2011). More comprehensive review of the specific crossings designs for different wildlife groups is provided in Kintsch and Cramer (2011).

3. Option C includes structures such as pre-fabricated closed bottom culverts that are acceptable where terrestrial and aquatic ecological functionality either are low (and likely to remain low) or are less dependent on crossing structure size.

Box 2: Example of the application of the *detailed assessment of natural heritage functions*

Route A is up for construction work including replacement of the crossing structure. In addition to the broader study requirements of TRCA *Environmental Impact Statement Guideline* (TRCA, 2007d), proponents of Route A will complete the *detailed assessment of natural heritage functions* in consultation with TRCA Planning Ecology staff to determine the crossing structure design within the valley corridor.



Step 1: Screening of the project
Route A is proposed to be a four-lane paved road with estimated Annual Average Daily Traffic of 20,000 vehicles. This suggests that Route A is not screened out in Step 1, and the proponent completes Steps 2-4 of the *detailed assessment of natural heritage functions*.

Step 2: Data compilation
Based on Table 6, the data on terrestrial functions, aquatic functions, and contextual information was compiled for the proposed crossing location. Table 6 - Column 2 provided the detailed listing of specific information to collect / compile and Column 3 provided the potential data source for the information. Pertinent data are shown in the figure above.

Step 3: Evaluation of data
The data compiled in the previous step was compared with the predefined priorities listed in Table 7 to identify whether the location was high priority for the crossing structure to maintain and, if possible, enhance habitat quality and connectivity. The priorities for the proposed crossing location are summarized below:

Terrestrial functions priority	Aquatic functions priority	Contextual information priority
1. Priority habitat quality – yes 2. Priority habitat connectivity– yes 3. Presence of sensitive fauna – no 4. Presence of sensitive vegetation – no	5. Priority habitat quality – no 6. Priority habitat connectivity– yes 7. Presence of sensitive species – no	8. High traffic impact – yes 9. No barriers are present or are mitigable – yes 10. Low urbanization – yes 11. Valley is deep and has dry passage – no

Step 4: Classification into appropriate crossing design
Flowchart 1 is used to identify the appropriate crossing design option using the results of Step 3. In this case, the recommended crossing option is Option B. Although terrestrial habitat quality is a priority, the valley is shallow with insufficient depth to allow larger wildlife to move under the structure. The broad design elements of Option B are identified using the information in Table 8 and further guidance is provided in the Option B section of *the detailed assessment of natural heritage functions* in Appendix 2.C.

1. Habitat distance data is used to identify the likely wildlife mobility class (Table 5) using the crossing structure. In this case, there are two forest and wetland patches bisected by the road that are 49 m apart. It is assumed that the most conservative, restricted mobility class of wildlife (<50 m) is able to access this habitat. Thus, the location of Option B should allow this movement to continue within the valley (Table 8).
2. The valley width at the crossing location is 100 m, which is greater than the restrictive mobility class movement capacity (50 m). Therefore, there will be a need for additional openings with maximum spacing of 50 m between them. This will ensure that all wildlife that would have access to the habitat patches will be able to access them, thus maintaining habitat and connectivity functions.
3. In addition, other design considerations including size, light, moisture, and substrate condition (Table 8) should be incorporated into the crossing design, based on the overall habitat and fauna species information, in consultation with TRCA staff.

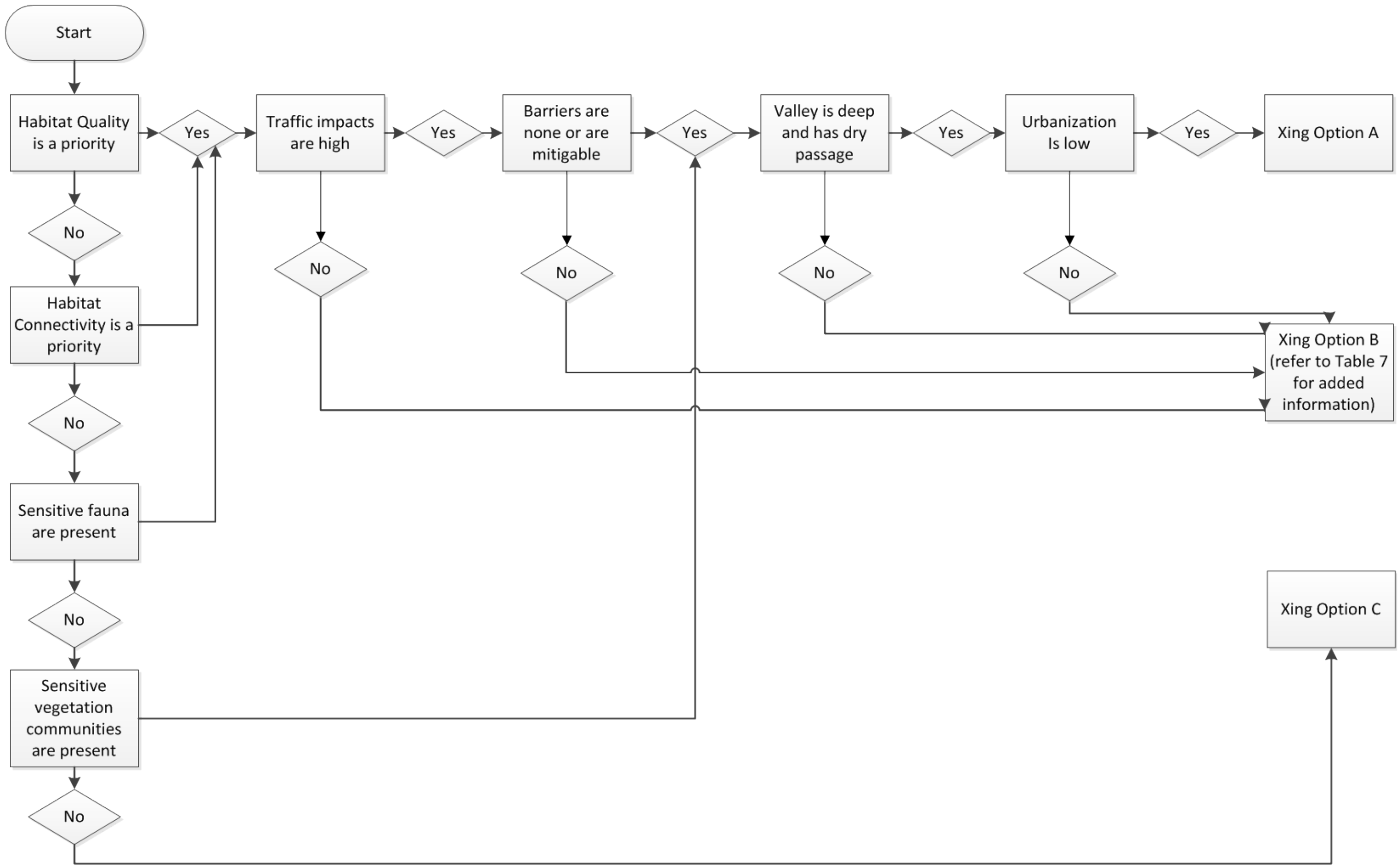
Table 6: List of terrestrial, aquatic, and contextual data to be collected / compiled for the *detailed assessment of natural heritage functions*

Terrestrial Functions / Criteria	Data collection / compilation *(TRCA should be consulted on all relevant data and use)*	Data Source *(TRCA should be consulted on all relevant sources)*	Relevant contacts and/ or collection protocol
i. Habitat quality	– Compile existing and target TNHS habitat patch quality rank – Collect or compile percent area of existing and target habitat patch within valley and stream corridors	– TRCA existing and target TNHS habitat patch L-ranks – TRCA or municipal refined existing and target TNHS (if available) – TRCA watershed scale *preliminary assessment of natural heritage functions* (Appendix 2B)	– TRCA data
ii. Habitat connectivity	– Regional and local connectivity priorities – Collect or compile habitat type (forests and wetlands) and distance between them if they are bisected by road with o field surveys if it's within 300m of the proposed road (if feasible) o orthophoto interpretation and secondary sources if it's not feasible and/or beyond 300 m	– TRCA watershed scale *preliminary assessment of natural heritage functions* (Appendix 2B) – Field collected or other secondary sources of data (including TRCA/municipal/other ELC/remotely sensed data (if available)	– TRCA data – Municipality data – Field survey
iii. Sensitive species	– Fauna presence (breeding birds and amphibians, as appropriate, and other incidental observations) – Fauna sensitivity ranks	– Field collected or TRCA/municipal/other fauna inventory data (if available) – TRCA TNHS fauna L-ranks or other relevant designations	– TRCA fauna inventory protocol – TRCA data
iv. Sensitive vegetation	– ELC vegetation communities presence – ELC vegetation community sensitivity L-ranks	– Field collected or TRCA data (if available) – TRCA TNHS ELC Vegetation Community L-ranks	– ELC protocol – TRCA data
Aquatic Functions			
v. Habitat quality	– Thermal regime – TRCA Fish Management Plan Zone priorities	– TRCA data (if available) – TRCA data (if available)	– TRCA data
vi. Habitat connectivity	– Regional connectivity priorities	– TRCA watershed scale preliminary assessment of natural heritage functions (Appendix 2B)	– TRCA data
vii. Sensitive species	– Fish presence	– Field collected, TRCA, or MNRF data (if available)	– OSAP or TRCA protocol
Contextual Information			
viii. Traffic impact	– Expected Annual Average Daily Traffic (AADT) or other relevant traffic estimate of the proposed road – Number of lanes	– Existing regional / municipal data or the project estimated number	– Municipality data / Proponent data
ix. Barriers	– Existing as well as potential upstream and downstream barriers for aquatic and terrestrial movement	– Field collected or TRCA data (if available)	– Qualitative field assessment – OSAP Module S4M11
x. Physical / valley form	– Depth – Bank-full width – Valley bottom	– Field collected	– Engineering field survey
xi. Urbanization	– Existing and future impervious percentage cover within 1km – Existing and future road density within 1km	– GIS analysis or TRCA data (if available) – GIS analysis or TRCA data (if available)	– municipal official plan data

Table 7: Terrestrial, aquatic, and contextual information priorities for *detailed assessment of natural heritage functions*. If any of these conditions are satisfied, then the associated functions or contextual information are priorities.

Priority Terrestrial Functions	**Priorities for maintaining natural heritage function through crossings design**
i. Priority Habitat Quality	– Identified as high **or** medium priority for maintaining high quality habitat patch in watershed scale *preliminary assessment of natural heritage functions* (Appendix 2B) **or** – Identified as priority for maintaining high quality habitat patch through site level assessments such as where forests or wetlands are bisected by the road
ii. Priority Habitat Connectivity	– Identified as high **or** medium priority for regional or local connectivity in the *preliminary assessment of natural heritage functions* (Appendix 2B) **or** – Presence of one or more forests bisected by the road as specified in Table 6 within the valley and stream corridor **or** – Presence of one or more forests and one or more wetlands bisected by the road as specified in Table 6 within the valley and stream corridor **or** – Presence of one or more wetlands bisected by the road as specified in Table 6 within the valley and stream corridor
iii. Sensitive Species Present	– Presence of fauna species (TRCA species of concern L1-L4) as specified in Table 6 radius of the proposed crossing location
iv. Sensitive Vegetation Communities Present	– Presence of TRCA ELC Vegetation Communities of Concern (L1-L4) within 120 m radius of the proposed crossing location
Priority Aquatic Functions	
v. Priority Habitat Quality	– Identified as high or medium priority for maintaining aquatic habitat quality in the *preliminary assessment of natural heritage functions* (Appendix 2B) **or** – Presence of cold or cool water thermal regime **or** – Presence of priority Aquatic Habitat/Fisheries Management Plan zones (if available)
vi. Priority Habitat Connectivity	– Identified as high or medium priority for regional connectivity in the *preliminary assessment of natural heritage functions* (Appendix 2B)
vii. Sensitive Species Present	– Presence of indicator species as determined by Aquatic Habitat Management Plan (if available)
Priority Contextual Information	
viii. High Expected Traffic Impact	– Greater than 1000 vehicles expected as Annual Average Daily Traffic (AADT) volume of the proposed road **or** – Greater than a two lane road
ix. No Barriers	– No existing **or** mitigable upstream **or** downstream barriers to aquatic **or** terrestrial movement
x. Deep Valleys with Dry Passage	– deep valleys (> 4.5 m) **and** – dry passage is possible (i.e. valley bottom width > bank-full width or as assessed by the ecologist) *[NB: additional dry passage structures are not possible when the valley bottom width is equal to the bankfull width]*
xi. Low Urbanization	– Less than 10% future impervious cover percentage (as indicated in Official Plan) within 1 km of the proposed crossing location **or** – Less than 1.5 km/sq.km projected road density within 1 km (as indicated in the transportation master plan)

Flowchart 1: Crossing design options decision tree for the *detailed assessment of natural heritage functions*



<u>Note</u>: These options must be considered in the context of the complete review of natural heritage functions and natural hazards functions for crossings, in accordance with this entire Guideline and other considerations outside the scope of this Guideline as per Section 3.3.

Table 8: Wildlife mobility class database (with examples based on TRCA's inventory data)

Mobility class	Wildlife group	Preferred habitat	Maximum spacing between openings	Minimum size of crossing needed	Preferred substrate condition	Preferred light condition	Preferred moisture condition	Other known preferred factors affecting the usage of crossings
Restricted Mobility	Some small mammals (e.g. moles)	Forests	25m spacing	Trench drains and specialized culverts; smaller than 0.5m (2') span but could be larger structures	Natural	Dark, cover	Dry	Prefer small structures with overhead cover, vegetative cover
Low Mobility	Most amphibians (e.g. frogs, salamanders) and reptiles (e.g., snakes)	Forests and Wetlands	61 m spacing, max 80-100m	Trench drains and specialized culverts; smaller than 0.5m (2') span but could be larger structures	Natural	Light	Dry or moist	Require moisture and light and should be as short as possible; drift fences useful to assist in passage
	Some small mammals (e.g. shrews)	Forests	250 m – 500 m spacing	Trench drains and specialized culverts; smaller than 0.5m (2') span but could be larger structures	Natural	Dark, cover	Dry	Prefer small structures with overhead cover, vegetative cover
Moderate Mobility	Some medium sized mammals (e.g. ermine, weasel, porcupine, river otter)	Forests and Riparian	2 km	Small underpass; small box or arch culverts 1.5 m (5') span or less	Natural	Some light	Dry	Prefer tall and narrow structures
	Reptiles (e.g. turtles)	Forests and Wetlands	1 km - 5 km	Small underpass; small box or arch culverts 1.5 m (5') span or less	Natural	Some light	Dry or wet	Prefer small underpasses, box or arch culverts, or eco-passages and should include minimal rock
High Mobility	Some larger mammals (e.g. black Bear)	Forests	5 km	Medium underpass; box or arch culverts larger than 1.5 m (5') span to 2.4 m (8') span	Natural		Dry, 1m high, wide	Prefer constricted passageways with vegetative cover
	Some medium sized mammals (e.g. fisher)	Forests	15km	Medium underpass; box or arch culverts larger than 1.5 m (5') span to 2.4 m (8') span	Natural	Some light	Dry	Prefer tall and narrow structures

Appendix 3: Natural Hazard and Natural Heritage Function Assessment Summary

Table 9: Summary of natural hazard and natural heritage function assessments and recommendations using TRCA Crossings Guideline

TRCA Objectives	**Natural Hazard and Natural Heritage Function Assessment Summary**	
Natural Hazard	**Assessment Factors**	**Assessment Recommendations**
Flooding	• flood levels • safe conveyance • conveyance capacity of existing structure	
Geomorphology (channel erosion)	• rate and direction of channel migration • proximity of infrastructure to hazard • level of risk to infrastructure and erosion • need for engineering works to protect infrastructure need to realign the watercourse	
Geotechnical (slope stability)	• proximity of the watercourse to adjacent valley slope • level of risk to infrastructure and valley slope failure • need for engineering works to protect infrastructure and valley slope stability	
Natural Heritage		
Terrestrial	• habitat quality (existing and potential) • regional and local connectivity priorities sensitive species • sensitive vegetation community	
Aquatic	• existing or potential habitat quality • regional connectivity priorities • sensitive species	
Final Recommendation for Crossing Design (based on TRCA's natural hazard and heritage objectives)		