Ontario

MINISTRY OF TRANSPORTATION

MTO Guide for Water Crossing Hydrotechnical Reports

2022

(Previously MTO Guide for Preparing Hydrology Reports for Water Crossings, 2009)

Standards & Contracts Branch

Highway Design Office

Contents

1.0 About this Document

A hydrotechnical study is required in the design of a new water crossing, or when a replacement/rehabilitation of an existing structure is being considered. A water crossing is a culvert, bridge or buried structure that is constructed to accommodate any natural or constructed body of water including lakes, ponds, streams, channels, wetlands etc. The flow of water may either continuous, intermittent, or ephemeral.

The hydrotechnical design process for a water crossing requires a multi-disciplinary approach that incorporates watershed hydrology, bridge hydraulics, foundation assessments, geomorphologic assessment (stream stability) and highway geometrics. The design also requires a comprehensive engineering approach that involves data collection, hydrologic analysis, hydraulic assessment, modeling, formulation of alternatives, evaluation and selection of the "best" alternative according to established criteria and modeling results, and documentation of the final design.

The hydrotechnical design of water crossings for projects within the jurisdiction of the Ministry of Transportation of Ontario (MTO) is to be based on and reflect the principles and procedures identified in the following:

- the MTO Highway Drainage Design Standards (HDDS),
- the MTO Gravity Pipe Design Guidelines,
- the MTO Structural Manual,
- the Canadian Highway Bridge Design Code (CHBDC),
- the MTO Environmental Guide for Fisheries and
- all current MTO Policy Memos
- and MTO Drainage Directives.

This guide identifies the process and information required for preparing a comprehensive Hydrotechnical report to satisfy MTO requirements. It provides the detailed documentation requirements for Hydrotechnical reports prepared for the MTO and the rationale for requiring this information.

This document was developed to:

- Provide a comprehensive set of MTO documentation requirements that are to be used in the preparation of hydrotechnical reports.
- Ensure completeness and consistency within hydrotechnical reports prepared for the MTO.

- Enable the designer to identify the relevant hydrologic, hydraulic, and environmental issues impacting the watercourse, water crossing, highway, surrounding lands and existing structures, at the earliest possible planning stage.
- Provide guidance for the preparation of 'Terms of Reference' for hydrotechnical studies, and for the Drainage and Hydrology Engineering Section of 'Request for Proposal' documents involving the design of water crossings.

It is the responsibility of the drainage practitioner to familiarize themselves with the requirements of the MTO and other Federal, Provincial or Municipal governing authorities and to provide all information required by the Ministry for evaluation, as outlined in this document. Technical details or policy statements provided in this document are for clarification purposes only. They are not to be considered as substitute for the original manuals, standards or policies referenced. It is the designer's responsibility to refer to the original documents for instruction and guidance.

2.0 Introduction

The purpose of the Hydrotechnical report is to:

(1) provide results of the hydrologic analysis.

(2) identify design criteria.

(3) provide results of the hydraulic assessment of the water crossing, and

(4) present hydrotechnical design of the water crossing.

The drainage practitioner must demonstrate that adverse drainage impacts to the highway right-of-way and adjacent landowners will not occur. The design of the crossing should be based on future runoff conditions which consider climate change and takes full account of present and probable future municipal controls over increases of runoff from new developments.

The documentation of a hydrotechnical design for a water crossing should clearly outline all the assumptions, procedures used, results achieved, and conclusions arrived at by the designer.

2.1 Organization of the Hydrotechnical report

This guide describes the tasks to be completed in a hydrotechnical design and the resulting information that is required to be documented in the Hydrotechnical report(s).

The following is the recommended structure for the Hydrotechnical report:

- Introduction
  - Project scope
  - Purpose and Scope of the Hydrotechnical Report
- Background Information
  - Watershed Description
  - Watercourse Characteristics
  - Site Conditions
  - Existing Drainage Structures
  - Requirements of Other Agencies
  - Existing Drainage Issues
- Hydrotechnical Analysis
  - Design Criteria
  - Hydrologic Analysis

    - Hydraulic Analysis
    - Scour Analysis
    - Regulatory Flood Impact
    - Ice Jam and Debris Flow Analysis
- Proposed Drainage Structure Design
    - Design Alternatives
    - Bridge or Culvert Opening Design
    - Recommending the Best Alternative
    - Bridge Deck Drainage
- Mitigation of Impacts of the Proposed Structure
    - Erosion and Scour Control Measures within watercourse
    - Fish Habitat Protection Measures
    - Assessment and mitigation of the Impacts on the adjacent lands
- Hydrotechnical Detail Design Elements
    - Erosion and Sediment Control During Construction
    - Temporary flow diversion system Feasibility
- Summary and Recommendations
- Appendix (ices)

Adherence to the structure when preparing Hydrotechnical reports will facilitate completeness of reports, provide consistency from one report to another, and expediate review and acceptance of the proposed designs and recommendations.

2.2 Determine the Requirements for Hydrotechnical report

A hydrotechnical study will be required when the design of a new water crossing, or a replacement/rehabilitation of an existing structure is being considered. The level of detail of the analysis will vary depending on the level of planning and design being undertaken. In the case of the rehabilitation of structures, if the work being proposed will be above the High Water Level and the High Ice Level, a Hydrotechnical report may not be required. This will have to be confirmed with the MTO Project Manager.

The level of detail of the analysis will depend on the level of structural planning the report is addressing. The three levels of structural planning include Corridor Planning, Route Planning, and Detail Planning. It is necessary that the proper level of detail undertaken in the hydrology study be commensurate with the level of structural planning the study is intending to complete. Depending on the level of structural planning, a Preliminary Hydrotechnical report and/or a Detailed Hydrotechnical report may be prepared.

Figure 1 illustrates the tasks required in a hydrotechnical design of a water crossing as they relate to the level of planning.

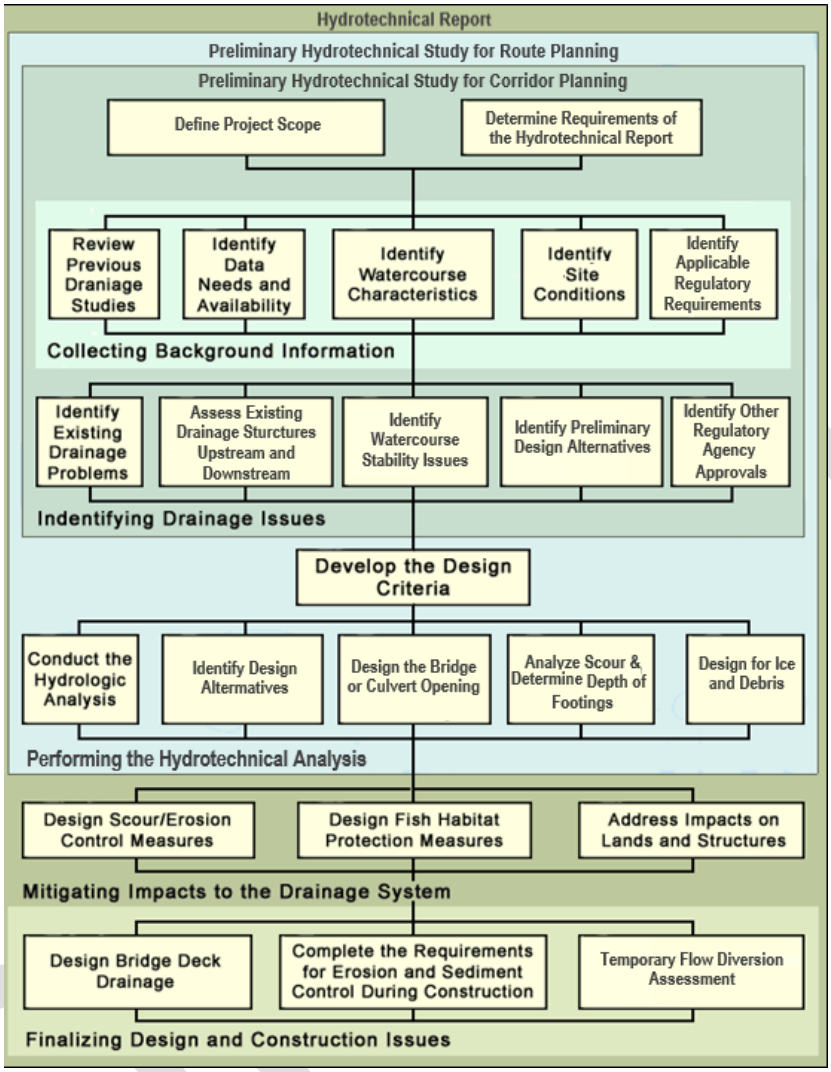

Figure 1: Hydrotechnical Design Summary Chart

Documentation Requirements

The Hydrotechnical report should clearly document the following:

- The level of planning and design being addressed in the report. The details of the information and analysis presented should be commensurate with the level of reporting.
- The rationale for preparing the report and who initiated the study.
- The number and locations of the watercourse crossings being considered.

- Reference to other reports associated with this watercourse crossing. Careful consideration should be given to the time elapsed between reports to ensure that the information in one report, for example the Preliminary Hydrotechnical report, has not become dated by the time the Detailed Hydrotechnical report is prepared.
- Approvals received at earlier stages of the planning process, if applicable.
- Any conditions that were placed by MTO or other authorities and how they have been met.

The documentation requirements should be included in the Introduction section of the Hydrotechnical report.

The checklists presented in ***Appendix A*** provide a comprehensive list of documentation requirements to be included in a Hydrotechnical Report submitted to the MTO. It is the responsibility of the designer to determine the applicability of the listed documentation requirements to the design being considered. The selection should be based on the suitability of the tasks to each design proposal, the scale, and the nature of the proposed project.

3.0 Collecting Background Information

Completion of the tasks in this group will ensure that all relevant information is considered in decision making and in developing the design criteria.

The drainage practitioner will complete the following tasks in this group:

- Review previous drainage studies.
- Identify data needs and availability.
- Identify characteristics of the watercourse.
- Identify on-site conditions.
- Identify requirements of other agencies.

3.1 Review Previous Drainage Studies

Previous drainage studies may have been done for the watershed, the watercourse, or the specific water crossing being considered.

Previous drainage studies include the following types of studies:

- **Watershed and Sub-watershed Studies/Plans** provide the goals, objectives, and criteria for the management of resources in a watershed, sub-watershed, or area of specific interest.
- **MTO Environmental Study Reports** document the alternatives studied, methods used, and recommended alternative, according to the requirements of the Environmental Assessment Act.
- **Preliminary Design Reports** are typically submitted at the early stages of design and may include an outline of all potential drainage issues, propose design alternatives, and recommend mitigative works for any impacts associated with the different alternatives.
- **Other Drainage Studies** may have been prepared by a Conservation Authority, MNDMNRF, Ministry of Environment, Conservation and Parks (MECP) and/or municipalities. These studies could include:
    - Flood Line Mapping Studies.
    - Flood Damage Reduction Program Studies (FDRP studies).
    - Erosion Control Studies; or
    - Flood Control Studies.

Documentation Requirements

The Hydrotechnical report should delineate the watershed and list all previously completed drainage studies relevant to the proposed water crossing site(s) in the Background Information section.

Any relevant information from a previous study should be provided in a related section of the Hydrotechnical report with clear references to the source of the information. Information to be included are previous objectives, goals and design criteria such as:

- Magnitude of extreme flood flows and water levels.
- Water quality objectives.
- Fish habitat restoration or protection objectives.
- Identification of flood or erosion prone areas; and
- Restrictions on the drainage system in the vicinity of the proposed water crossing locations.

The information contained in previous studies should be considered and incorporated in the final Hydrotechnical report, however previously completed drainage studies will need to be revisited and verified to account for any changes in the contributing watershed with the necessary modifications documented.

As well, changes that have occurred to MTO or other governing agencies' drainage practice must be considered. If there have been changes, the report must demonstrate how the previously completed drainage study is in conformance with current MTO other governing agencies' drainage practices.

3.1.1 Watershed and Sub-watershed Studies

Where a **Watershed and Sub-watershed** study/plan is in existence the report must clearly indicate if the MTO formally endorsed the study/plan.

- **If the MTO endorsed the Watershed and Sub-watershed study/plan**, documentation of relevant objectives, goals, design criteria and other elements of the referenced study must be included (with clear references to its source). This may include:
    - Limits on regulatory flood flows and water levels.
    - Fish habitat restoration or protection objectives.
    - Identification of flood or erosion prone areas.
    - The type of drainage system that is required.

Adherence of the Hydrotechnical report to the referenced drainage study must be clearly documented.

- **If MTO did not endorse the Watershed and Sub-watershed study/plan**, there may be two reasons. The Hydrotechnical report should document which of the following reasons apply.
    - MTO may not have endorsed the previous drainage study since MTO was not on the circulation list and had not reviewed it. In this case, the previous drainage study should be reviewed by MTO for conformity to MTO drainage practices. Should the study be acceptable to the MTO, an endorsement can be issued. Once complete, the proposed Hydrotechnical report can be reviewed on the basis of conformity to the previous drainage study.
    - MTO may not have endorsed the previous drainage study because of a disagreement with certain objectives, goals, design criteria, methods or other elements of the previous drainage study. Determine the aspects of the previously completed drainage study that were not acceptable to the MTO. Once this has been established there are two options available.
        - If the proposed Hydrotechnical report does not encompass any area of disagreement, the MTO can review the Hydrotechnical report in isolation of the previously completed drainage study. The review would be based on conformity with current MTO drainage practices.
        - If the proposed Hydrotechnical report encompasses an area of disagreement, a meeting between all supporting regulatory agencies is warranted to sort out those controversial aspects of the previously completed drainage study.

3.2 Identify Data Needs and Availability

The process of completing the hydraulic design of a water crossing requires the collection of a significant amount of data. The type of data required, and the availability of this data will vary from site to site. Once previous drainage studies have been reviewed it will be easier to determine which information is available and which information must still be collected. It may also become clearer what information is not available.

Depending on the type of data available, the method of analysis may vary. For example, in locations where stream flow data is not available, using data from an adjacent, hydrologically similar, watercourse may be necessary. In other cases, hydrologic analysis methods using precipitation and watershed characteristics may be the only

means to determine the design flow rates. More than one method of flow rate analysis should be conducted to verify the watercourse flow estimates.

The following are the types of data that are commonly required to complete the design and assessment of a water crossing alternative.

- **Precipitation and Other Climatic Data** - IDF Curves for Ontario can be found on the MTO website. Data is also available from Environment Canada, Conservation Authorities, and Municipalities. Environment Canada collects precipitation data for several rainfall gauging stations in Ontario. This data is more abundant than stream flow data and is therefore, available for more potential crossing sites. The data is provided either as a continuous record over a long period of time, as Intensity-Duration-Frequency curves (IDF curves), or as a mathematical representation of the rainfall distribution.
- **Topographic Data** - These are usually obtained from the Ontario Base Maps (OBMs) topographic layer, the National Topographic Series or municipal engineering departments. Missing information can be gathered from field surveys.
- **Ground Cover Data** - This data can be obtained from the OBMs, photo mosaics, site visit and municipal sources.
- **Air Photos - These** are available from the Geomatics sections of MTO, Conservation Authorities, MNDMNRF, and other sources. The data to be documented should include the findings on topography, land use, soil and vegetative cover, layout of bridges, culverts and roadside ditches, types of paved roadway, buildings and other ground features.
- **Soil Data** - This data will include:
    - Soil data for the watershed, which is to be used in the hydrologic analysis. This information will be provided from several sources including soil survey maps, watershed studies and/or sub-watershed studies.
    - Soil data for the watercourse, which will be used for stream stability analysis, scour analysis, and design of erosion protection measures. This information is obtained from soil investigations that are usually submitted under a separate geotechnical report.
- **Watercourse cross-sections** - This data can be obtained from field surveys and from Conservation Authorities if flood profile models have been prepared for the watercourse.
- **Water Levels at Lakes, Harbours and Controlled Structures** - This data is available from Water Survey of Canada, dam operators, Waterway Authorities,

Conservation Authorities, and hydroelectric agencies such as Ontario Power Generation (OPG).

- **Fish, Wildlife and Terrestrial Data** - This data is available from the MECP and the MNDMNRF.
- **Field surveys** - These will be done to compliment and verify other sources of data. In some cases, such as when collecting watercourse cross-section profiles, this may be the main source of data.

Documentation Requirements

The availability, or lack of, relevant data should be documented in the Hydrotechnical report. The resolution to the issue of missing data should be documented. If alternative methods of analysis are to be used due to the lack of data, the rationale and justification for this decision should be presented.

This data can be documented in the appendices and/or within the body of the report in a corresponding section. The documentation requirements for specific collected data are described in more detail under the following headings in this document:

- Identify Characteristics of the Watercourse
- Identify On-Site Conditions
- Identify Requirements of Other Agencies
- Conduct the Hydrologic Analysis

3.3 Identify Characteristics of the Watercourse

An essential task required to develop a water crossing is to collect information and data that describe the watercourse being crossed and the contributing watershed. This data serves as input to all aspects of planning, development and design of the water crossing alternatives.

Documentation Requirements

The following outlines the information required to describe the watercourse being crossed. This data should be documented in the Hydrotechnical report either in the appendices, the computer input/output summaries or in the main body of the report. The watercourse characteristics to be obtained and documented include:

- **Cross-sections upstream and downstream of the crossing**: As this data will most likely be used as input to a water surface profile analysis application, the documentation of this data can be done through the provision of the input files.
- **Watercourse bed slope**: The cross-section data and field surveys will provide the bed slope of the watercourse. This data should be documented in schematic diagrams, tables and/or text. The impact of bed slope on the characteristics of the flow (critical, subcritical or supercritical), analysis techniques and design options should be identified.
- **Meander pattern of the river reach, and the meander at the location of the crossing:** The meander pattern (if the stream is straight or on a bend, having single or multi-channel configuration) should be described. The implications of the meander patterns on stream stability and design considerations should be included in the discussion associated with this data.
- **Channel bank condition:** An assessment of the bank conditions, such as weathered, vegetated, eroding, and slumping, should be included in the watercourse description and the implication to the structural design and stream stabilization works discussed. The bank condition may be determined based on the study of aerial photographs, photo mosaics, contour maps, and field surveys. Bank condition is required to predict the watercourse stability, both during floods and over an extended period of time.
- **Soil Data:** Soil data within the watercourse are obtained from soil investigations that are usually submitted under a separate geotechnical report. The information to be documented in the hydrotechnical analysis includes:
    - borehole data, defining the various soil layers with borehole locations plotted on Plan and Elevation views:
    - recommendations for the bed and side slopes, excavation, backfilling,
    - differential settlement and
    - slope instability problems.

  Soil information related to anticipated abutment and pier foundation design can be quite extensive. Therefore, only a brief summary of the conclusions/findings should be included in the Hydrotechnical report. Data that will be used in scour, stream stability and erosion control analysis should be provided in detail. The Soils Report should be clearly referenced wherever the data from the report is used in the analysis.
- **Stream Flow Data**: Water Survey of Canada, in co-operation with Conservation Authorities provide stream flow data for a number of stream gauging stations in Ontario. The Hydrotechnical report should document the gauging station used and an assessment of the quality of the data should be completed and

summarised. If transposing of the data from distant gauging stations was done, it should be identified, and the methods used described. Flow or water level controls upstream and downstream of the proposed water crossing should be identified and their impact on the usability of the data should be confirmed. In cases where stream gauges in the vicinity of the crossing cannot be found, this should be clearly stated and the implications on the design methods and analysis should be described.

- **Water Levels at Lakes, Harbours and Controlled Structures**: This data is available from Water Survey of Canada and/or the authority that controls these facilities such as, the Waterway Authorities, Conservation Authorities, or Hydro-electric Agencies such as Ontario Power Generation (OPG). The documentation should identify if such controls will affect the hydraulic performance of the proposed structure. A summary of water level records should be provided showing the critical water levels. Water level control curves should also be included in the report, if applicable.
- **The History of Flooding**: This includes historical records, high water marks, if available, residence reports, dates of flooding events, extent of flooding and damages.
- **The History of Debris Carrying Flows or Ice:** The possibility and extent of debris and ice jamming problem needs to be identified. This information should include date of historic events, locations and elevation of marks associated with high ice, extent of damage that occurred, identification of the sources of the data and the characteristic of the watershed and the watercourse that are associated with debris and ice jamming problems.
- **Fish, Wildlife and Terrestrial Data**: DFO, MNRF, and the Conservation Authority (if one exists) would provide this information as well as the requirements for protection for fish habitat.

3.3.1 Investigate Stability of the Watercourse

One of the critical considerations when designing a new water crossing is the suitability of the location where the crossing is to occur. It is always preferable, wherever possible, to locate the crossing at a stretch of a watercourse reach that is stable and where shifting of the stream channel or erosion and deposition of sediment will not occur in any significant way during the life span of the structure.

If a stable reach is practically not attainable, additional works to protect the structure and the channel bed and banks will most likely be required. As well, additional maintenance requirement may become necessary over time.

Documentation Requirements

For each of the proposed crossing locations the following should be provided:

- A geomorphologic assessment of the stream to assess the stability of the proposed crossing location(s).
- The effect of channel stability on the design criteria of the crossing.
- Cost implications.

The above information should be supported with the following data and information:

- A historic record of flooding, channel alignment and erosion problems.
- Aerial photographs showing the meander pattern of the stream.
- Soil type for the channel bed and banks.
- Justification for the distance upstream and downstream, from the proposed location, where the stability assessment was conducted. The drainage practitioner will have to exercise judgement in selecting the minimum distances.

In some cases, it may be necessary to realign the stream channel at the location of the crossing. In such cases the following information and analysis should be documented:

- An inventory of the existing channel and geomorphic characteristics including:
    - Typical width and depth
    - Channel slope
    - Channel form i.e., Bend / reach configuration.
    - Bank Full Discharge / Channel Forming Discharge
- For the proposed channel, the following should be provided
    - Channel characteristics
    - Assessment of impacts
    - Methods of mitigating impacts
    - Approval of other agencies such as MNDMNRF, the Conservation Authority and DFO

3.4 Identify Site Conditions

Each water crossing has unique site conditions that will impact the design alternatives that can be considered. Site conditions can be identified from several sources, as described previously. A site visit is critical in confirming the collected information and for identifying conditions that are not apparent from other sources. A site visit will also

assist in identifying restrictions on the design criteria and on the complexity of the solutions that will be required.

Documentation Requirements

The documentation of site conditions should include, but is not limited to the following:

- The elevations of the top of bank, toe of bank and channel bed.
- Bank traverse.
- Utility/fence/property lines.
- Overland slopes.
- Restrictions on the approach slope and elevation and any other restrictions resulting in limitations on the clearance of the structure and freeboard at the approach.
- Storm sewer and channel outlets adjacent to the proposed crossing location, as well as other features that may require protection as part of the design of the crossing.
- Special soil conditions and geological features that must be avoided, accommodated, or removed.
- Other structures and features, upstream and downstream, that could have an impact on the proposed crossing or can be impacted by it. *Table 1* provides additional details on the information that should be documented under this section.
- Evidence of historical events. Historic high-water surface elevations can be identified on site from several indicators such as: marks on trees and structures and by interviewing long-term local residents along the watercourse. Such information should eventually be tied in with field surveys to a common datum. This data should relate to known historic events, whenever possible.

Site information is generally required to be tied-in with field surveys and plotted in Plan and Elevation views at appropriate scales. A bridge waterway opening would eventually be designed to fit in with or modify the site conditions. Therefore, these details would be used as a part of final design and drawings.

3.5 Identify Applicable Regulatory Requirements

There are a number of agencies that are involved in the management and regulation of natural watercourses in Ontario. The mandate of these regulatory agencies may require restrictions to be placed on the design. Other Regulatory agencies may include

MNDMNRF, MECP, DFO, Transport Canada, Conservation Authorities, and local municipalities.

In the case of crossing of municipal drains, the local municipality and the Drainage Superintendent may place restrictions on the design.

Other regulatory agency may constrain certain design parameters such as location, type, size, span or clearance of the proposed structure. They may also add requirements for additional works for fish habitat protection, erosion control and channel training. For example:

- **Fish Habitat Protection** - Generally, in land development proposals, the MNDMNRF, DFO, or the local Conservation Authority will determine fish habitat requirements. Since fish habitat requirements are based on the sensitivity of the watercourse, requirements may be set before any impact assessment has been completed.
- **Regulatory Flood Line Requirements** - The local Conservation Authority, will in most cases have information on the flood lines that need to be maintained. The Conservation Authority should be contacted to identify and agree on their requirements before setting the design criteria for the proposed structure.
- **Navigable Waters Requirements** - Transport Canada administers the Navigable Waters Act and accordingly, the clearance requirements may be determined based on consultation with Transport Canada.
- **Environmental Assessment Requirements** - If an Environmental Assessment was completed for the highway project which the water crossing structure is part of, design requirements and constraints may have been set and will have to be adhere to

Documentation Requirements

All requirements and approvals of other regulatory agencies, which must be considered/acquired as part of the design of a bridge or culvert structure, should be identified in the Background section of the Hydrotechnical report with confirmation that they have been met. These include requirements under:

- Federal and Provincial fishery and wildlife protection legislation.
- The Environmental Assessment Act.
- Conservation Authority flood plain planning policy under the Planning Act.
- Federal Navigable Waters Legislation
- The Drainage Act

- The Ontario Water Resources Act
- Other applicable legislation

Restrictions applicable to the water crossing and the source of the restriction should be documented in the Report.

As an agent of the crown, the MTO will not proceed with the construction of a water crossing that contravenes drainage management policies of other regulatory agencies.

Where any design criterion conflicts with a drainage management policy, guideline or manual of a regulatory Agency it must be approved by the MTO. A meeting between the parties may be warranted to resolve the conflict.

3.6 Identifying Drainage Issues

This group of tasks uses the information and data collected to identify the drainage issues that need to be addressed at the proposed water crossing location(s) to identify design alternative. Some analysis will be required to complete this set of tasks.

An investigation must be completed to determine if any drainage impacts will occur as a result of the MTO works to the drainage system and upstream and downstream riparian lands.

The drainage practitioner will complete the following tasks in this group:

- Identify Existing Drainage Problems.
- Assess Existing Drainage Structures Upstream and Downstream.

3.6.1 Identify Existing Drainage Problems

Before proceeding with the design of a water crossing it is necessary to identify any existing drainage problems at the site that may impact the design criteria for the new structure. The cause of the existing drainage issues should be assessed to determine the potential for further aggravation (refer to the section Mitigating Impacts to the Drainage System).

Important insight to the drainage problems in the area can be provided from the site inspection and from MTO regional and district staff. Contacting the local conservation authority, municipality, or the local MECP and MNDMNRF can also provide further information into the history of the area.

Documentation Requirements

The Hydrotechnical report should document existing problems with upstream or downstream property to ensure that any liabilities assumed by the MTO are clear and that opportunities for corrective measures are addressed early in the design process. The report should include the steps taken to identify an issue including any hydraulic and hydrologic analysis. This documentation should cover possible problems such as:

- Upstream or downstream flooding of structures and lands.
- Upstream or downstream erosion problems.
- Problems in the roadside ditching system.
- Beaver dam activity.

In the case of projects that involve the replacement of existing water crossing structures, it is important to also document the following:

- Incidents where the structure's hydraulic capacity have been exceeded, identifying high-water marks, other signs of overtopping and structural damage, citizen reports and other documented sources.
- Deterioration of the structure in excess of normal degradation.
- Signs of blockage due to siltation, vegetation overgrowth or obstruction.
- Damages to other structures and land in the immediate vicinity.

3.6.2 Assess Existing Drainage Structures Upstream and Downstream

Any existing structures on the watercourse, located in close proximity to the crossing site, upstream and downstream, should be assessed for hydraulic adequacy and performance. The assessments should be carried out by reviewing the history of the structures and by a visual inspection.

It may be necessary to conduct hydrologic and hydraulic analysis to determine the water surface profile without the new crossing in place.

Documentation Requirements

As a part of the Hydrotechnical report, each existing structure should be documented for:

- Spans, finished roadway width, skew, distance from the proposed crossing and year of construction.
- Waterway opening, size, width and height, design flood, velocity, and HWL if available.

- Hydraulic performance of opening through visual evidence of past floods and channel scour.
- Any rip rap/bank protection measures constructed or added later, and any problem areas and related mitigative measure taken to address these problems. Any monitoring, or maintenance aspects, which should be considered.
- Any geotechnical considerations, constraints or problems related to the stability of the road or bridge approach fills, settlement problems and the performance of abutments and piers
- Any structural/safety problems that may be obvious.

In addition, the waterway opening for each structure should be assessed and documentation provided for:

- Its past hydraulic performance, identifying whether it was under or over-designed with respect to the structure's performance.
- The erosion of banks, fill slopes or channel bed, and
- Any maintenance/repairs carried out in the past.

Table 1: Documentation Requirement for Existing Drainage Components

Documentation Requirement for Existing Drainage Components	
Component	**Relevant Information to be Provided in Hydrotechnical report**
Bridges	Location, distance, structural characteristics (soffit elevation, span arrangement, pier details, abutments, and superstructure type)
Culverts	Culvert type (e.g., elliptical, box, open footing, etc.), culvert configuration (e.g., single barrel, double barrel, etc.), diameter or span/rise, length, slope, material (e.g., CSP, concrete, etc.), and inlet/outlet configuration (e.g., head walls, wing walls, flared entrances, collars, etc.).
Erosion protection works	Lining material/cover work, bank drainage, buffers strips, runoff diversions, drop structures, energy dissipaters, stilling basins, chutes, retaining walls and check dams.
Dams	Size of reservoir, dam height, type, operational rule curve, spillway location, maintenance responsibilities, and ownership.
Other Water bodies, (e.g., ponds and drainage ditches)	Name (if applicable), location, changes proposed and impacts on other system and performance, if any.

4.0 Performing Hydrotechnical Analysis

This group of tasks uses all the information and data collected to perform the hydrotechnical analysis for the detailed design of the bridge or culvert. The design will take into account the drainage issues identified and provide the design alternative that will address these issues.

The drainage practitioner will complete the following tasks in this group:

- Establish Design Criteria
- Conduct the Hydrologic Analysis
- Conduct the Hydraulic Analysis
- Analyse Scour and Determine the Depth of Footings
- Design for Ice Flow and Debris
- Assess if Design shall Convey the Regulatory Storm

4.1 Establish Drainage Design Criteria

Design criteria shall be approved by the regional engineering office responsible for the project. The regional office should be contacted to determine the approval requirement. It is advisable to acquire the necessary approvals before completing the design of the project. Where design criteria have been adopted based on a previous drainage study, these criteria should be clearly identified.

Documentation Requirements

This section of the report should include a comprehensive list of the design criteria that will govern all the alternatives being considered. These criteria will identify, but are not limited to the following:

- The proposed location of the structure. This information should be supported with sketches, maps, photo mosaics and descriptions.
- Special considerations addressing the following, if applicable:
    - Crossing of inland lakes.
    - Tidal Crossings.
    - Consideration of wave action.
    - Physical modelling of bridge.

- The return period for the design storm and the regulatory storm, as per the Highway Drainage Design Standards. This section should outline the hydrologic design criteria adopted and the underlying rationale for selecting these criteria for the proposed bridge crossing. This should be based on the class of road, present and future projections of traffic density and Ministry directives, policies and practices.
- Any deviations from the minimum requirement set by the Highway Drainage Design Standards. The rationale for this deviation must be documented.
- Highway profile and horizontal alignment.
- The vertical clearance, as defined by the CHBDC. If the requirement of the CHBDC can not be met, a deviation report must be prepared that will provide the rationale for this deviation/exception. There is a specific requirement for the information that is to be included in the deviation/exception report. Refer to the section MTO Approvals for the requirements for approving the design criteria for water crossing structures over waterways, contravening the CHBDC.
- Freeboard requirements at the approach.
- The number of footings, pier spacing and location of abutments.
- The existing drainage problems that will be addressed by the proposed design criteria.
- Restrictions based on other structures upstream or downstream.
- Requirements for permanent erosion control measures.
- Relief flow requirements.
- Fish passage requirements.
- Debris and ice flow requirements.
- Navigation requirements.
- Local stream modifications.
- Any other external constraints.
- Minor access routes under water crossings.

The rationale for selection should be included for all the above criteria. Should any design criteria, drainage management policy, guideline or manual of an upstream or downstream riparian landowner's conflict with a design criterion, drainage management policy, guideline or manual of MTO, or vice versa, a meeting between the parties may be warranted to resolve the conflict.

4.1.1 MTO Highway Drainage Design Standards, Specifications and Policies

MTO drainage design criteria are provided in the MTO Highway Drainage Design Standards and other guidelines, manuals and memos found on the MTO Technical Publications Website.

MTO Drainage Directives and Engineering Memos are MTO policies that are to be applied whenever highway drainage works are being designed or may be impacted by works external to the MTO right-of-way. The Drainage Directives include:

- PHY Directive B-012: Addresses MTO policy and procedures relating to the Drainage Act. It specifically deals with Municipal Drains. It may be relevant when dealing with bridge or culvert structures crossing municipal drains.
- PHY Directive B-013: Addresses MTO policy and procedures on Private Pipe Drains from agricultural lands and individual private residences which outlet onto or cross provincial highway. It may be relevant if the outlets of these drains are located within the vicinity of a proposed water crossing site.
- PHY Directive B-014: Drainage management policy and procedures. It provides direction and guidance relative to stormwater runoff, urban drainage, detention ponds and highway drainage. It may be relevant to issues associated with deck drainage.

4.1.2 MTO Approvals for Standards Deviation

In some cases, it may be determined that one or more of the drainage standards requirements may not be achieved without significant changes to the highway profile, surrounding lands or the watercourse. Therefore, it may become necessary to consider a design option that deviates from the MTO Drainage Standards.

Any standard deviation must be validated, recorded and have an appropriate level of authorization before proceeding with the design. Where a deviation from the CHBDC is recommended a justification or exemption report is required.

4.1.3 Approval Requirements for Design Criteria not Meeting the CHBDC

The MTO is governed by the CHBDC & the MTO Structural Manual in the design of all bridges and culverts 3000 mm in diameter/total span or greater. However, in some cases, it may be determined that one or more of the requirements may not be achieved

without significant changes to the approach, surrounding lands, or other crossings upstream. Therefore, it may be necessary to consider a design option that deviates from the requirements.

If such deviations are necessary, MTO approvals will have to be sought before the design alternative can be accepted. A justification/exception report will be required to document the rationale for proposing the deviation.

The Justification or Exception Report

If a design option that contravenes the CHBDC or the MTO Structural Manual is being proposed, it is necessary to document the information needed to justify the decision to proceed with such a design. The following information should be included in the report, as a minimum:

- The design criteria for the structure.
- A summary of the design considerations to accommodate the impacts of constructing the bridge or culvert structure at a lower elevation. This should also include the impact on maintenance requirements and access to the underside of the structure.
- Summary of the hydrologic and hydraulic analysis for all the alternatives being considered.
- Site restrictions and impacts that influenced the decision to consider the contravening alternative. This includes, but is not limited to:
    - Impacts on other bridge or culvert structures upstream and downstream.
    - Requirements of other agencies such as Conservation Authorities, Ministry of Northern Development, Mines, Natural Resources and Forestry (MNDMNRF), or municipalities.
    - Impacts on vertical and horizontal road alignments before and after the structure.
    - The impact on scour at the bridge.
    - The location where relief flow will occur.
    - The impacts on lands and structures within the floodway.
    - Impact on the flood lines.
- Maps, sketches, photographs, and photo mosaics to adequately describe the situation.
- Cost analysis.

Determining the Cost Estimates:

The costs associated with the construction of a bridge or culvert are to include both the cost of the structure and the cost of addressing the impacts associated with each design alternative. The cost estimates should include the following:

- The cost of construction of the proposed bridge or culvert structure and approach.
- The cost of potential damages to the structure during high flow rate conditions.
- The cost of added protection to the structure to resist lateral and longitudinal forces due to debris and ice flows and vertical forces due to buoyancy, air entrapment and ice.
- The cost of potential erosion and scour impacts on the stream channel at the structure and in the vicinity of the structure both upstream and downstream.
- The cost of compensation for damages to lands and structures if additional flooding is to occur as a result of the proposed design.
- The cost of future repairs to the bridge approach during flooding events.
- The cost of replacement of the structure if the life span of the structure is reduced due to more frequent and prolonged submergence conditions.
- The cost of loss of access at the bridge or culvert during flooding events.

4.1.4 Other Regulatory Requirements

The regulatory agencies are responsible for regulating different aspects of natural and man-made watercourses. Each agency will determine criteria required to regulate the watercourse within its mandate and will place restrictions on works or structures that interfere with it.

The local Conservation Authority and/or municipality should be contacted for design criteria applicable to the watercourse or water management aspect for which they have jurisdiction.

Requirements of other agencies such as MNRF, MECP, OMAFRA and DFO that are to be considered in design criteria must be listed with the appropriate level of detail and timeline for a permit application or consultation period.

4.1.5 Design to Convey the Regulatory Storm

A regulatory flood is a design flood specified by MNDMNRF for floodplain management purposes. In Ontario, the regulatory flood can be one of the following:

- Hurricane Hazel
- The Timmins Storm, or
- The 100-year flood.

the MTO Highway Drainage Design Standards identify the regions where these regulatory floods apply and where they must be assessed in a design

Designing for the regulatory flood could be achieved either through providing for relief flow or by accommodating the regulatory flood through the structure. This will depend on the highway geometrics, the level of service, safety and other considerations.

Designing for relief flow means allowing the flow to bypass the main waterway opening and pass over the approach grade or through one or more relief structures. It is generally preferred that the relief flow occur away from the water crossing structure. This would occur by placing the structure away from the road sag.

Relief flow is beneficial in that it acts as a "safety valve" against bridge or culvert failure in the event of an extreme flood.

- It is a means of reducing backwater during ice jams or extreme floods.
- It reduces the cost of maintenance as it reduces the potential damage to the bridge or culvert.

Documentation Requirements

The hydraulic analysis providing the water levels under relief and non-relief flow conditions should be documented. The rationale for selecting the best approach should be presented.

If the relief flow option is selected, the path of the relief flow and the impact on adjacent lands and buildings must be documented in the report. The documentation must identify:

- The major flow path presented in maps, schematics, and text. The locations of all lands and structures affected by the major flow should be indicated.
- Water levels at the structure, over the approach and along the major flow path.

- The design of mitigating measures to reduce the impacts of the flow of water on the bridge or culvert and the approach grade.
- In cases where flow relief structures are proposed in the approach embankment, the design of structures should also be documented.
- Flood protection measures, if applicable.

4.2 Hydrologic Analysis

The purpose of a hydrologic analysis is to establish the flow rates for the drainage system under existing and proposed conditions. To determine the size of the opening of the bridge or culvert it is essential to determine the flow rate that should be accommodated by the bridge or culvert structure. This flow may be accommodated through the structure as well as allowed to bypass the structure as relief flow. The hydrologic analysis must be done for, but not limited to the following:

- The 2, 5, 10, 25-, 50- and 100-year flood for the year corresponding to the end of service life of the structure (including climate change)
- Additional return period floods if identified for:
    - Fish passage
    - Navigation
    - Ice and Debris analysis
- The check flood .
- The regulatory flood, as defined by directives and the local Conservation Authority, to assess the impacts of the proposed design on adjacent land, structure and relief flow on the roadway.

Documentation Requirements

This section should discuss and document the design flood discharge arrived at, based on the design criteria adopted, and outline the method used in the analysis.

Documenting the Computational Methodology (*Table 2*), below gives the information that should be covered in the documentation.

Recognizing that the techniques generally used to arrive at a design flood estimate are statistical in nature and the results may vary with additional data in later years, several methods should be used to verify the results.

If a stream flow gauging station with a long period of record is available, Single Station Frequency Analysis should be used to derive the design flow rate. The most reliable stream gauge data available from the nearest stream gauging station should be used for Single Station Frequency Analysis. The flow rate data documented in the past by other agencies or in other reports should be used with caution and as a rough estimate only.

If there is no gauging station close to the crossing location or if data is not available, data from other gauging stations on the watercourse can be transposed to the location of the crossing. If such data is not available, data from an adjacent watercourse can be transposed to the crossing location, as long as the two watersheds are hydrologically equivalent. In cases where transposition of the stream flow data is conducted, confirmation of the resulting stream flows, for the different return periods, should be done using other precipitation based hydrologic methods.

If single station frequency analysis is not feasible the use of other methods based on precipitation data must be used. In all cases, methods based on precipitation data will be required for the determination of the Regulatory flow rates.

For the precipitation data used, the following should be documented:

- Rainfall station name, number and location. A clear map should be included that shows this information.
- Type of precipitation data collected (IDF curves, single event, continuous record, or regulatory storm).
    - In the case of continuous precipitation records, the data should be analysed to ensure the quality of the data is suitable for use in the hydrologic analysis. A description of this assessment, the quality of the data and any analysis required to prepare the data for the hydrologic analysis should be included.
- Design Storm Events:
    - Type and duration.
    - Rainfall discretization.

It is the responsibility of the designer to arrive at the design discharge based on accepted engineering standards and practices, and application of state-of-the-art techniques.

This section should document all the methods used in determining the flow rate and provide the underlying assumptions. Reference to any reports, technical papers, textbooks, and manuals should be provided.

Table 2: Documenting the Computational Method

Documenting the Computational Method	
Computational Analysis	**Documentation in Hydrology Section of the Report**
Flow Rate Calculation	Method used, variables, and applicability limitations of the method must be documented. Assumptions made must be stated.
Identifying Catchment Inputs	The subsequent values of the different parameters, any method used to calculate these values, and justification for selecting these values must be documented. Assumptions made must be stated.
Selecting Precipitation Data	The type of storm data used: single event (continuous, synthetic, historic, or IDF curves), meteorological station used, and storm duration time step (where applicable) must be documented. The rationale for selecting all the above and the assumptions made.

The Report should include a description of the method used and justification for the use of this method on highway projects in Ontario. Based on the location of the project, the applicability of the methods used for Canadian Shield and non-Shield areas should also be confirmed.

Where hydrologic modeling is used to simulate the rainfall runoff and to generate peak flows, a rationale for the applicability of the software used and a summary table of input parameters and a summary output table must be provided.

4.2.1 Climate Change Consideration

Climate change shall be considered when undertaking the design of MTO drainage infrastructure. Designer shall ensure that the drainage infrastructure will accommodate future rainfall values for the year corresponding to the end of the Design Service Life of the structure in the design of conveyance, scour, erosion and other drainage structure elements. The report should document how climate change has been applied in accordance with MTO specifications.

4.3 Hydraulic Analysis

The purpose of the hydraulic analysis is to assess the proposed water crossing performance under the design flows and provide recommendations for hydrotechnical design alternatives that will address the proposed structure requirements.

A hydraulic model should be developed to simulate the hydraulic performance of the existing and proposed drainage system.

Where hydraulic modeling is used, a rationale for the applicability of the software used and a summary table of input parameters and a summary output for existing and proposed conditions must be provided.

4.3.1 Design Alternatives

In every project there are usually a variety of options to consider. The number of these options will depend on site conditions as well as on the stage of planning being undertaken. As the planning stages progress and additional information is gathered and analysed, some options will be rejected, and others will remain viable options.

The alternatives being considered may differ and could include, but are not limited to, the following:

- Different location, orientation, and skew.
- Different spans and clearance, whether the structure will interfere with the watercourse.
- Different type of structure, bridge, or culvert.
- Different structural design.
- Different material, for example concrete or steel.
- Different type of foundation.

Documentation Requirements

The type of information to be documented to satisfy this section is primarily a summary of the different alternatives being considered. The complete information for each alternative will be documented as is described under the different sections of this document. Alternatives that will be no longer considered would be documented to the extent where the information was sufficient to make the decision to exclude these alternatives.

For each alternative, the following information should be included as a minimum:

- The type of crossing.
- The location of the crossing, height (as accurately as possible) and skew.
- Spans, type of piers and abutment.
- Schematics of the proposed structure, showing the layout and dimensions.
- Hydrologic and hydraulic advantages and disadvantages of the alternative.
- Reasons for excluding the alternative.

After the design of all alternatives has been completed, the proposed best alternative is to be identified and all the alternatives summarised.

4.3.2 Design the Bridge or Culvert Opening

The process of assessing the optimum size of the opening involves iterative hydraulic analyses, refining the opening until all the design criteria are met.

There are a number of methods that can be used to determine the size of the opening(s) of the structure. It is the responsibility of the designer to apply the appropriate method based on accepted engineering standards and practices, and application of state-of-the-art techniques.

This section should document the methods used in the hydraulic analysis and provide the underlying assumptions. Reference to any reports, technical papers, textbooks, and manuals should be provided.

Documentation Requirements

The Hydrotechnical report should provide a complete documentation of the different aspects of the design of the bridge or culvert structure.

For Bridges

The Hydrotechnical report should document the information listed below:

- The analysis and results of the bridge opening size.
- All input parameters. This information should be provided in a summary table and in the input files for the computer software model.
- Upstream and downstream water level controls and water surface elevations.
- Water surface profiles for the different design flow rates used in the analysis: This information is to be provided in tables in addition to cross-section drawings and

longitudinal profile drawings. The predevelopment water surface elevations should be documented along side those for the proposed alternatives.

- Resulting soffit elevation and freeboard at the approaches supported with drawing and sketches indicating the cross-section elevations of the structure and the natural watercourse.
- Assessment of impact of the proposed design(s) on debris and ice accumulations as well as fish passage. Refer to the section Design for Ice and Debris for detailed information.
- Details of flow controls, drops and the potential for development of hydraulic jumps. The details are to include location, water levels upstream and downstream and methods of addressing their impacts, physical and hydraulic.
- The type of flow condition under the different flow rates whether, open channel flow, pressure flow or weir flow and whether critical, subcritical, or supercritical flow.
- The type of hydraulic analysis methods and modeling software used. The discussion in this section should include confirmation that the methods used are acceptable to MTO. These references also provide the documentation requirements if the methods used have not been evaluated by MTO.
- Calibration and verification of the water surface profile model used. This section should describe the calibration process undertaken and how the available data was used to calibrate and verify the model. Sensitivity of parameters should be identified. In some cases, water surface profile models may have been developed. This should have been identified in the section on existing drainage studies. The results of these models may be used but must be verified. The verifications should ensure that the model reflect the present conditions, realistic future development scenarios and up- to-date water management policies.
- Sketch of proposed structure(s) and roadway grades in plan and profile showing crown grade elevation, super structure, bent locations, limits and elevations of rip rap and any channel modifications.

For Culverts

The Hydrotechnical report should document the information listed below.

- Culvert type, shape, size, material, skew and number of barrels
- Culvert slope, inlet and outlet elevations and longitudinal profile, note cases where there are drops inside the culvert.

- Tailwater elevation and associated analysis. The analysis is to be included in an appendix.
- Type of inlet and outlet treatments including slope tapers, collars, wing-wall, etc. This information should indicate the rationale for selecting the proposed end treatments and an assessment of structural vulnerability to lifting, piping and other forces. If clay seals are required, this should be indicated and their location identified in drawing and sketches. The inlet, outlet and other minor energy loss coefficients should also be documented.
- The type of hydraulic analysis methods used (design tables or computer software). The discussion in this section should include confirmation that these method(s) are acceptable to MTO.
- Hydraulic analysis for all required flow rates.
- Headwater elevations for inlet and outlet control conditions identifying the maximum allowable headwater elevation, as described in the design criteria.
- Inlet and outlet velocity, as well as velocity within the culvert.
- Performance curve for inlet, outlet control and the governing conditions.
- Energy dissipaters, debris control measures and special erosion control measures upstream and downstream.
- Details of protection measures for corrosion or abrasion inside the culvert, if applicable.

The Design Water Levels

The Design Water Level estimates for the each of the design flow rates used in the analysis should be documented with background information and calculation procedures(s) included in an appendix and briefly described in the body of the report.

In addition to the above, the report must document the analysis and design for scour, ice and debris.

4.3.3 Scour Analysis

Scour is the lowering and/or widening of the streambed due to the erosive forces exerted by flowing water. Channel scour is an important consideration in the design of water crossings as it may undermine the foundations of the structure.

- Various methods of calculating the depth of scour should be considered depending on the site characteristics:

- The limitations of each method should be reviewed. Applicability of the method used should be documented. If a particular method is not suited to the site conditions, it should not be used.
- Scour depths resulting from any analysis should be compared with soil stratigraphy at that depth, including relative compaction, to verify that the initial assumptions of soil properties are valid.

Documentation Requirements

This task should identify the extent of scour, both local and general (natural), and the resulting decision on the type, depth, and location of the bridge footings. The information to be documented should include but is not limited to the following:

- The check flood used for the analysis of scour.
- Input parameters to the analysis. This would include:
  - Stream width, depth and slope
  - Stream bed material
  - Constrictions in the channel opening
  - Obstructions in the channel opening
- The method used in the analysis of local and natural scour.
- The results of the analysis and the methods used to arrive at the final scour depth.
- The type of footings being proposed and the proposed depth of footing for the abutments and piers.
- Plot of estimated scour depths on profile view, for each of the design alternatives being considered.

4.3.4 Ice Jam Analysis and Debris Flow Analysis

The design of a crossing should be checked for the potential impact of ice and debris on the flow through the structure. Ice and debris jams are caused by:

- Constriction of flow
- Obstruction of flow
- Channel bend (Radius < 4 times the channel width)

Ice jams are usually formed during ice break-up and are a result of solid ice sheet downstream acting as an obstruction due to upstream flows experiencing earlier ice break-up (e.g., Rivers flowing north to James Bay or Hudson Bay).

The Hydrotechnical report should include an assessment of river ice conditions and an estimate of design high ice elevation, including conducting an ice jam modeling. Results of ice jam modeling shall be provided for consideration during bridge soffit and pier design.

The Hydrotechnical report should also include an assessment of the potential for debris flow and an estimate of high debris flow elevation for consideration during bridge soffit and pier design.

Documentation Requirements

Design ice flow conditions including high ice elevation and the effective thickness of ice floes related to the CHBDC should be estimated and documented based on anticipated discharges and stages.

Where possible, such assessments should be complemented or verified with field data such as ice scars on trees, banks, and historic information based on interviews with long term residents in the area. This information is valuable for the design of piers and abutments and should be included in the hydrotechnical report.

Where the potential for jamming due to debris or ice has been identified, the implications on the proposed waterway opening should be assessed and documented. This would include assessing the minimum span between piers, span configurations, minimum clearance between the HWL and the soffit. In those cases, historical information gathered from residents or archives should be included in this discussion.

Where ice or debris problems require the construction of control devices the design of such devices should be provided and their impact on the flow in the watercourse under ice/debris free conditions should be documented.

4.3.5 Recommending the Best Alternative

After the design of all alternatives has been completed, a summary of the different alternatives should be provided, and the recommended alternative be identified. The documentation of the recommended alternative should be supported with the rationale for the recommendation.

Documentation Requirements

The documentation should include:

- A summary description of the proposed design alternatives indicating the main features of each design such as:

    - Description of the structure such as: type, span(s), pier and abutment arrangement
    - Soffit elevation, clearance, road elevation and freeboard
    - Backwater
    - Type of footing, scour depth and scour mitigation measure.
- A summary of any modifications to the approach, the watercourse, private or public utilities (including drainage outlets), lands and structures.
- The rationale for recommending the preferred alternative.
- Cost. The evaluation and selection of a "best" alternate must include an economic analysis to ensure that the selected alternate provides the least total cost from a construction, maintenance, and operation standpoint.

4.4 Bridge Deck Drainage

Bridge deck drainage may be considered as a special case of pavement drainage. Bridge deck drainage is important to traffic safety in wet weather and in winter.

The hydrologic design criteria for bridge deck drainage is set by the MTO Highway Drainage Design Standards, where the return period will vary between 2-10 years depending on the class of road. Bridge deck drainage may not be needed for all bridge structures especially for bridges with short spans.

Documentation Requirements

The design of bridge deck drainage will determine the location and spacing of drain inlets at the approach and on the deck of the bridge.

Accordingly, the following information should be documented in the Hydrotechnical report:

- Input parameters identified in the design criteria and from collected data.
- Design flow rate.
- The type of hydraulic analysis methods used, whether using design tables or computer software. The discussion should demonstrate suitability of the method(s) used and its acceptability to MTO.
- Deck Inlets spacing, type and spacing.
- Down pipe size, number, location and spacing.
- Ground Level Drainage Outlet locations, type and configuration.

5.0 Mitigating Impacts to the Existing Drainage System

The water crossing design must meet the hydraulic performance standards of MTO and other regulatory agencies in the vicinity of the water crossing. However, the MTO recognises that the environment and property of landowners located upstream or downstream of the crossing cannot be damaged as a result of the construction of the water crossing.

Accordingly, the drainage practitioner will complete the following tasks in the group:

- Designing Erosion and Scour Protection Measures
- Design Fish Habitat Protection Measures
- Address Impacts on Lands and Structures

5.1 Designing Erosion and Scour Protection Measures

With the introduction of a water crossing structure, modifications to the watercourse may be required to accommodate the structure and to address the possible impact due to the changes to the watercourse.

The average flow velocity for a given cross-section area provides the conveyance available for the passage of a flood. However, its magnitude also reflects the potential of the flow to cause erosion and scour. It should be noted that, depending on a given flow situation, the local prevailing velocities may be much greater than the average calculated value, especially in the areas of local acceleration such as on the outside of river bends.

Documentation Requirements

The following information should be included:

- Assessment of the erosion and scour potential upstream, downstream, and through the structure.
- Type of erosion and scour protection method proposed.
- The analysis conducted to determine the suitability of the erosion and scour protection methods used.
- Engineering drawings, schematics and illustrations showing plans and cross sections describing the design, location and layout of these measures. These should include dimensions, material type, anchoring and support of the material used.

Where modifications to a watercourse need to be accepted by, or subject to requirements of an operating authority or agency, the design criteria of the watercourse modifications should be

set in consultation with the authority or agency. The Hydrotechnical report must document all requirements and identify how they were accommodated. Where there are conflicts between MTO requirements and those of the other organisation, discussions should be undertaken to reach a resolution. The resolution to any conflict(s) should be documented.

Requirements set based on drainage management and environmental policies, guidelines and manuals of other regulatory agencies should be adhered to and documented. Should any design criteria, drainage management policy, guideline or manual of a regulatory agency conflict with a design criterion, drainage management policy, guideline or manual of MTO, or vice versa, a meeting between the parties may be warranted to resolve the conflict.

Where design criteria have been adopted based on a previous drainage study, these criteria should be identified.

For simple erosion protection works: If the proposed modification only involves simple erosion protection works such as lining material or rip-rap placement, the Hydrotechnical report need only document how the proposed method will provide the necessary erosion protection for the flow velocities at the reference points and range of frequencies.

5.2 Design Fish Habitat Protection Measures

Fish habitat protection measures are a requirement placed by DFO or MNDMNRF/Conservation Authority on their behalf. They are intended to accommodate the passage of fish through a water crossing structure and to address the impact of changes to the channel in the vicinity of the structure. Habitat protection measures are commonly used in culverts however, some are applicable to bridges.

Flow velocities, occurring during the migration periods must be evaluated for the proposed structure. If velocities exceed those that will allow fish species to migrate upstream, then fish habitat protection measures must be considered.

Fish habitat protection measures may be installed to allow fish passage and create or enhance habitat - this will mitigate loss of habitat due to encroachment into the stream or channel realignment. Habitat protection measures include:

- Pools
- Clusters
- Riffles
- Deflectors
- Sills
- Groins
- Weirs

Documentation Requirements

The Hydrotechnical report should document the requirements of the regulatory agencies and provide a listing of the alternative measures considered to address these requirements.

Once a preferred and agreed upon option has been identified, the rationale for the selection of that option should be documented. An option may include a combination of protection measures. At this stage the hydraulic impact of introducing these habitat protection measures should be completed and the analysis documented. The impacts could include but are not limited to the following:

- Increased backwater
- Increased erosion upstream and/or downstream
- Changes in the flow regime and associated increased potential for occurrence of a hydraulic jump.

The increases in backwater effect and/or erosion should be mitigated either through redesign of the opening or by reducing the head loss through the structure. The summary of this analysis should be included.

5.3 Address Impacts on Adjacent Lands

The construction of a water crossing may aggravate flooding problems and could be the cause of increased impacts on surrounding lands and structures. As per MTO HDDS, the new drainage structure shall, at a minimum, not have an adverse impact on the adjacent lands beyond the preconstruction level for design flow event.

Documentation Requirements

The Hydrotechnical report should clearly identify the lands and structures that will be impacted by the design flow event as well as extreme flow events (100-year and/or regulatory as defined in the MTO Highway Drainage Design Standards), with the new water crossing structure in place. This should include the following information for each structure:

- Location.
- Design flow and regulatory flow water level elevation.
- A measure of the importance of the structure/roadway (social and economic value).
- Hydraulic modeling results showing the extent of the impact on the adjacent lands and structures, for each event, resulting from the new water crossing.
- The proposed design shall maintain the preconstruction water levels at the design flow.

- If maintaining the preconstruction water levels are not achievable, the impact mitigating design shall be provided.
- Consultation with the conservation authority, the municipality and effected landowners should be undertaken to ensure the proposed impact mitigation measures are acceptable.

6.0 Mitigating Construction Issues

The hydrotechnical design may include the following elements:

- Requirements for Erosion and Sediment Control During Construction
- Temporary Flow Passage Systems and Temporary Drainage Facilities

6.1 Requirements for Erosion and Sediment Control During Construction

Where applicable, a sediment and erosion control plan stamped by a Professional Engineer should be completed before final approval of a water crossing design. The plan is required to ensure that proper techniques will be used to minimize the impacts on the watercourse and the surrounding environment. The MTO Environmental Guide for Erosion and Sediment Control During Construction of Highway Projects details measures.

Documentation Requirements

Issues to be addressed and documented in the Erosion and Sediment Control Plan are listed below.

- **Construction timing** and the proposed construction timeframe and timing constraints for construction (spring, fall constraints) should be noted.
- **Construction phasing** and timeframes for the different phases should be included. Indicate whether the entire site is to be developed all at once or whether the proposed land development is to be phased. Sediment control techniques must address both pre-serviced and serviced phases of construction.
- **Stabilization requirements** and the allowable timeframe for land to remain exposed before it is stabilized with sod, mulch, or hydro seeding, should be noted. Indicate provisions for the stockpiling of soil.
- **Topsoil stockpile storage locations** for soil storage piles and their distance from roads and drainage channels should be clearly shown. Timeframes and proposed works for the stabilization and remediation of topsoil stockpiles should be provided.
- **Inspection and maintenance requirements** of the sediment and erosion control works should be noted. Maintenance should be performed as required to ensure the proper operation of sediment and erosion controls, and the works should be inspected after each storm to ensure proper operation.

6.2 Temporary Flow Diversion Assessment

An assessment of the constructability of the proposed design where a Temporary flow diversion system is required should be included in the report.

The MTO HDDS identify the return periods and hydraulic performance standards for the sizing of temporary drainage works (e.g. pumps, channels, pipes, culverts and bridges) for conveyance of surface water and/or natural watercourses.

The standard applies to:

- Temporary Flow Passage Systems (TFPS) implemented within a watercourse (ditch or natural channel) to convey or divert water past an area under construction where flow is contained within the existing alignment.
- Temporary drainage facilities (e.g. channels, pipes, culverts and bridges) constructed as a temporary alignment of a watercourse.

Appendix A – Requirements Checklist

Checklist 1: Collecting Background Information

	Report Requirements	Applicable	Comments
Review Previous Drainage Studies	Review and reference watershed, sub-watershed, or master drainage plans.		
	Review and reference MTO Environmental Study Reports.		
	Review and reference other drainage studies such as: - Flood Damage Reduction Program Study (FDRP) - Erosion Control Study - Flood Control Study - Other:_____		
	Conformance to previous highway studies (e.g. preliminary design reports).		
Identify Data Needs and Availability	Identify data needs and how much of the data is available.		
Identify Characteristics of the Watercourse	Identify the physical characteristics of the watercourse.		
	Identify the history of flooding.		
Investigate Stability of the Watercourse	Identify the geomorphic stability of the stream at the proposed crossing location.		
	Establish the design criteria that would address the conditions of the watercourse at the proposed crossing location. - Location of the crossing - Location of piers and abutments - How the major flow will be addressed (pass through the structure, overtop the approach, or overtop the structure) - Depth of the foundation - Requirements for watercourse training works - Requirements for channel armouring		

Checklist 1: Collecting Background Information

	Report Requirements	Applicable	Comments
Identify Site Conditions	Complete a site inspection at the proposed water crossing sites and collect required data and information.		
	Identify site constraints.		
Identify Applicable Regulatory Requirements	Identify regulatory fish habitat requirements from: - MNR - MOE - DFO - Others:_____		
	Identifying regulatory flood line requirements from: - Conservation Authorities - Others:_____		
	Identify approval requirements from other agencies.		
Identify Existing Drainage Problems	Identify existing drainage problems on upstream and downstream riparian property.		
Assess Existing Drainage Structures Upstream and Downstream	Identify if there are bridge or culvert structures upstream or downstream, including their configuration and distance from the proposed structure.		
	Identify existing drainage problems of other bridge structures upstream or downstream.		
	Identify impact of the other structures on the design criteria for the crossing being considered.		

Checklist 2: Performing Hydrotechnical Analysis

	Report Requirements	Applicable	Comments
Establish Drainage Design Criteria	Develop the design criteria for the proposed structure based on collected data, MTO standards, policies, guidelines, manuals, and the CHBDC.		
	Acquire approvals for the proposed design criteria and modify design criteria if necessary.		
Approval Requirements	Acquire MTO Approvals for: - The design criteria - Deviations for CHBDC, if applicable - Preliminary Hydrology Report and - Detailed Hydrology Report.		
Other Regulatory Requirements	Determine the requirements of other agencies such as MNRF, MECP, OMAFRA and DFO that are to be considered in design criteria and identify timelines for permit applications and/or consultation period.		
Design to Convey the Regulatory Storm	Identify the High-Water Level, flood plain and flow path for the regulatory flow event.		
	Identify if the post-development extreme event will flow over the approach, over the structure, or through the structure.		
	Determine the depth of flow: at the approach and over the structure.		
	Identify design features that will allow the structure to withstand additional forces due to overtopping, if applicable.		
Hydrologic Analysis	Perform the hydrologic analysis or verify existing analysis. determine the design, check and regulatory flow rates using appropriate stream gauge station. Perform frequency analysis on stream flow data for 2, 10, 25, 50, 100-year return periods.		

Checklist 2: Performing Hydrotechnical Analysis

	Report Requirements	Applicable	Comments
	Perform the hydrologic analysis or verify available analysis. determine the design, check and regulatory flow rates. apply the alternative runoff simulation methods based on precipitation and watershed characteristic data for (2, 10, 25, 50, 100-year return periods). Document results of the analysis		
	Identify how climate change has been applied in accordance with MTO specifications		
Design Alternatives	Identify the different possible alternatives for crossing such as different locations, different configurations, spans or height of structure, and different types of structure (bridge or culvert).		
Design the Bridge or Culvert Opening	Perform the hydraulic analysis to size the bridge or culvert opening(s).		
	Conduct water surface profile calculations, or verify existing analysis, to determine backwater and assess the resulting impacts upstream and downstream. (An appropriate number of stream cross sections must be selected and defined for an accurate assessment of the water surface profile.) - Identify downstream/upstream reference point - Perform analysis - Document results of the analysis		
	Determine flow velocities for all storm events modelled.		
Scour Analysis	Perform the analysis to ensure the level of scour will not jeopardise the structural integrity of the bridge or culvert crossing.		
	Determine the appropriate depth of footing for the piers and abutments.		

Checklist 2: Performing Hydrotechnical Analysis

	Report Requirements	Applicable	Comments
Ice and Debris Jam Analysis	Determine the requirement for conveying ice and debris flow and avoiding ice jams.		
Recommending the Best Alternative	Provide a summary of the different alternatives and identify the recommended alternative.		
Bridge Deck Drainage	Determine the location and spacing of drain inlets at the approach and on the deck of the bridge		

Checklist 3: Mitigating Impacts to the Existing Drainage System

	Report Requirements	Applicable	Comments
Designing Erosion Protection Measures	Provide scour and erosion control measures at the location of the crossing , upstream, and downstream if necessary.		
Design Fish Habitat Protection Measures	Design fish habitat protection measures. - Select the appropriate type of measures - Ensure flow velocities are suitable for migration of fish species - Ensure hydraulic suitability of proposed measures - Address any impact upstream and downstream		
Address Impacts on Lands	Determine the impact on surrounding lands and structures and develop solution to address these impacts, if feasible.		
	Determine the impact on the highway and develop solution to address impact, if feasible.		
	Determine the requirements for compensation to affected structures or lands, if applicable.		

Checklist 4: Mitigating Construction Issues

	Report Requirements	Applicable	Comments
Requirements for Erosion and Sediment Control During Construction	Where applicable, a sediment and erosion control plan stamped by a Professional Engineer should be completed which identifies: - Construction timing - Construction phasing - Stabilization requirements - Topsoil stockpile storage locations - Inspection and maintenance requirements		
Temporary Flow Diversion Assessment	Assessment of the constructability of the proposed design where a Temporary flow diversion system is required. Applicable for both Temporary Flow Passage Systems and Temporary drainage facilities		