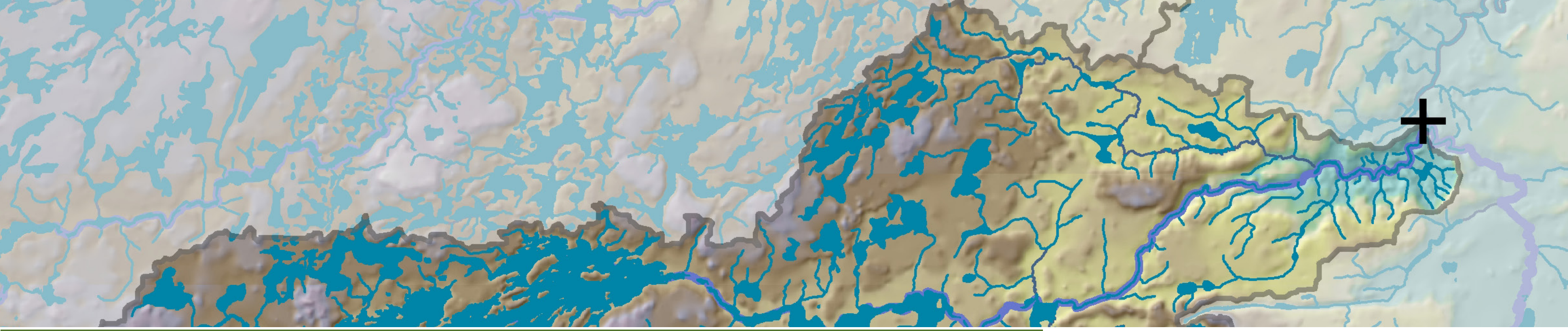


User Manual
Ontario Flow Assessment Tool III

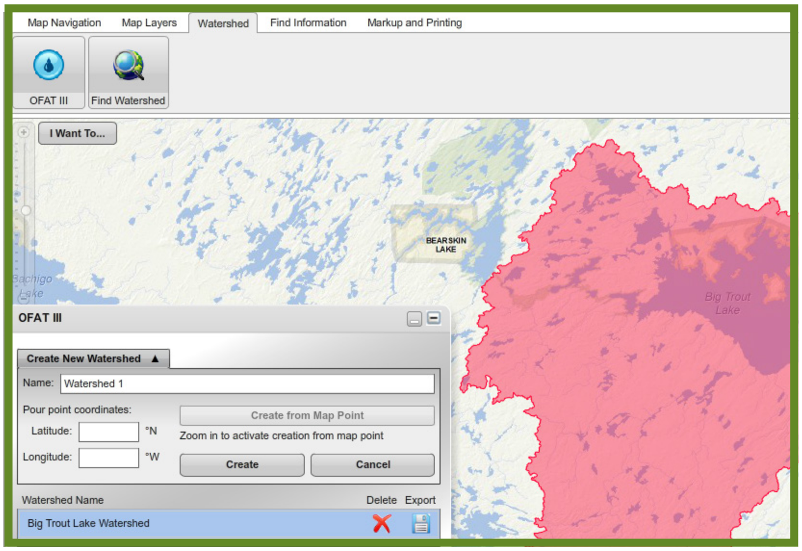
2013

Objective

Ontario Flow Assessment Tools, version III (OFAT III) is an online, spatially-based application to automate a series of labour-intensive technical hydrology tasks. OFAT III calculates flow quantity estimation values and several intermediate outputs, such as watershed delineation and characterization. These derivatives can be used by a variety of users and applied to many water-related applications.

Using a newly redesigned base map, the OFAT III user enters a watershed drainage point on a mapped hydrology feature, such as a stream, river, or lake anywhere within the land boundary of Ontario, including Ontario's far north. The resulting watershed can then be used as a mask within OFAT III to summarize key watershed characteristics. The watershed layer and the characteristics, along with other spatial data, can be fed into Flood Flow, Low Flow and Mean Annual Flow models.

The user can view all spatial and tabular outputs online and download these outputs to the users' desktop for further specialized viewing or analysis. Only a standard Internet browser is required to use OFAT III.



Background

This document contains detailed help from using OFAT III to the specifics around input data and models OFAT III uses to produce the generated outputs.

If further help is required, persistant problems occur with the application or the data that OFAT III uses, or if anything is omitted from this Help document, please contact Spatial Data Infrastructure, Ontario Ministry of Natural Resources; sdi@ontario.ca.

Ontario

Executive Summary

Ontario Flow Assessment Tools, version III (OFAT III) is an online, spatially-based application to automate a series of labour-intensive technical hydrology tasks. OFAT III calculates flow quantity estimation values and several intermediate outputs, such as watershed delineation and characterization. These derivatives can be used by a variety of users and applied to many water-related applications.

Using a newly redesigned base map, the OFAT III user defines a watershed drainage point on a mapped hydrology feature, such as a stream, river, or lake anywhere within the land boundary of Ontario, including Ontario's far north. The resulting watershed can then be used as a mask within OFAT III to summarize key watershed characteristics. The watershed layer and the characteristics, along with other spatial data, can be fed into Flood Flow, Low Flow and Mean Annual Flow models.

The user can view all spatial and tabular outputs online and download these outputs to the users' desktop for further specialized viewing or analysis. A standard Internet browser is required to use OFAT III.

Résumé

Ontario Flow Assessment Tools (outils d'évaluation des débits d'eau en Ontario), version III (OFAT III) est une application d'information géographique en ligne qui automatise une série de tâches techniques liées à l'hydrologie exigeantes en main d'œuvre. OFAT III estime le débit des eaux et produit plusieurs autres renseignements intermédiaires comme les limites du bassin hydrologique et ses caractéristiques. Ces renseignements dérivés peuvent être utilisés par de nombreuses personnes et appliqués à plusieurs domaines liés à l'eau.

Utilisant une carte de base récemment remaniée, l'utilisateur OFAT III entre un point de drainage du bassin hydrologique sur un lieu hydrologique cartographié, comme un ruisseau, une rivière ou un lac, n'importe où à l'intérieur des limites terrestres de l'Ontario, y compris le Grand Nord de l'Ontario. Le bassin hydrologique résultant peut ensuite être utilisé comme masque dans OFAT III pour résumer des caractéristiques clés du bassin hydrologique. Des modèles de débit de crue, de débit faible et de débit annuel moyen peuvent être appliqués à la couche du bassin hydrologique et aux caractéristiques ainsi qu'à d'autres données spatiales.

L'utilisateur peut voir toutes les données de sortie spatiales et tabulaires en ligne et télécharger ces données de sortie sur son propre ordinateur pour examen ou analyse spécialisés ultérieurs. Un fureteur Internet standard suffit pour utiliser OFAT III.

Cette publication hautement spécialisée Technical Release – Ontario Flow Assessment Tools (OFAT) Version 3.0 – User Manual, n'est disponible qu'en Anglais en vertu du Règlement 411/97 qui en exempte l'application de la Loi sur les services en français. Pour obtenir de l'aide en français, veuillez communiquer avec au ministère des Richesses naturelles au mnr.nric.mnr@ontario.ca ou 1-800-667-1940.

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Where to Go for More Help

This document contains detailed help from using OFAT III to the specifics around input data and models OFAT III uses to produce the generated outputs.

If further help is required, persistant problems occur with the application or the data that OFAT III uses, or if anything is omitted from this Help document, please email Spatial Data Infrastructure, Ontario Ministry of Natural Resources; sdi@ontario.ca

System Requirements

OFAT III requires an internet connection, current internet browsers, and a minimum screen resolution of 1024 x 768. Recommended screen resolution is 1280 x 1024.

Table of Contents

1.0 OFAT III Quick Start

The general sequence of a complete OFAT III run is to:

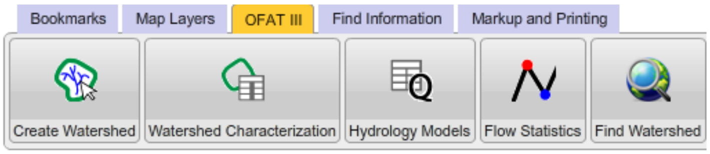
1. Create a watershed
2. Characterize the watershed
3. Execute hydrology models for the watershed.

At any time, Flow Statistics for select northern Ontario HYDAT gauges can be viewed.

1.1 Create a Watershed

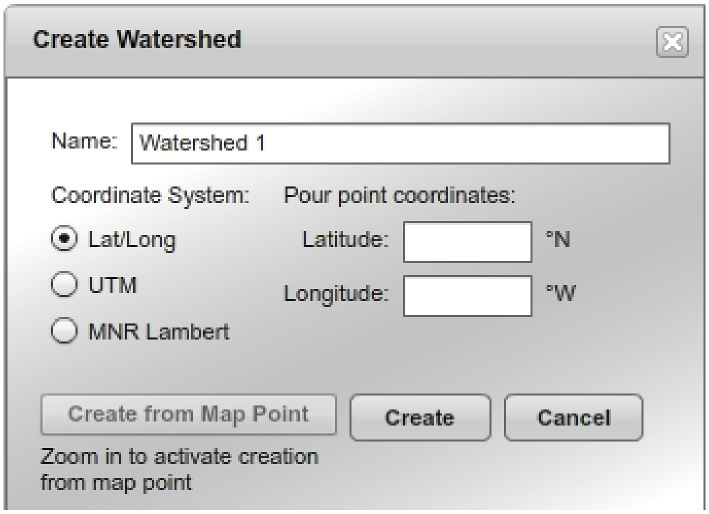
A watershed is created in OFAT III by entering a pour point (a point through which all the water of the watershed will drain through). In OFAT III, a pour point must exist on a mapped hydrology feature (lake or stream), and must exist within the land boundary of Ontario; a point within the Great Lakes will not generate a watershed.

a. Click on the OFAT III Menu.



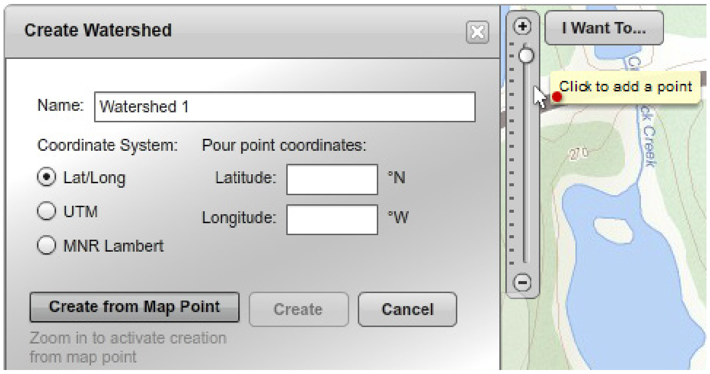
b. Click on the *Create Watershed Button*.

c. The *Create Watershed* widget will appear on the left side of the application. A default name of Watershed 1 is auto populated. This can be changed prior to establishing a pour point.



d. Establish a pour point. A pour point can be established by two different methods:

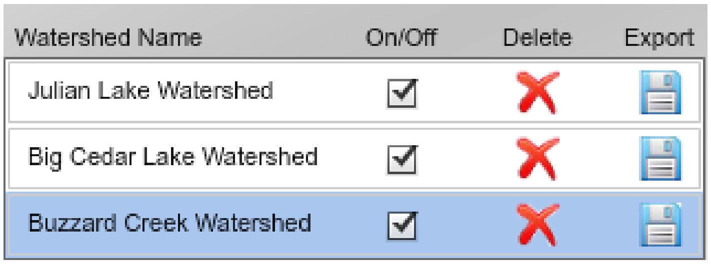
i. Enter the Coordinates of the pour point in the text boxes of the Create Watershed widget. The coordinates can be entered by using one of three supported projections. Choose between the projections by clicking the associated radio buttons as seen in the image to the right. The coordinates entered must be within 90 metres of a mapped hydrology feature.



ii. Create a pour point by a mouse click on a hydrology feature. To do this, zoom into the feature until the *Create from Map Point* button is enabled. The button is enabled at the second zoom level from the top. The point created by the mouse click must be within 90 metres of a mapped stream.

e. If successful, the generated watershed is then added to the *Watershed Name* TOC (Table of Contents).

f. Additional watersheds can be generated by the same steps as above. The results will be added to the *Watershed Name* TOC.



1.2 Characterize the Watershed

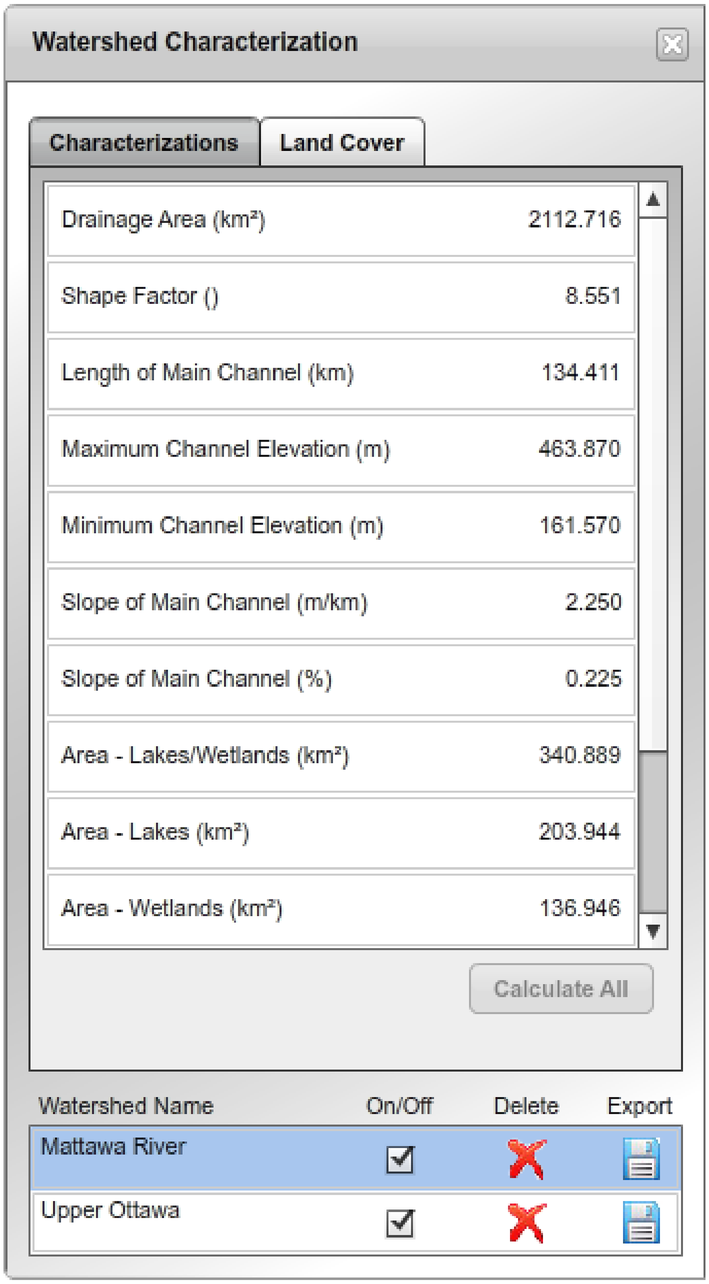
Currently twelve characterizations, and a land cover summary can be computed for each generated watershed. See the accompanying figures to the right.

To compute the physiographic watershed characterizations:

a. Click the *Watershed Characterization* Tab within the Watershed Characterization widget.

b. Within the *Watershed Name* TOC highlight the desired watershed to compute its characterization(s).

c. Click the *Calculate* button next to each of the characterizations to compute that characterization. To compute all characterizations, click the *Calculate All* button.



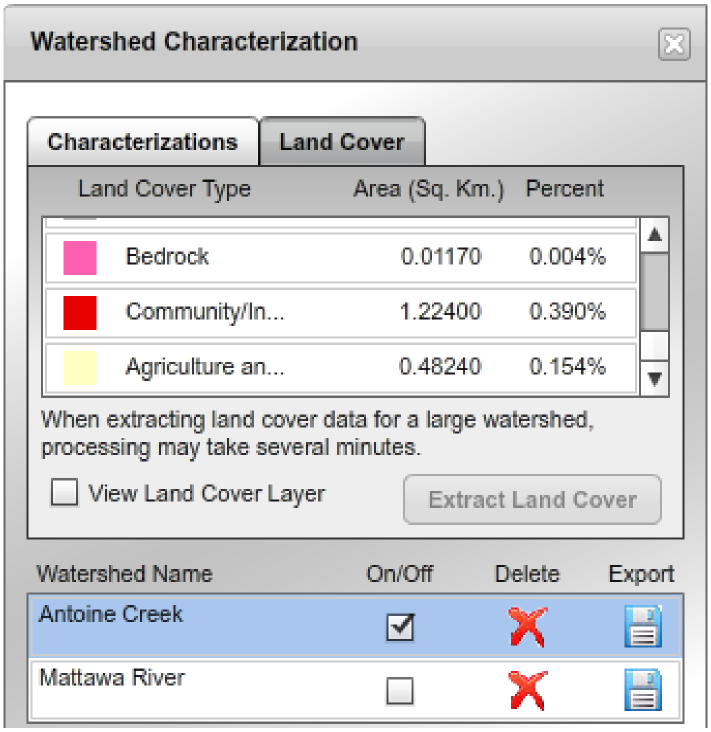
To compute the land cover summary;

a. Click the land cover tab within the Watershed Characterization widget.

b. Within the Watershed Name TOC highlight the desired watershed to summarize its land cover.

c. Click the Extract Land Cover button underneath the summary table.

To view the land cover on the map, click the View Land Cover Layer checkbox in the widget.



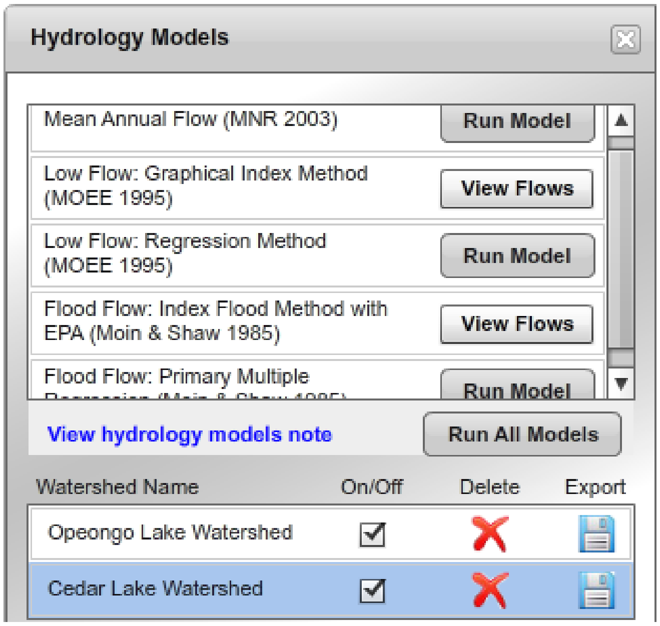
1.3 Execute Hydrology Models

Currently five hydrology models can be computed for each generated watershed. See the accompanying figure.

a. Click the *Hydrology Models* button within the OFAT III menu to activate the widget.

b. Within the *Watershed Name TOC* highlight the desired watershed to compute the hydrology model(s) flows.

c. Click the *Run Model* button next to each of the hydrology models to compute the flows. To run all models, click the *Run All Models* button.



1.4 View Flood Flow and Low Flow Gauge Statistics

Mean Annual Flows (MAF), Flood Flow and Low Flow gauge statistics, and Flow Duration Curves (FDC) can be viewed for HYDAT gauges in the southwestern Hudson Bay and Ontario's portion of the Nelson River basin.

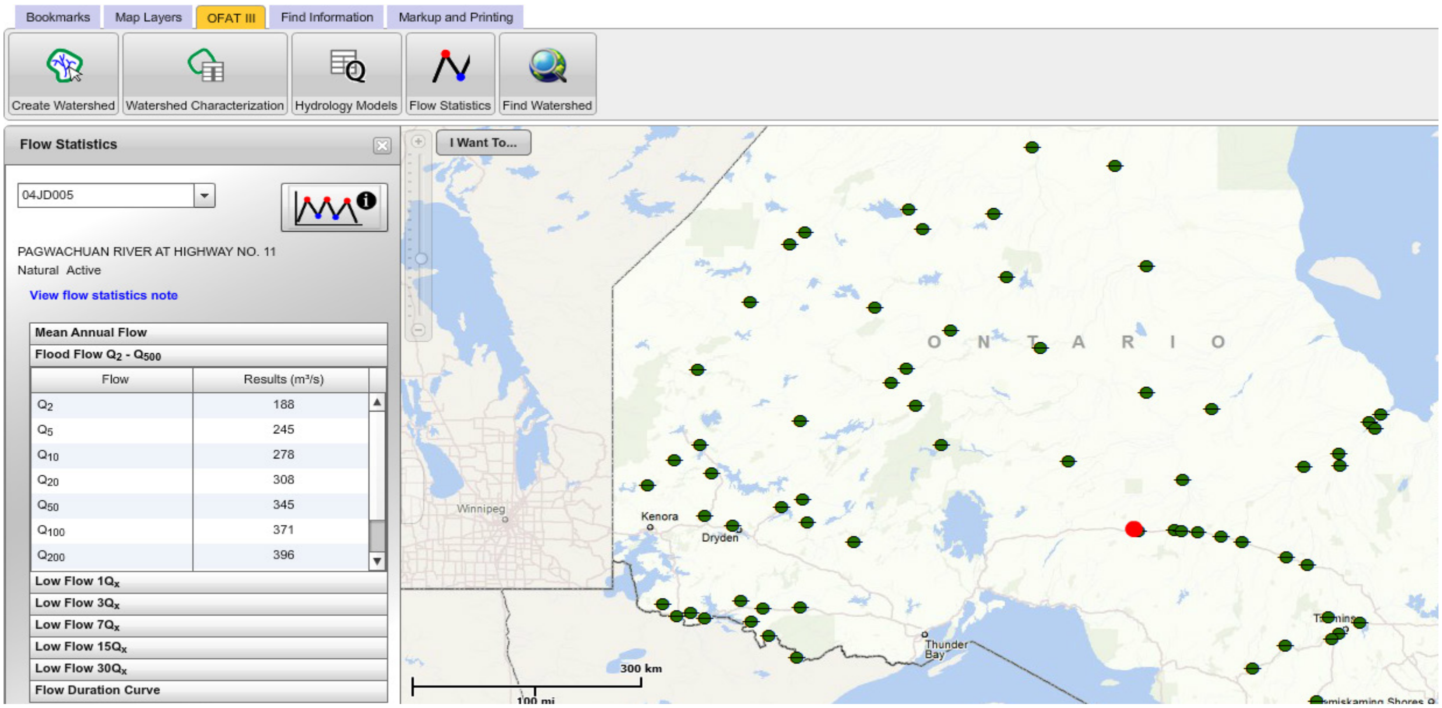
a. Activate the Flow Statistics widget from the OFAT III menu. When the widget activates, the available gauges are drawn on the map, and station IDs arepopulated within the combo box on the widget interface.

b. Selecting a gauge to view statistics can be accomplished by one of two ways;

i. Select the gauge in the combo box. Typing the gauge ID in the combo box will narrow the selection.

ii. Select the gauge by activating the gauge statistics info button, and then selecting on the map.

c. When a station has been selected, the MAF, Low Flow and the Flood Flow Statistics, and FDC will be populated in the accordian tables on the left. Click the desired header to see the contents



2.0 Overview of OFAT III

2.1 Introduction

Ontario Flow Assessment Tools, version III (OFAT III) is an online, spatially-based application to automate a series of labour-intensive technical hydrology tasks and view select hydrology information such as low flow and flood flow statistics. OFAT III calculates flow quantity estimation values and several intermediate outputs, such as watershed delineation and characterization. These derivatives can be used by a variety of users and applied to many water-related applications.

Using a newly redesigned base map, the OFAT III user enters a watershed drainage point on a mapped hydrology feature, such as a stream, river, or lake anywhere within the land boundary of Ontario, including Ontario's far north. The resulting watershed can then be used as a mask within OFAT III to summarize key watershed characteristics. The watershed layer and the characteristics, along with other spatial data, can be fed into Flood Flow, Low Flow and Mean Annual Flow models.

The user can view all spatial and tabular outputs online and download these outputs to the users' desktop for further specialized viewing or analysis. Only a standard Internet browser is required to use OFAT III.

2.2 Background

When initially released in 2002, Ontario Flow Assessment Techniques I (OFAT I) developed by the Ministry of Natural Resources'(MNR) North East Science and Information (NESI) was a system ahead of its time. OFAT I was visionary, providing automated implementation of existing, very labour intensive, manual hydrology calculations (Chang et al. 2002). This system provided users with the potential to estimate flow regimes representing low flows (e.g., 7Q2, 7Q10, 7Q20, etc.), flood flows (e.g., Q2, Q10, Q25, Q100, etc.), mean annual flows, minimum instream flow requirements, and bankfull flows for watersheds in Ontario outside the extent of the far north of Ontario. This functionality allowed users to compare and explore obtained results across regional models with the confidence of standardized Geographic Information System (GIS) processes and attribute handling.

OFAT I was a customized add-on to proprietary GIS software. Updates to newer versions of GIS software necessitated a re-work of OFAT. In 2003, work began on OFAT II, but was never fully completed or documented. A major innovation with OFAT II was the inclusion of a "Daily Flow Toolkit". Using the refined and quality controlled time-series flow data from Environment Canada's Hydrometric (HYDAT) database, this Toolkit contained the functionality to derive 6 daily flow calculations.

The provincial need for "OFAT-like" functionality across Ontario has not diminished over the intervening years, evidenced by regular requests for OFAT and OFAT outputs. In the far north of Ontario, this need was heightened with the initiation of land use planning activities across this zone. These factors led the MNR's Water Resources Information Program* (WRIP), with support from the Far North Branch, Integration Branch, and the Land and Resources Cluster, to build OFAT III.

2.3 Functionality

A central requirement of any spatial hydrology modelling tool is the ability to accurately delineate and characterize watersheds. An objective of this project was to develop such a tool that was easily and openly accessible for widespread application via the Internet. Such an application serves the needs of the flow modelling community and can be actively employed to support science and policy groups across the Ontario Public Service (OPS) (and beyond) that require access to authoritative watershed definitions and

* As of late 2013, WRIP has been merged into the Spatial Data Infrastructure Unit, Geographic Information Branch, OMNR

characteristics. For example, the Ontario's Far North planning area represents 44% of the province and within this zone there is a severe shortage of flow monitoring data. Understanding our water resources in this part of the province requires a heavy reliance on modelled approaches.

At the core of OFAT was the automated implementation of 18 existing regional hydrologic models and empirical relationships pertaining to flow estimation in Ontario. In recognition that many of these models/equations are now dated and/or rarely used in Ontario, it was decided early in this project that an independent evaluation of regional models/empirical relationships would be conducted by Trent University's Institute of Watershed Science. This evaluation, and consultation with the hydrology community to gauge the applicability/value of the individual models, led to the implementation of five regional hydrology models for OFAT III.

Table 1. Current OFAT III Hydrology Models

Type	Model
Flood Flow	Index Flood with Expected Probability Adjustment (Moin & Shaw 1985)
	Primary Multiple Regression Method (Moin & Shaw 1985)
Low Flow	Graphical Index Method (MOEE, 1995)
	Regression Method (MOEE, 1995)
Mean Annual Flow	Mean Annual Flow (MNR 2003)

2.4 Use and Limitations of OFAT

The most fundamental function of OFAT is to generate a watershed within 90m of a watercourse in Ontario. Watersheds can be included in a wide variety of planning and analysis.

Most often stream flow statistics are required in areas where stream flow gauges do not exist. OFAT III generates modelled stream flow statistics for any mapped stream reach in Ontario. Depending on the use of the output, field verification may be appropriate.

Among other applications, baseline flow information is needed to:

- design hydraulic structures such as culverts, bridges, dams, etc
- protect or enhance fish habitat
- support an ecosystem approach to land and water management
- water use and wastewater permitting analysis
- support various academic studies.

Provincial specific application areas of OFAT III are listed in Appendix 2.

The generated stream flow statistics from the models assume natural flow conditions within the watershed of interest. Influences that regulate flow in any way, such as dams, or withdrawals, can significantly alter the flow quantity. Also, the flow models require certain ranges of input parameters such as drainage area of the watershed. If parameters fall outside of the range required for the model, such as the drainage area for a very small watershed, results may contain small to large errors. Model outputs in OFAT III include a statement on the status of input parameter ranges for the particular model.

OFAT III obviously can not provide tools for all water related applications, which is why all data generated in OFAT III can be downloaded to the users' desktop. The spatial watershed boundary and its associated physical characteristics that are implemented in OFAT III provide nearly instant, accurate results that otherwise could be a significant undertaking.

2.5 Data

As OFAT was first being developed in 2000, base data projects were underway to create the provincial hydrology, elevation and derivative GIS datasets necessary to support spatial hydrology analysis. In the absence of yet established provincial datasets WRIP developed a full suite of required data layers as "one-off" products strictly to support OFAT and OFAT users. While this was a practical response to this data gap, it was not optimal in terms of data quality, data updates and longer term "integratability" with other data. Since the initial OFAT development, these required datasets have been produced in Universal Transverse Mercator (UTM) projections in a more rigorously standardized and quality controlled environment (Kenny and Matthews 2005; Kenny et al. 2008; WRIP 2008a, 2008b, 2008c; Zhao et al. in press). These data products are substantially refined and are now openly available to Ontario's water management community.

As refined and useful as these hydrology and elevation data holdings are, there were still several limitations to using these data uniformly across the province in a modelling environment that might encompass watersheds that span more than half the province. These challenges include;

- The scale of provincial base data and derived data is variable. There exists 1:10,000 scale base data in southern Ontario and 1:20,000 scale base data in northern Ontario,
- The raster hydrology, elevation and derivative data layers were developed in a UTM projection (4 zones) which critically limits spatial watershed representation across UTM zones, and
- The data holdings were not Provincial in scope (a usable hydrology base in the Far North is absent).

To address these items listed above, the WRIP has now completed a major undertaking producing separate GIS hydrology, elevation and hydrology derivative datasets in a seamless, provincial standard Lambert Conformal Conic (LCC) projection for the entire province. The base hydrology data in this projection allows users to work in a seamless data environment. To address base data scale differences all developed raster data layers have been created at a uniform 30 metre grid resolution and are available as an "Integrated Hydrology Data Package" that was first available in late 2012 (WRIP 2012). This seamless LCC data is employed as the backbone of OFAT III.

A detailed data description, and links to metadata used in OFAT III is provided in Section 6.0.

2.6 Website

The OFAT III release is a spatial web application. Deployment in a web environment offers numerous advantages over that of a desktop application or GIS extension. Updates and additions to the tool can be implemented readily and improved data can be interchanged easily without the need of any action from the user group. Large data volumes sent out on storage media that the user must manage will not be required. Downloading of generated data conforming to a well documented data model is available to the user along with metadata of the input data used to generate the results. The data model and metadata links are available in this document.

URL: TBD (At time of press, URL was not available)

2.7 Future Enhancements

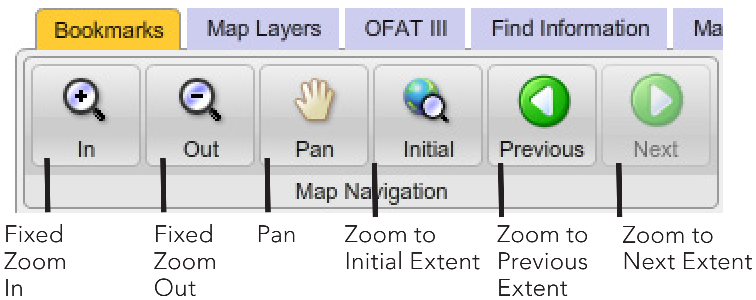
OFAT III is not a static application. Enhancements are already in progress. The Mapping and Information Resources Branch/Spatial Data Infrastructure Unit of the OMNR is willing to entertain any partnerships or suggestions that are compatible with the vision of OFAT.

3.0 The OFAT III Interface

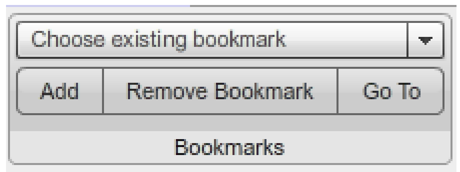
Only an internet browser is required to run OFAT III. Upon starting OFAT III the user is presented with a full view of Ontario, along with the surrounding provinces and states. The functions of OFAT III are only available for Ontario. Five Menu Tabs placed horizontally across the screen below the OFAT III banner each have a set of tools associated with them. These menu tabs; Bookmarks, Map Layers, OFAT III, Find Information, Markup and Printing and their group of tools are briefly explained below.

3.1 Map Navigation

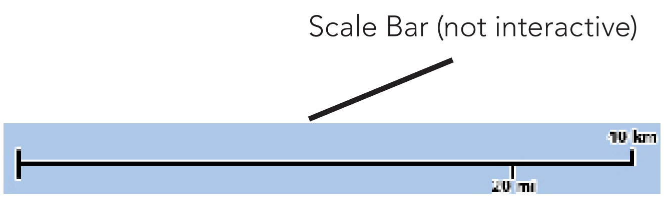
Map Navigation is only found under the Bookmarks Menu. Other sub menu's do not include the map navigation tools.

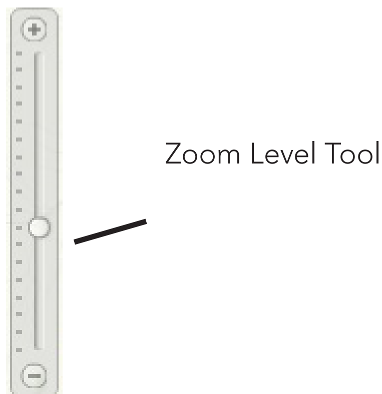


Create, use, and manage bookmarks. Bookmarks are named and user defined map extents are saved for the current session.



Other map navigation tools located on the map:





3.2 Map Layers

Selecting the *Map Layers* Menu, followed by clicking the *Map Layers* button will bring up a layer list with two main categories 'Map Data' and 'Background Map and Imagery'. Within 'Map Data' there are two categories - 'Watersheds' and 'OFAT III Viewable Data':

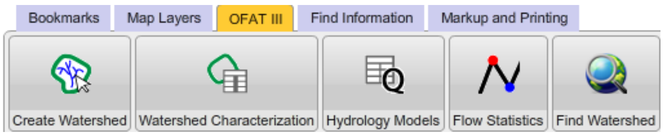
OFAT III Viewable Data contains application specific data that can be viewed. These include the Extreme Flow Statistics layer used in the OFAT III/Flow Statistics widget, and the Primary, Secondary, and Tertiary Watersheds layers are included for general reference of Ontario's watersheds. Any watersheds layer may take some time to draw.

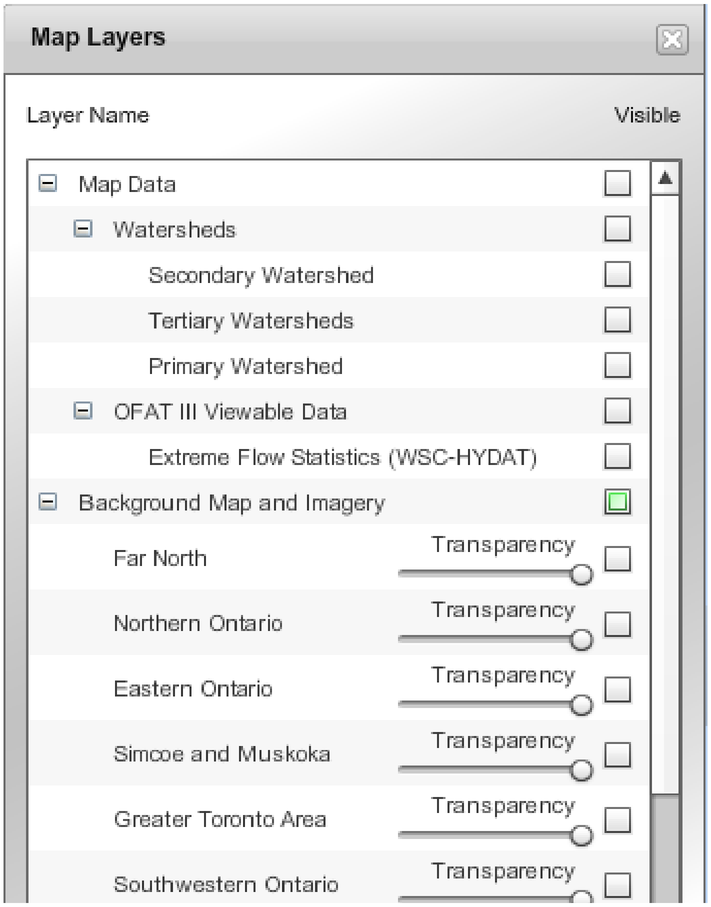
Background Map and Imagery Data includes controls to adjust the visibility of the base map, and any imagery that is currently available. Some imagery layers have defined extents, and will not cover the entire province. The Ontario Land Cover Compilation can be turned on from this widget as well as from the *Watershed Characterization* widget in the OFAT III menu.

Checking the *Visible* box turns the associated layer on and off, while the slider adjusts the *Transparency* of the layer.

3.3 OFAT III

The *OFAT III* menu contains the majority of the specific OFAT III functionality. When the menu is clicked, the OFAT specific buttons are displayed. The functionality of these widgets are explained in detail in Section 4.0, OFAT III Toolset.



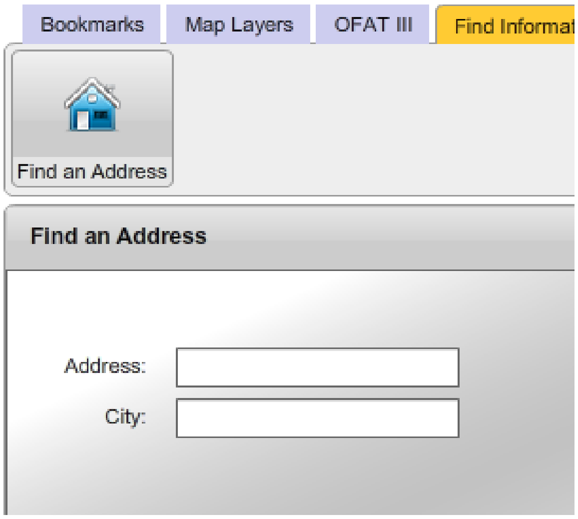


Map Layers Menu

3.4 Find Information

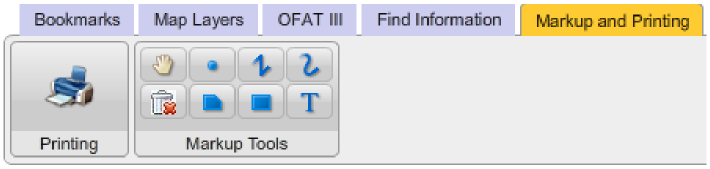
The *Find Information* menu contains an address locator tool.

The *Find Address* tool allows the user to enter an address that is located within Ontario after the *Locate* button is clicked.



3.5 Mark Up and Printing

The user can select from a variety of scales in addition to the current extent print the current extent of the map. The *Drawing and Mark Up* Tools allow for text and basic drawings to be added to the map by the user to highlight information on the print out.



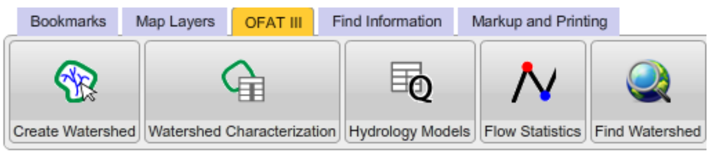
4.0 The OFAT III Toolset

This section explains in detail how to use the specific OFAT III Tools. This section also outlines some tips on using the tools and limitations the users should be aware of.

4.1 Watershed Delineation

OFAT III is capable of delineating a watershed from any user defined point in Ontario that satisfies certain criteria. In OFAT III, generating a watershed is the initial point of the work flow for many of the functions. A watershed is required to perform the subsequent operations in the work flow such as generating watershed characteristics, and executing the hydrology models.

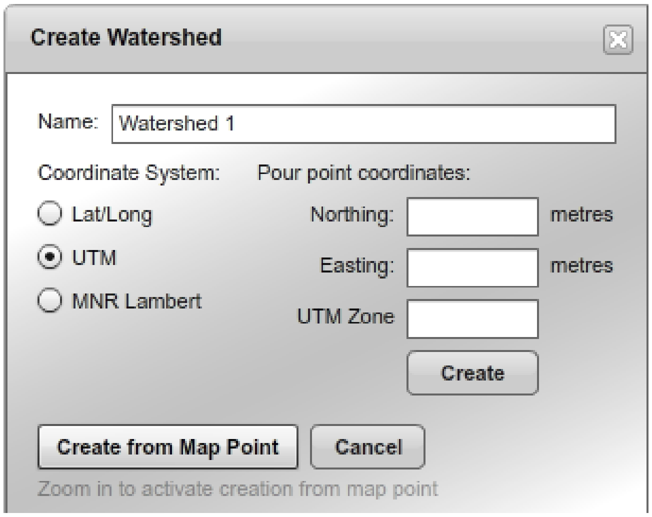
A watershed is created in OFAT III by entering a pour point (a point through which all overland flow of the watershed will drain through). In OFAT III, a pour point must exist on a mapped hydrology feature (lake or stream), and must exist within the land boundary of Ontario; a point within the Great Lakes, St. Lawrence, Ottawa River, St. Clair, Hudson Bay, James Bay, or similar area will not generate a watershed. To create a watershed, follow the steps below:



a. Click on the *OFAT III* Menu

b. Click on the *Create Watershed* Button.

c. The *Create Watershed widget* will appear on the left side of the screen. A default name of *Watershed 1* will appear in the text box. This can be changed at this time if desired. The name cannot be changed after the watershed is created.



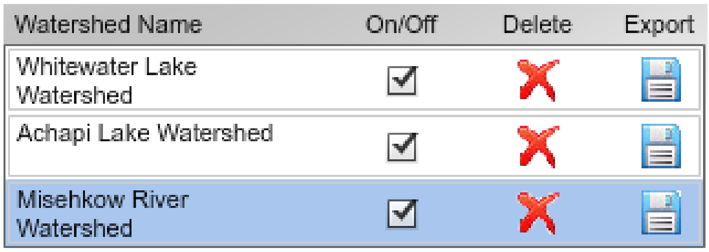
d. Establish a pour point. A pour point can be established by one of two methods:

  i. Enter the coordinates of the pour point in the text boxes of the *Create Watershed* Tab. One of three coordinate systems can be specified, and the entered coordinates must be within 90 metres of a mapped hydrology feature.

  ii. Create a pour point by a mouse click on a mapped hydrology feature. To do this, zoom into the feature until the *Create from Map Point* button becomes enabled in the *Create Watershed* Tab. The button becomes enabled at the second zoom level from the top. This point created by the mouse click must be within 90 metres of a mapped stream. Failure to be within 90m of a mapped hydrology feature will return a user error.

e. If successful, the generated watershed is then added to the *Watershed Name* TOC (Table of Contents) and the map zooms to the watershed extent.

f. Within a session, multiple watersheds can be created. Additional watersheds are generated by using the same steps as above. The results will be added to the *Watershed Name* TOC.



g. The *Watershed Name* TOC provides some simple tools for viewing the watershed. By activating a watershed, (clicking anywhere on the watershed row, which turns blue when activated) the map view will zoom to that watershed. The watershed can also be turned on and off in the map by clicking the *On/Off* checkbox. This is especially effective when there are multiple overlapping watersheds in the map view. The *Delete* and *Export* Tools in the *Watershed Name* TOC are discussed in section 4.4.

4.1.1 Notes about Watershed Generation

Each watershed generated in OFAT III is its own entity, independent of any other watershed generated in OFAT III. Therefore, watersheds that overlap (e.g. subwatersheds) can be generated.

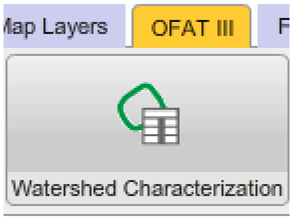
When placing a pour point near a stream confluence, following certain practices can yield more desireable results. In generating the watershed, OFAT III uses a 30 metre resolution raster Enhanced Flow Direction Grid. Due to the 30 metre raster resolution, stream confluences within the grid are 'in the area' of the mapped stream confluence that is shown within the map. To include the stream junction in the watershed delineation place the pour point at least 30 metres downstream of the confluence. To delineate a watershed upstream of a confluence place the pour point at least 30 metres upstream of the confluence.

OFAT III allows users to generate watersheds from within water bodies or large rivers (sometimes referred to as double line streams). Not visible on-screen are virtual segments that flow through water bodies and large rivers. Virtual segments are part of the underlying stream network that maintain flow though water body features. The user-defined pour point must fall within 90 metres of the virtual segment. Because it is not visible on screen, a user pour point may not fall within the tolerance and may have to be re-entered by the user. This is generally only an issue with very large hydrographic features. Generally the virtual segment will be near the centre of the water body, and many virtual segments may be contained within the water body that represent flow from contributing streams. OFAT III uses a pre-defined OMNR base map, that does not show virtual segments.

Water flow does not start, or stop at the borders of Ontario. The information OFAT III uses to generate watersheds does not extend beyond the borders of Ontario and therefore *will not* provide a complete, reliable watershed boundary if its contributing area extends beyond the border. Users must be aware of possible incomplete watershed delineations at the borders of Ontario.

4.2 Watershed Characterization

4.2.1 Physiographic Characterizations



Currently twelve physiographic characterizations can be computed for each generated watershed. To access the watershed characterizations, Click the *Watershed Characterizations* button within the OFAT III menu to activate the widget. There are two tabs available within the widget; *Characterizations* and *Landcover.* Click the Characterizations tab to access the ability to calculate the physiographic characterizations. summarizes the current characterizations.

To calculate the characterizations:

a. Highlight the watershed to calculate the characterizations for in the *Watershed Name* TOC below the characterizations table.

b. Click the *Calculate* button next to each of the characterizations to compute that characterization. To compute all characterizations, click the *Calculate All* button.

The results of the watershed characterizations are displayed next to the parameter name. To calculate or view the characterizations from another watershed, highlight the desired watershed in the *Watershed Name* TOC. The values of the computed characterizations will be updated with the values of the highlighted watershed.

For processing efficiency, some characterizations will be calculated at the same time. Clicking *Calculate* for one characterization may trigger the calculation of others.

Table 2 below briefly explains each of the characterization specifics.

Watershed characterizations for each watershed can be exported from OFAT III. See Section 5 for details.

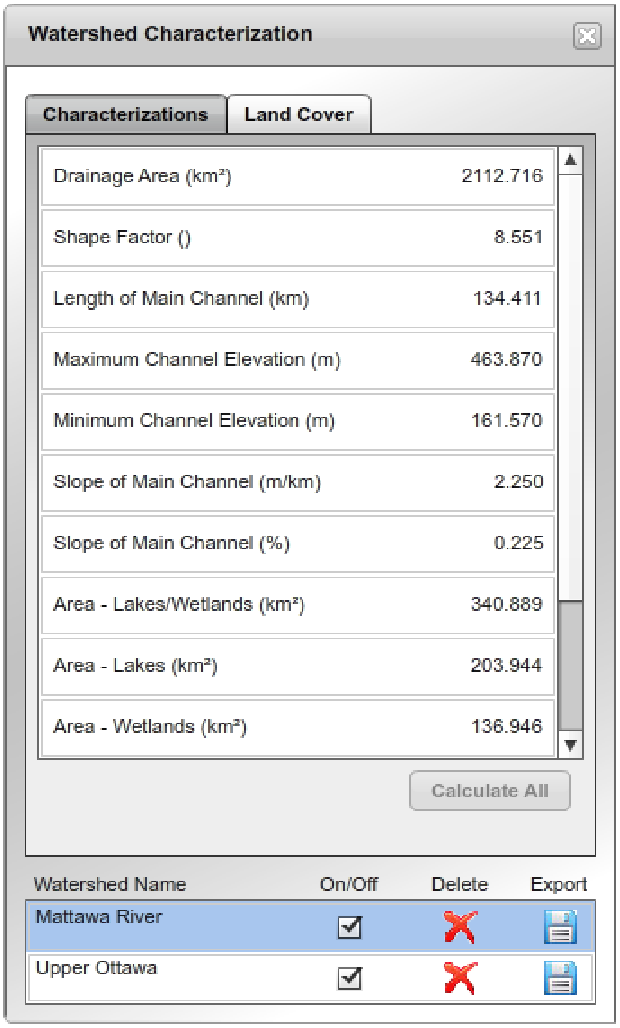


Table 2. OFAT III Characterizations

Characterization	Units	Description
Drainage Area	km2	The area of a watershed measured in a horizontal plane.
Shape Factor	dimensionless	The square of the length of the main channel divided by the drainage area.
Mean Elevation	m	The average elevation value of the DEM within the delineated watershed.
Maximum Elevation	m	The maximum elevation value of the DEM within the delineated watershed.
Mean Slope	Percent	The average slope of the watershed calculated using the slope grid.
Length of Main Channel	km	Alternate name is Longest Flow Path. The longest flow path upstream from the pour point of the watershed to a point on the drainage divide.
Maximum Channel Elevation	m	The maximum channel elevation (located at the head of the main channel).
Minimum Channel Elevation	m	The minimum channel elevation (located at the watershed pour point). This can also be considered the watershed minimum elevation.
Slope of the Main Channel	m/km (Percent)	The calculated slope along the longest flow path, between the most upstream point of the path, to the pour point.
Area of Lakes and Swamps	km2	The area covered by lakes, rivers, and wetlands within the delineated watershed.
Area of Open Water	km2	The area in the watershed covered by open rivers and lakes.
Wetland Area	km2	The area in the watershed covered by wetlands.

4.2.2 Landcover Characterization

Watersheds generated in OFAT III can be summarized by the land cover type contained within the watershed. The data used for the summary is a compilation of three land cover data sets that cover the entire province. This data set, The Ontario Land Cover Compilation, consists of 30 land cover classes derived by combining the Provincial Land Cover Database (2000 Edition), Far North Land Cover Version 1.3, and the Southern Ontario Land Resource Information System (Version 1.2). The data is intended for regional to landscape level analysis (1:50,000 - 1:100,000). See Appendix 1 for a detailed explanation of the land cover classes.

Extracting and summarizing land cover for a watershed is performed from the Characterization widget, which is opened from clicking the *Watershed Characterization* button under the OFAT III menu. Click the *Land Cover* tab within the widget.

a. Highlight the watershed to extract and summarize the land cover for in the Watershed Name TOC below the Land Cover Type summary table.

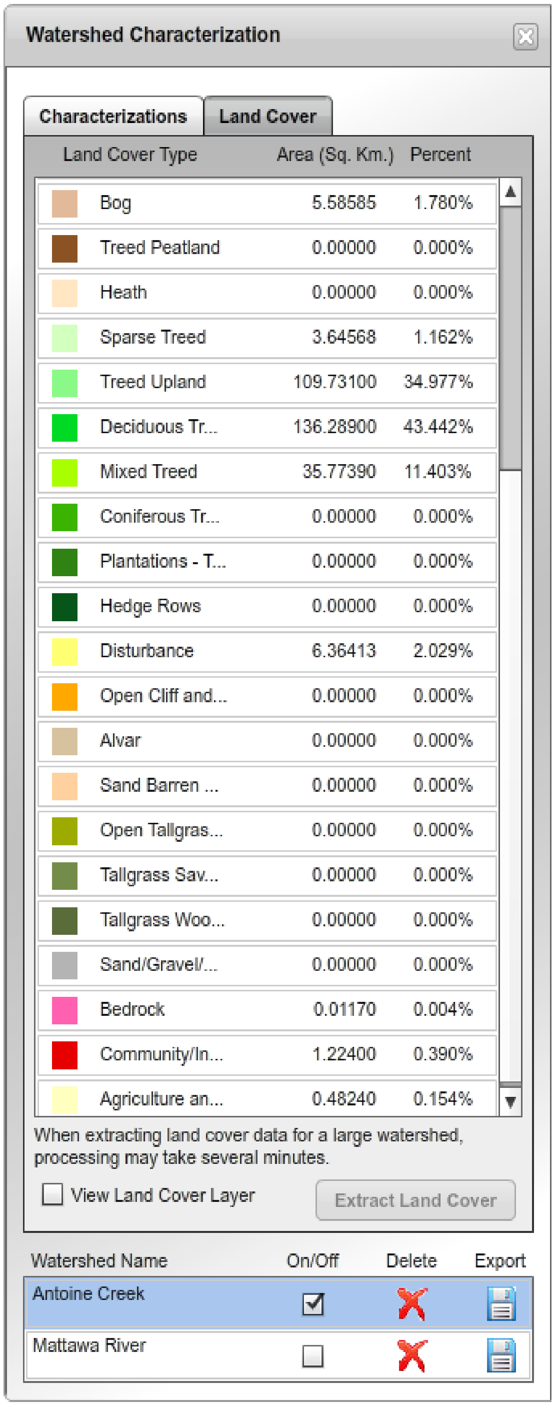
b. Click the Extract Land Cover button below the summary table to extract and summarize the land cover.

The extraction could take several minutes depending on the size of the watershed. At completion, the land cover type is summarrized by area (km^2) and percent coverage within the watershed.

Any of the generated watersheds within the *Watershed Name* TOC can have the land cover summarized. Simply highlight the watershed in the TOC to control what is displayed in the *Land Cover Type* summary table.

The land cover can be viewed on the map by selecting the *View Land Cover Layer.* The viewable layer is for the entire province, not just the watershed.

The extracted landcover is exportable. See section 5 for details.



4.3 Flow Prediction: Regional Hydrology Models

OFAT III contains a series of regional hydrologic models and empirical relationships that generate water flow information. Flow regimes can be determined for a watershed after the watershed has been generated, and the required characterizations computed.

OFAT III currently contains three flow model categories. Each category contains one or more models. See Appendix 1 for a description of each of the models currently in OFAT III. For further details about each individual model, please refer to the original literature listed in the references section.

a. Low Flow Prediction Models (LOF). This type of model generates low flow predictions such as mQn representing m-day low flow in an n-year return period. For example 7Q20 represents the 7 consecutive day average low flow in a 20 year return period. The low flow prediction models provided in OFAT III are:

i. Graphical Index Method (MOEE, 1995)

ii. Regression Method (MOEE, 1995)

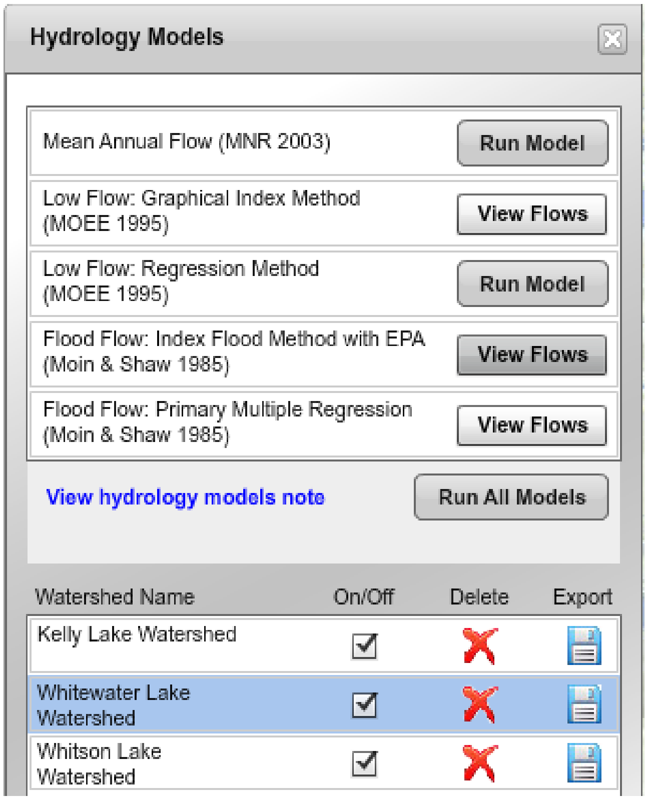
b. Flood Prediction Models (HIF). This type of model generates flood flows such as Q_n representing the flood flow in an n-year return period. For example, Q_{10} represents the flood flow in a ten year return period. The flood flow prediction models provided in OFAT III are:

i. Index Flood Method With Expected Probability Adjustment (Moin & Shaw, 1985)

ii. Primary Multiple Regression Method (Moin & Shaw, 1985)

c. Mean Annual Flow Prediction Model (MAF). This type of model generates the mean annual flow for the watershed.

i. Isoline Method (MNR 2003)



Executing the Hydrology Models in OFAT III is straight forward. Refer the accompanying figure when reading the text below .

a. After at least one watershed has been created, click the *Hydrology Models* button within the OFAT III menu group to activate the hydrology models widget. The *Watershed Name* TOC will be placed below the hydrology model list.

b. Within the *Watershed Name TOC* highlight the desired watershed on which to run the hydrology model(s).

c. Click the *Run Model* button next to each of the hydrology models to compute the flows. To run all models, click the *Run All Models* button.

To view the results of each of the executed hydrology models click the *View Flows* button to the right of each model name. The values shown in the table are those associated with the highlighted watershed in the *Watershed Name* TOC.

For both Low Flow, and both Flood Flow models, the ranges of the input parameter values to each model are tested. The results of the input parameter tests are stated at the bottom of the table shown when the *View Flows* button is clicked. To see the full statement regarding the parameter test results, hover the cursor over the lower row(s) of the results column. Table 3 summarizes the parameter range statements for each of the applicable models.

Table 3: Parameter Range Statements for OFAT III Regional Hydrology Models.

Model	Field Name	Parameter Statements
Low Flow: Graphical Index	Area Limit	Drainage Area Parameter in/not in range for model.
Low Flow: Regression Method	Range Limit	Parameters DA/LNTH/BFI/MAR are in/outside of the range used to create this model.
Flood Flow: Index with Expected Probability Adjustment (EPA)	Area Limit	Drainage Area Parameter in/not in range for model.
Flood Flow: Primary Multiple Regression	RngQ2Q20	Parameters DA/SLP/ACLS/BFI/MAR are in/outside of the range used to create this model.
	RngQ50Q100	Parameters DA/SLP/ACLS/BFI/MAR are in/outside of the range used to create this model.

DA = Drainage Area, LNTH = Length of Main Channel, SLP = Slope of Main Channel, BFI = Base Flow Index, MAR = Mean Annual Runoff, ACLS = Area of Lakes and Swamps.

4.3.1 Notes about Flow Prediction Models

All model output units are cms (cubic metres per second).

Most models included in OFAT III are regional hydrologic models. To estimate flows for a watershed, OFAT III uses a model specific region data set (e.g. low flow regions or flood regions) to determine automatically which region or sub-region the watershed is located. Then appropriate sets of equations/relationships are used to calculate the desired flow information.

Each flow model in OFAT III has its own limitations. This means that the models included in OFAT III should only be used for a watershed within the ranges of the parameters (e.g. drainage area) that were originally used for developing the models. Use of the equations/relationships is not encouraged outside of their parameter ranges. It is strongly suggested that the original model document be referred to, or consult with a water professional, before using generated flow values for any decision making purpose.

Values of -9999 will be inserted for some flow values if the model does not accomodate the specific input parameters for the particular area of the province. These values do not represent an error.

4.4 Streamflow Statistics

OFAT III contains estimates of stream flow (statistics) for select Water Survey of Canada HYDAT gauges in the Southwestern Hudson Bay and the Nelson River watershed systems that lie within the Province of Ontario. The resultant streamflow statistics include:

a. Mean Annual Flow (MAF): Mean Annual Streamflow (m^3/s) is the average streamflow, for years where daily streamflow values exist for the complete year. The calculation is performed on a calendar year basis with historic data from January 1970 (inclusive) to December 2012. The value is the average for the number of years of record available.

b. Flood Flow and Low Flow:

i. The flood magnitude with recurrence intervals of 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, 1:200 and 1:500 years.
ii. The n-day drought severity (1,3,7,15 and 30 days) with recurrence intervals of 1:2, 1:5, 1:10, 1:20, 1:50, 1:100 years.
iii. The 3-day flood magnitude with a recurrence interval of 1:10 years.

A detailed report about the Flood Flow and Low Flow Single Station Frequency Analysis can be found here.

c. Flow Duration Curve (FDC): Flow Duration Curve represents the relationship between magnitude and frequency of streamflow exceedance. It disregards the sequence of occurrence. It is drawn with the streamflow values arranged from highest to lowest (y axis) and percent exceedance (x axis).

Exceedance Probability (P) is expressed as:

$$P = 100*[M/(n+1)]$$

Where: P = the probability that a given streamflow will be equaled or exceeded (% of time)

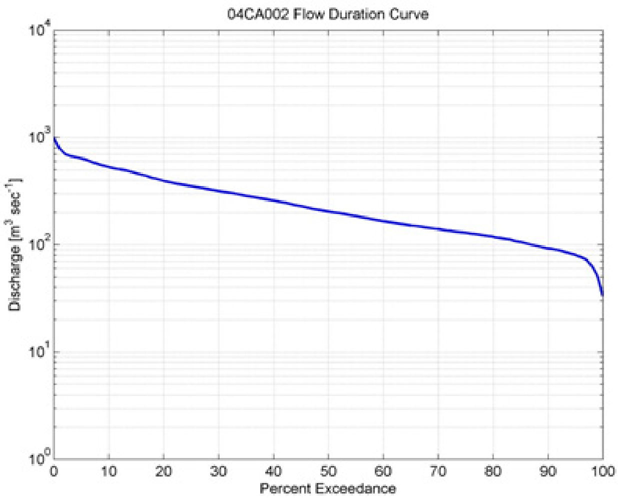
M= the ranked position on the listing (dimensionless)

n =the number of events for period of record (dimensionless)

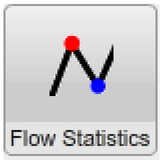
The Flow Duration Curve analytical tool, is one of the most versatile tools used in watershed studies with wide range of applications. For example the FDC can be used to characterize the flow regime, design hydropower facilities, perform water budget studies, compare watersheds etc.

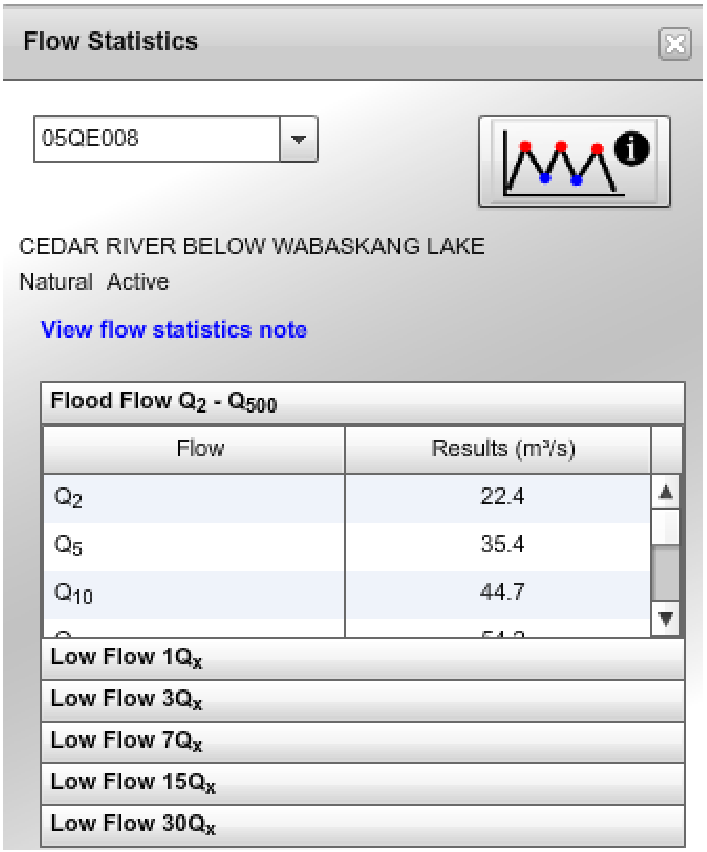
Historic daily streamflow records from the Water Survey of Canada HYDAT database from January 1970 to December 2012 were used to generate the Flow Duration Curves. Active gauges with more than 20 years of records, both regulated and natural, were selected. The minimum length of record required for high data quality is 20 years. Active gauges with more than 10 years of record (but less than 20) are also included for reference. It is highly recommended that the data with less than 20 years of record be used with caution. The results include the tabular values of annual and monthly Flow Duration Curves and the graphical output of annual Flow Duration Curves.

The Flow Duration Curve is created by the period of record method. The date and the corresponding daily streamflow discharge constitute the data required for the analysis. Streamflow Analysis and Assessment Software (SAAS) version 3 is used for the creation of Flow Duration Curve data. For displaying the Annual Flow Duration Curve in OFAT III, the estimated flow exceedance output values from SAAS is used and the graph is generated on the fly.



The Low Flow/Flood Flow Single Station Frequency Analysis results, Mean Annual Flows, and Flow Duration curves for select gauges can be explored through the Flow Statistics widget that is opened by clicking on the Flow Statistics button within the OFAT III menu. When opened the map view will zoom to the extent of available gauges for query.





Accessing a gauge to query can be accomplished using one of two simple methods:

a. Click the combo box at the top of the widget and select a gauge according to its HYDAT D. It is possible to type in the combo box to narrow the selection.

b. Click on the gauge statistics info button on the top right of the widget, and then select a gauge on the map (green symbols). As you zoom in on the map, the gauge name will appear.

The selected gauge will highlight in red on the map, and the flow statistics will be populated in the first 7 accordian tables on the bottom half of the widget. Click on a table header to see the flow values within that table. Above the tables, and below the combo box/info button, the gauge name, regulation type, and status are also displayed.

Clicking on the Flow Duration Curve accordian header will yield a period of record length summary for the FDC at the gauge. When this accordian is opened, a FDC curve is generated from the data on the fly. To view the curve, click the *View FDC* button. Hovering the cursor over the curve will show the values at that point.

A table that contains annual and monthly flow values for each percent exceedance, for the currently selected station can be downloaded in Database File (.dbf) format to the users desktop. This occurs outside of the Watershed Information Exporting that is explained in Section 5.0. To obtain the table, click the Download FDC Data button.

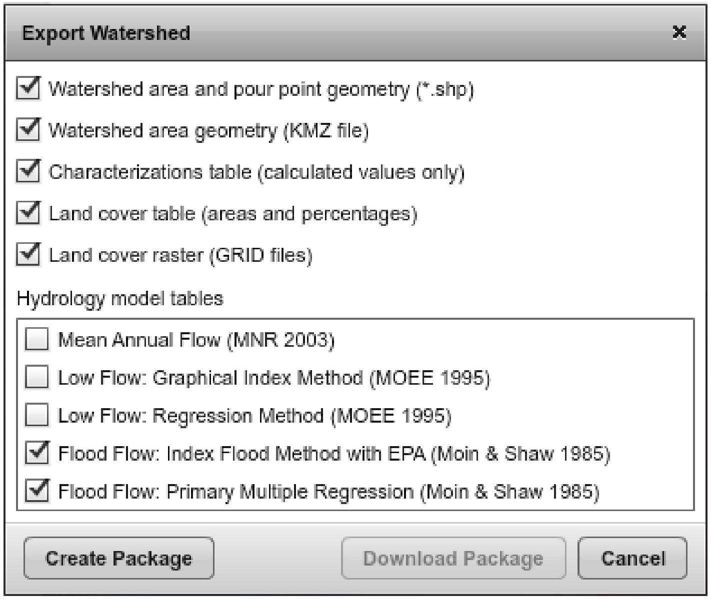
4.5 Find Watershed

The *Find Watershed* widget contains a table that lists tertiary watershed common names alphabetically with the Tertiary ID. Adjacent to the name and ID is a *Zoom* button for each tertiary watershed feature and when pressed will zoom to that particular watershed feature.

5.0 Exporting/Deleting Watershed Information

All watersheds, watershed characterizations, and hydrology model outputs can be exported to the users' desktop directly from the OFAT III website. To export the data for any particular watershed and its associated characterizations and hydrology model outputs, click the export button next to the watershed listed in the Watershed Name TOC.

An export dialog box appears presenting a list of options to include in the export. By default the Watershed and Pour Point geometry are included in the export. Subsequent items, such as the characterizations and the hydrology model outputs, are available only if they have been executed. Check the desired items to include in the export and then select *Create Package.* The selected items are then added to a zip file which can be downloaded to the users' desktop by clicking the *Download Package* button. A file save as dialog box is presented to select the location of the file on the users' computer.



5.1 Export Contents

All possible contents of the export are listed in Table 4. These include GIS geometry files, rasters, and tables. Files included in the export but not listed here are supporting GIS files. These files must remain grouped with the shapefiles (.shp) or the raster files (GRID). The 'info' folder location relative to the land cover raster folder must be maintained as this is a requirement of GIS software.

After the package is created by OFAT III, downloaded to the desktop, and extracted, the file structure as it apprears in ArcCatalog is illustrated in the figure to the right. The parent folder is named the same as it was listed in the OFAT III *Watershed TOC.*

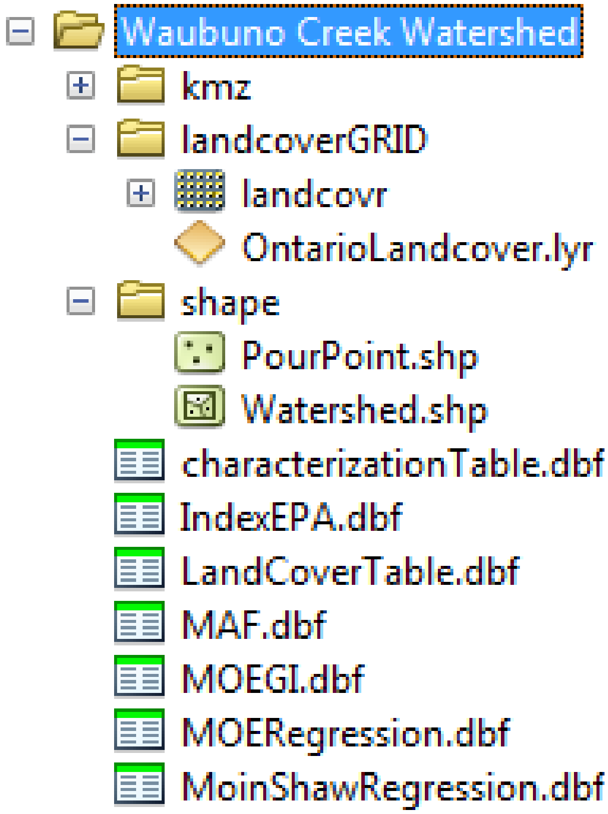


Table 4: All Possible Export Contents

Name	Type	Description
[Watershed 1] - as named in OFAT III	Google Earth .kmz file	Google Earth File
PourPoint.shp	GIS Geometry	User defined watershed pour point GIS file
PourPoint.dbf	Table	Table associated with the outputPourPoint.shp
Watershed.shp	GIS Geometry	Watershed GIS file
Watershed.dbf	Table	Table associated with the outputWatershed.shp
CharacterizationTable.dbf	Table	Watershed characterization results
landcovr	GIS Raster	GIS Raster File
OntarioLandcover.lyr	Layer File	GIS Layer File to be used as a legend file in ArcGIS
LandCoverTable.dbf	Table	Summary by area of the land cover within the watershed
MAF.dbf	Table	Mean Annual Flow Values
IndexEPA.dbf	Table	Moin & Shaw Flood Flow Index with EPA results
MoinShawRegression.dbf	Table	Moins & Shaw Flood Flow Primary Multiple Regression results
MOEGI.dbf	Table	MOE Low Flow Graphical Index results
MOERegression.dbf	Table	MOE Low Flow Regression results

5.1.1 Field Explanations of Exported Tables

Field Names and their description of contents are outlined in Table 5. As highlighted, each table will contain an attribute called OFATID, with the exception of the Land Cover table. OFATID is an auto-generated number when the user defines a pour point. The ID is carried through to the watershed, the characterizations, and the hydrology model outputs. The OFATID is present to assist the user in re-organizing data, or appending like tables or geometries in their GIS system if they wish to.

System generated ID fields are omitted in the explanations.

Table 5: Field Descriptions for OFAT III exported tables

Table: PourPoint.dbf	
Field Name	**Description**
Shape	The geometry of the GIS file. The value will be Point.
OFATID	Auto-generated OFAT ID
WTertiary	The code for the tertiary watershed where the pour point is located
Latitude	The latitude in decimal degrees (NAD 83)
Longitude	The longitude in decimal degrees (NAD 83)
X_LCC	X coordinate in Lambert Conformal Conic (NAD 83)
Y_LCC	Y coordinate in Lambert Conformal Conic (NAD 83)
Table: Watershed.dbf	
Field Name	**Description**
Shape	The geometry of the GIS file. The value will be Polygon.
OFATID	Auto-generated OFAT ID

Table: CharacterizationTable.dbf	
Field Name	**Description**
OFATID	Auto-generated OFAT ID
AreaKm	Area of the watershed in square kilometres
ShapFactr	The square of the length of the main channel divided by the drainage area
MeanElevM	The average elevation value of the DEM within the delineated watershed
MaxElevM	The maximum elevation value of the DEM within the delineated watershed
MeanSlpPc	The average slope of the watershed calculated using the slope grid.
LeOMChKm	Length of the main channel (or longest flow path) in kilometres
MaxChElvM	Maximum channel elevation in metres at the most upstream point of the flow path
MinChElvM	Minimum channel elevation in metres (at the pour point)
ChSlp_M_Km	Channel slope in metres/kilometre (most upstream point of flow path to the pour point)
ChSlp_Pcnt	Channel slope in percent (most upstream point of flow path to the pour point)
WatrAreaKm	Area covered by Lakes, Rivers, and Wetlands within the watershed in square kilometres
OpWAreaKm	The area in the watershed covered by open rivers and lakes.
WetlAreaKm	The area in the watershed covered by wetlands
Table: LandCoverTable.dbf	
Field Name	**Description**
Value	Grid cell value
Area	The area of the land cover classification within the watershed in m2
Percentage	The percentage of area of the land cover classification within the watershed
Class_Name	The land cover classification
Table: MAF.dbf	
Field Name	**Description**
OFATID	Auto-generated OFAT ID
Model	The name of the model
Units	Units
MAF	The flow quantity estimation

Table: MOEGI.dbf	
Field Name	**Description**
OFATID	Auto-generated OFAT ID
Model	The name of the model
Units	Units
AreaLimit	The result of the model input parameter (watershed area) range test
LF_(x)Q(y)	The Low Flow Quantity averaged over (x) days for a specific return period (y)
Table: MOERegression	
Field Name	**Description.dbf**
Model	The name of the model
OFATID	Auto-generated OFAT ID
Units	Units
RangeLimit	The result of the input parameters range test
LF_(x)Q(y)	The Low Flow Quantity averaged over (x) days for a specific return period (y)

Table: IndexEPA.dbf	
Field Name	**Description**
OFATID	Auto-generated OFAT ID
Model	The name of the model
Units	Units
AreaLimit	The result of the model input parameter (watershed area) range test

Table: MoinShawRegression.dbf	
Field Name	**Description**
Model	The name of the model
OFATID	Auto-generated OFAT ID
Units	Units
RngQ2Q20	The result of the model input parameters range test for the flow estimates between Q2 and Q20
RngQ50Q100	The result of the model input parameters range test for the flow estimates between Q50 and Q100
FF_Q(x)	The Flood Flow Quantity for specific return period (x)

5.1.2 Desktop Viewing of Exported Contents

Outlined in the table below are a brief series of options for viewing the contents of the export package. The options are listed by file type.

File Type	Viewing Options	Notes
.kmz	Open the .kmz file from Windows explorer to view in Google Earth.	Must have Google Earth installed on computer.
.shp	Shapefiles can be viewed in many GIS packages. ArcGIS explorer is free GIS viewer that can load shapefiles.	Do not alter the associated .dbf files (same name as the .shp file) as it will corrupt the GIS file
.dbf	DataBase File can be opened by database, GIS, or spreadsheet software.	
GRID	ESRI GRID's, are raster files that are opened by GIS software, capable of viewing rasters.	The Land Cover is extracted in OFAT III without the generation of pyramids. If fast viewing in ArcMap is required, generate the pyramids for the Land Cover Grid in ArcCatalog.
.lyr	A Layer file used to color code the Land Cover Raster. This is an ESRI that can be loaded into ArcGIS.	Load the layer file into ArcMap, and set the data source as the land cover GRID.

5.2 Deleting Information from the Session

All watersheds, watershed characterizations, and hydrology model outputs can be deleted from the OFAT III session by clicking the delete button next to the watershed listed in the *Watershed Name* TOC. When this button is clicked, *the watershed is deleted along with the characterizations and hydrology model outputs, if created, for the particular watershed.* After a watershed and its associated characterizations and hydology models are deleted, they are not recoverable, but can be reproduced.

6.0 Data Used in OFAT III Analysis

This section outlines the details of the data used in OFAT III analysis operations of watershed delineation, characterizations and hydrology models, as well as the flow statistics data. The OFAT III basemap is made up of a variety of data from the Ontario Land Information warehouse and is not discussed in this document. Where possible, metadata links, and document references are provided rather than duplicating published material in this guide.

6.1 Data Used in Watershed Delination

The data used for watershed delineation in OFAT III is based from data in the Water Resources Information Programs' (WRIP) Ontario Integrated Hydrology Data Packages. The Ontario Integrated Hydrology Data packages are currenly stored and distributed through Land Information Ontario (LIO) [www.lio.gov.on.ca].

Within LIO, metadata for Ontario Integrated Hydrology Data can be accessed through the LIO Metadata Management Tool [https://www.appliometadata.lrc.gov.on.ca/geonetwork/srv/en/main.home]. Specific data sets used in the function are the Stream Geometric Network, and the Enhanced Flow Direction grid.

6.2 Data Used in Watershed Characterization

6.2.1 Watershed Shape Factor:

The Watershed Shape Factor is the square of the the Length of the Main Channel divided by the drainage area.

6.2.2 Watershed Mean Elevation:

The Watershed Mean Elevation is calculated by averaging the values from the Digital Elevation Model contained in the Integrated Hydrology Package, within the watershed.

6.2.3 Watershed Maximum Elevation:

The Watershed Maximum Elevation is the maximum value from the Digital Elevation Model contained in the Integrated Hydrology Package, within the watershed.

6.2.4 Watershed Mean Slope:

The Watershed Mean Slope is calculated by averaging the values from a slope percent grid within the watershed. The slope percent grid was pre-computed using the Slope function in ESRI's Spatial Analyst on the Digital Elevation Model contained within the Integrated Hydrology Package.

6.2.5 Length of Main Channel

The length of the main channel from a user defined pour point is obtained by a query to an Upstream Flow Length grid at the pour point. The Upstream Flow Length grid was created from ESRI's Spatial Analyst Flow Length function using the Enhanced Flow Direction Grid from the Ontario Integraged Hydrology Package as input to the function.

6.2.6 Maximum Channel Elevation

The Maximum Channel Elevation is the elevation value from the Digital Elevation Model contained in the Integrated Hydrology Package, at the most upstream point along the main flow path.

6.2.7 Minimum Channel Elevation

The Minimum Channel Elevation is the elevation value from the Digital Elevation Model contained in the Integrated Hydrology Package, at the pour point.

6.2.8 Slope of the Main Channel

The slope of the main channel is computed using the Upstream Flow Length as determined in Length of the

Main Channel together with elevation values from the pour point, and the most upstream point along the main flow path. The elevation values are queried from the Digital Elevation Model contained in the Ontario Integrated Hydrology Package.

6.2.9 Area of Lakes and Wetlands

The area within a watershed that is covered by a lake, major river, or wetland is determined by summarizing a data layer created for OFAT III called WaterBodyArea Raster. This raster dataset is composed of data sourced from the following data layers, each with a metadata record in the LIO Metadata Management Tool:

1. Ontario Hydro Network – Waterbody (**Metadata URL**)
2. Wetland Unit (Metadata URL)

Each dataset was converted from vector polygons to a 30 metre raster. The two raster datasets were then merged into a single integer raster dataset, where a value of 1 represents lakes and major rivers, and a value of 2 represents wetlands. In areas where the two original datasets overlapped the lakes and major rivers took precedence.

6.3 Data used in Watershed Land Cover Summary

The Ontario Land Cover Compilation serves as a consistent land cover map for the entire province to meet regional - to - landscape level analysis (1:50,000 – 1:100,000). This product is comprised of three separate land cover databases, each with separate class structures and which have been rationalized into a single classification.

The Ontario Land Cover Compilation consists of 30 land cover classes derived by combining the Provincial Land Cover Database (2000 Edition), Far North Land Cover Version 1.3 and the Southern Ontario Land Resource Information System (Version 1.2). Each of these separate land cover databases was resampled to a common pixel spacing (15 metres), re-projected to a common projection (NAD83 Lambert Conformal Conic) and reclassified into a common class structure. See Appendix 1 for detailed explanations of the land classes.

6.4 Data Used in Hydrology Models

Hydrology models in OFAT III pull information as required from derived watershed characteristics. There are additional data layers required for the regression models. Additional data include:

6.4.1 Mean Annual Runoff

The OFAT III Mean Annual Runoff Surface is a 1 km resolution raster data set that represents the mean annual runoff in mm at a particular location. This grid was created by North East Science and Information Branch of MNR. The source data to create the grid was taken from Moin and Shaw "Regional Flood Frequency Analysis for Ontario Streams" 1985. Hard copy maps were digitized to create a mean annual runoff contour dataset, which were then interpolated into a surface using TOPOGID. This data is stored in OMNR Lambert Conformal Conic Projection. WRIP is not the custodian of this data set.

6.4.2 Base Flow Index

The OFAT III Base Flow Index Surface is a 1 km resolution raster data set that represents the portion of flow in a stream derived from soil moisture or groundwater (baseflow). The grid value in any one location represents the ratio of base flow to total flow volume (dimensionless). This grid was created by North East Science and Information Section of MNR. The source data to create the grid was taken from Moin and Shaw "Regional Flood Frequency Analysis for Ontario Streams" 1985. Tabular data from this study was used to create point values which were then interpolated into a continuous surface raster using TOPOGRID. The grid does not cover the entire province. This data is stored in OMNR Lambert Conformal Conic Projection. WRIP is not the custodian of this data set.

7.0 References

This help document contains some content from the original Users Manual for Ontario Flow Assessment Techniques (OFAT) where applicable.

Chang, C., F. Ashenhurst, S. Damaia, and W. Mann (2002). "Ontario Flow Assessment Techniques (OFAT)", Hydraulic Information Management, Editors, Brebbia, C.A., and W.R. Blain, WIT Press, Ashurst, Southampton, U.K., pp. 421-431.

Kenny, F.M., Matthews, B., 2005. A methodology for aligning raster flow direction data with photogrammetrically mapped hydrology. Computers & Geoscience 31(6), 768-779. http://mnronline.mnr.gov.on.ca/odms/search/view.asp?attachment_id=1&document_id=11159

Kenny, F.M, Matthews, B., and Todd K. 2008. Routing Overland Flow through Sinks and Flats in Interpolated Raster Terrain Surfaces. Computers & Geoscience. 34 (2008), pp. 1417-1430 DOI information: 10.1016/j.cageo.2008.02.019 http://mnronline.mnr.gov.on.ca/odms/search/view.asp?attachment_id=1&document_id=11165

MOEE (1995). "Regionalization of Low Flow Characteristics" for various regions in Ontario,

Ministry of Environment and Energy (MOEE), Ontario, Canada.

Moin, S. and M. Shaw (1985). "Canada/Ontario Flood Damage Reduction Program - Regional

Flood Frequency Analysis for Ontario Streams", Volume 1, 2, and 3, Environment

Canada, Ontario, Canada.

WRIP Fact Sheet 2008(b) Digital Elevation Model http://mnronline.mnr.gov.on.ca/odms/search/view.asp?attachment_id=1&document_ id=14381

WRIP Fact Sheet 2008(c) Arc Hydro http://mnronline.mnr.gov.on.ca/odms/search/view.asp?attachment_id=1&document_ id=14378

WRIP Technical Release 2012. Ontario Integrated Hydrology Data: Elevation and Mapped Water Features for Provincial Scale Hydrology Applications.

Zhao, J., Todd, K., Hogg, A., and Kenny, F. 2008 Improving Ontario's Provincial Digital Elevation Model. Internal Report, Water Resources Information Program, Ministry of Natural Resources 90p.

Appendix 1: Ontario Land Cover Compilation Version 1.0

The Ontario Land Cover Compilation Data Specifications Version 1.0 appendix was supplied by Provincial Remote Sensing Specialist, Science and Information Branch, Ontario Ministry of Natural Resources. (705) 755-2154.

Disclaimer

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1.0 Data Specifications Sheet

Date: July, 2013

Section 1: Data Standard Information

This section identifies the name, abbreviation, and extent of the 2013 Ontario Land Cover Compilation, and provides contact information for the producer and custodian of this data layer.

Layer Name: Ontario Land Cover Compilation
Layer Abbreviation: OLC
Layer Description: Regional, ecologically based, land cover and change inventory. Represents the landscape current to between 1999-2011.
References: Far North Land Cover Methodology
Production: Science and Information Branch, Ministry of Natural Resources (MNR)
Product Contact: Provincial Remote Sensing Specialist, Ontario Ministry of Natural Resources, Science & Information Branch, (705) 755-2154
Extent: Province of Ontario
Custodian: Science and Information Branch, MNR

Section 2: GIS Data Layer Specifications

This section identifies the geospatial criteria for this data layer.

1. File Information
File Type: GRID
Projection File Name:
Geometry Type: Grid
2. Coordinate System: Lambert
Horizontal Coordinate System: GCS North American 1983

Ontario Land Cover Classification

Overview

The Ontario Land Cover Compilation serves as a consistent land cover map for the entire province to meet regional - to - landscape level analysis (1:50,000 – 1:100,000). This product is comprised of three separate land cover databases, each with separate class structures and which have been rationalized into a single classification.

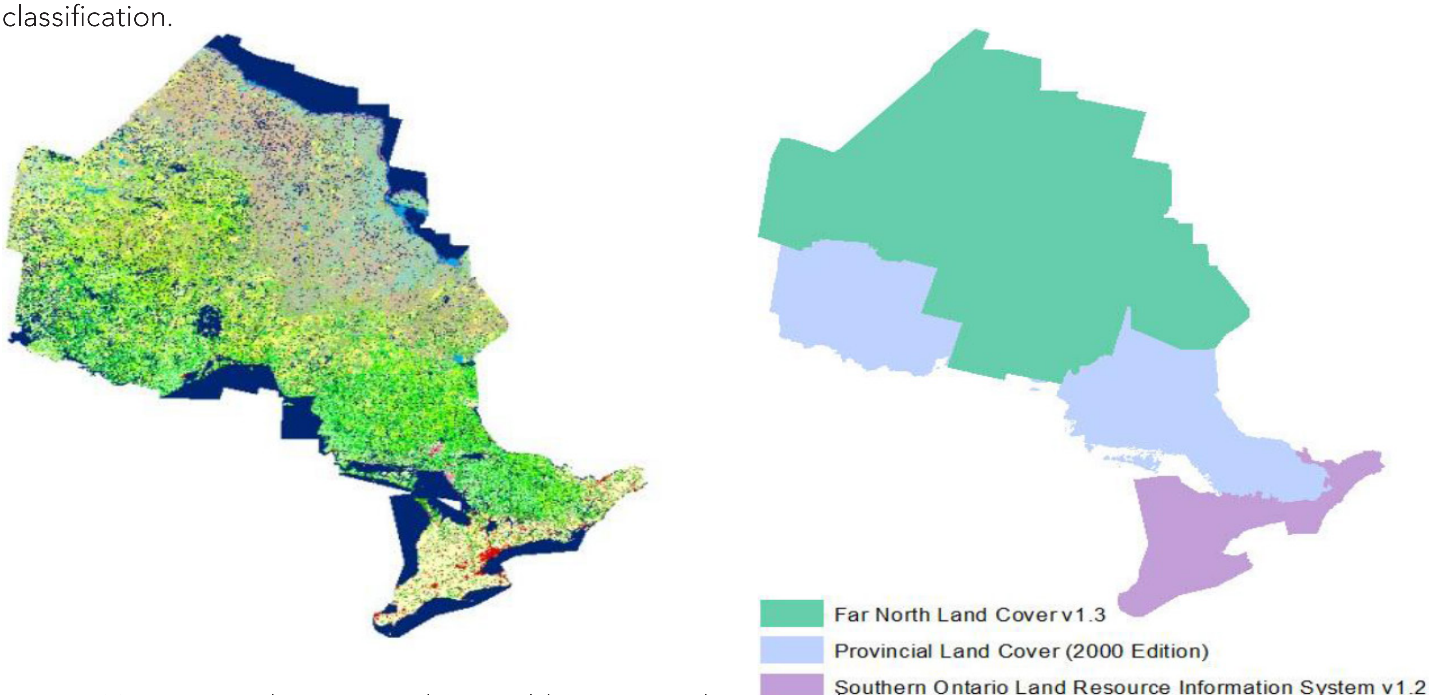


Figure 1: (a) Ontario Land Cover Compilation and (b) Source Land Cover Databases

The Ontario Land Cover Compilation consists of 30 land cover classes derived by combining the Provincial Land Cover Database (2000 Edition), Far North Land Cover Version 1.3 and the Southern Ontario Land Resource Information System (Version 1.2). Each of these separate land cover databases was resampled to a common pixel spacing (15 metres), re-projected to a common projection (NAD83 Lambert Conformal Conic) and reclassified into a common class structure. The reclassification scheme is described in section 2.3 of this data specification document.

Source Land Cover Databases

The Provincial Land Cover Database (2000 Edition) (PLC2000)	This database consists of 27 broad land cover types and was produced in 2004 from an unsupervised classification of approximately 55 Landsat-7 ETM satellite images acquired between 1999 and 2002. The PLC2000 was produced as 4 overlapping rasters, one for each UTM zone within the province, with a pixel resolution of 25 metres.
Southern Ontario Land Resource Information System (SOLRIS) Version 1.2 (SOLRISv1.2)	The SOLRIS database consists of 25 land cover classes which follow the Ministry of Natural Resources' Ecological Land Classification (ELC) for southern Ontario. This database was produced in 2008 from an object oriented classification of 11 Landsat-7 ETM satellite images acquired between 1999 and 2002. SOLRIS was produced as 2 overlapping rasters, one for each UTM zone in southern Ontario, with a pixel resolution of 15 metres.
Far North Land Cover Version 1.3 (FNLCv1.3)	The Far North Land Cover consists of 27 land cover types and was produced in 2013 from an object oriented classification of Landsat-5 TM satellite images acquired between 2005 and 2011. The FNLC was produced as 3 overlapping rasters, one for each UTM zone in northern Ontario, with a pixel resolution of 30 metres.

Data Dictionary

The following table is provided as a data dictionary for the Ontario Land Cover Compilation. For each class, the class name, code number and the source land cover class and class description are included. For more details on the source land cover products, including potential class confusions, please refer to the corresponding data dictionaries of these products.

Table 1: Ontario Land Cover Compilation Classification As Related to the Source Land Cover Classification

Unit Name	Code	Source Unit Name	Source Unit Description
Clear Open Water	1	PLC2000: Water – deep clear	Water – deep clear: Deep or clear waterbodies.
		SOLRIS v1.2: Open Water	Open Water: No macrophyte vegetation, trees or shrub cover
		FNLC v1.3: Clear Open Water	Clear Open Water: This class is characterized by water with minimal or no evidence of turbidity or sediment. There is also an absence of macrophyte vegetation, tree or shrub cover.
Turbid Water	2	PLC2000: Water – shallow / sedimented	Water – shallow / sedimented: Shallow waterbodies and waterbodies with a high concentration of suspended sediment.
		SOLRIS v1.2: -	
		FNLC v1.3: Turbid Water	Turbid Water: This class is characterized by water with varying degrees of turbidity, sediment and marl. Sparse floating and submerged vegetation is also included in this class as tones are similar to water with turbidity and sediment. Little to no tree or shrub cover is present. The mixture of sparse emergent and floating vegetation, suspended sediment, turbid water and clear water create a unique and identifiable image tone.
Shoreline	3	PLC2000: -	
		SOLRIS v1.2: Shoreline; Open Shoreline	Shoreline; Open Shoreline: Substrate consists of unconsolidated parent or mineral material. Subject to active processes / < 25% vegetative cover
		FNLC v1.3: -	
Mudflats	4	PLC2000: Mudflats	Mudflats: Unvegetated coastal areas of the Hudson Bay-James Bay Lowlands, partly submerged at high tide.
		SOLRIS v1.2: -	
		FNLC v1.3: Intertidal Mudflat	Intertidal Mudflat: Completely unvegetated coastal areas of Hudson and James Bays. These features are covered by varying depths of water depending on distance from the coast, as well as the point in the tidal cycle when the imagery was acquired. These features have a unique and identifiable image tone due to the combination of wet and exposed soil. Proximity to James and Hudson Bays also aids detection.
Marsh	5	PLC2000: Marsh – intertidal; Marsh – supertidal	Marsh – intertidal: Coastal marshes of the Hudson Bay-James Bay Lowlands lying between the coastal mudflats and the supertidal zone. Marsh – supertidal: Coastal marshes of the Hudson Bay-James Bay Lowlands lying inland of both the coastal mudflats and intertidal marshes, and subject to only exceptionally high tides.
		SOLRIS v1.2: Marsh	Marsh: Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree and shrub cover ≤ 25% - dominated by emergent hydrophytic macrophytes
		FNLC v1.3: Intertidal Marsh; Supertidal Marsh; Fresh Water Marsh	Intertidal Marsh: Primarily open communities containing living and senesced grasses, sedges and emergents. These marshes are directly adjacent to the Hudson and James Bay coasts between mudflats and the supertidal zone, and are constantly influenced by brackish and freshwater. They are flooded at high tide and slowly drain as the tide falls; a process that leaves a mosaic of pools of standing water. Estuarine intertidal marshes are found at the outflows of freshwater rivers and are also included in this class. Last year's dead vegetation is sometimes present while fluctuating water levels and other natural disturbance (e.g. overgrazing by abnormally high geese populations) can also stress vegetation in this zone causing it to senesce early. A combination of higher amounts of dead and senesced grasses and heterogeneous conditions provide a unique mosaic of image tones that allows for mapping. Proximity to James and Hudson Bays also aids detection. Supertidal Marsh: Primarily open communities containing some shrubs and trees. Tree and shrub cover ≤ 25% and dominated by emergent hydrophytic macrophytes. Water table is seasonally or permanently at, near, or above substrate surface. This class includes coastal marshes beyond the intertidal zone and as such, subjected to salt water via exceptional tides and storm surges. Lower amounts of visible sensed vegetation and water along with proximity to James and Hudson Bays allows for image detection.

Unit Name	Code	Source Unit Name	Source Unit Description
		FNLC v1.3: Intertidal Marsh; Supertidal Marsh; Fresh Water Marsh (Cont'd)	Fresh Water Marsh: Fresh water marshes occur in close proximity to Hudson and James Bays. They are often adjacent to supertidal marshes but not subjected to any salt water influences. Otherwise, freshwater marsh features are relatively rare in the Far North but do occur. When they occur these features are located on inland lakes and rivers in the southern portion of the Ontario Shield and in river oxbows in the Hudson Bay lowlands. These are generally open communities where the water table is seasonally or permanently at, near, or above substrate surface. Vegetation is composed primarily of grasses, sedges and emergents while tree and shrub cover ≤ 25%.
Swamp	6	PLC2000: Swamp – deciduous; Swamp - coniferous	Swamp – deciduous: Hardwood swamps of Southern Ontario occurring along rivers and in old lakebeds and other low-lying areas. Swamp – coniferous: Swamps with dense conifer tree or shrub cover occurring in Southern Ontario.
		SOLRIS v1.2: Swamp	Swamp: Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree or shrub cover > 25% - dominated by hydrophytic shrub and tree species
		FNLC v1.3: Thicket Swamp; Coniferous Swamp; Deciduous Swamp	Thicket Swamp: Greater than 25% hydrophytic shrub species capable of growing taller than 2 metres and tree cover less than 10%. These are typically found within or on the edges of small to large flowing water bodies and in supertidal portions of the Hudson Bay Lowlands. Their mineral or organic soil is subject to seasonal flooding or characterized by a high water table. In many cases a circulation of water rich in dissolved minerals allows for dense vegetation growth. Their association to water and unique image tones due to high deciduous leaf densities enables mapping. Coniferous Swamp: Greater than 25% hydrophytic shrub and/or coniferous tree species. Their mineral or organic soil is subject to seasonal flooding or characterized by a high water table and a circulation of water rich in dissolved minerals. Hydrologically these features exist in isolated depressions or adjacent to streams, lakes, fens or bogs. Deciduous Swamp: Greater than 25% hydrophytic shrub and deciduous tree species. The tree cover mostly deciduous is greater than 10%. Their mineral or peaty phase substrate is subject to seasonal flooding or characterized by a high water table and a circulation of water rich in dissolved minerals. Hydrologically these features exist in depressions or level slope, adjacent to lakes, streams and rivers, or open peatlands.
Fen	7	PLC2000: Fen – open; Fen - treed	Fen – open: Fens generally lacking tree cover that may support some shrub cover and tamarack. Open fens include fens with an open water surface, graminoid fens, pattern fens, and shrub-rich fens. Fen – treed: Fens supporting a sparse to dense cover of trees or shrubs.
		SOLRIS v1.2: Fen	Fen: Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface. - tree cover (trees > 2m high) ≤ 25% - sedges, grasses and low (< 2 m) shrubs dominate, sedge and brown moss peat substrate
		FNLC v1.3: Open Fen; Treed Fen	Open Fen: Fens develop in areas of generally slow flowing water and often have saturated or flooded surfaces. These features are fed by water from precipitation, ground and/or surface water, with the latter two sources enriched by contact with surrounding mineral soils. These conditions enable slightly more vegetative diversity and density than bogs. Mosses (generally not sphagnum), graminoids and low ericaceous shrubs are all common. Tall shrubs may also be present but at densities of less than 25%. Conditions such as open water surfaces and saturation, dense graminoids, string patterns and textured ericaceous shrub-rich communities all aid their remote detection. Additionally, low tree cover, approximately zero to 10%, also aids identification. Treed Fen: As described above fens receive ground and surface water. These conditions allow for slightly higher vegetation density than bogs. Tamarack is usually associated with fens due to its adaptation to the telluric conditions common in this wetland type. At densities predominately over 10%, trees display a unique image tone that, when combined with the other observable conditions noted for open fen, allow for their detection on imagery. Black spruce is also present in these features, but not typically used as an image identifier as these trees are also evident in several other land cover classes.

Unit Name	Code	Source Unit Name	Source Unit Description
Bog	8	PLC2000: Bog – open; Bog - treed	Bog – open: Bogs generally lacking tree cover. Bog – treed: Bogs supporting a sparse to dense cover of trees.
		SOLRIS v1.2: Bog	Bog: Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree cover (trees > 2m high) ≤ 25% sphagnum peat substrate
		FNLC v1.3: Open Bog; Treed Bog	Open Bog: Bogs have a thick accumulation of peat often forming dome, plateau and hummock-like landforms that are level or slightly higher than surrounding surfaces. These thick layers of organic peat material are virtually unaffected by surface runoff or groundwater from surrounding mineral soils; the primary water source is precipitation. Open bogs have water tables seasonally or permanently at, near, or above substrate surface. Substrates are sphagnum peat. Hydrologic and substrate properties significantly limit vegetation growth and diversity. In open bogs tree cover is sparse at less than 10% while tall shrubs can occur at densities less than 25%. Dense and pure sphagnum and lichen ground cover are the primary contributors to image identification. Various densities of ericaceous shrubs can also occur; higher densities also produce a unique image tone that can be used for mapping. Treed Bog: The ecological characteristics of treed bog are similar to those described for open bog. Treed bogs have either tree cover greater than 10% and tall shrub cover less than 25%. A combination of low ericaceous shrub, lichen, sphagnum moss and black spruce all aid detection.
Treed Peatland	9	PLC2000: -	
		SOLRIS v1.2: -	
		FNLC v1.3: Treed Peatland	Treed Peatland : Sparsely vegetated, situated in low lying, poorly drained, peat dominated areas. Tree cover (primarily tamarack or black spruce) is ≤ 40% canopy cover (> two metres in height). Class represents the ecotone between treed fen and bog classes where clear distinction between these communities is unclear without ground validation. May include a combination of treed bog, treed fen type features and sparse coniferous swamp (e.g., sparse tamarack/graminoid or sphagnum moss).
Heath	10	PLC2000: Tundra Heath	Tundra Heath: Low tundra vegetation growing on slightly raised beach deposits and strand lines along the Hudson Bay coast.
		SOLRIS v1.2: -	
		FNLC v1.3: Heath	Heath: Heath commonly occurs on the raised mineral soils deposited as beach ridges and strandlines. The slightly higher elevations and close proximity to the coast ensures these features are constantly exposed to all intensities of prevailing and coastal winds. The relative high elevation and coarse soil ensures these areas are well drained therefore water table is typically well below the substrate surface creating upland conditions. Although vegetation cover is greater than 25%, extreme conditions limit vegetation primarily to lichen, artic herb and various ericaceous shrub species. The combination of lichen and ericaceous shrub image tones, proximity to the coast and spatial coincidence with beach ridges allow for identification and mapping.
Sparse Treed	11	PLC2000: Forest - sparse	Forest – sparse: A patchy or sparse forest canopy composed of coniferous or deciduous species or a combination of the two.
		SOLRIS v1.2: -	
		FNLC v1.3: Sparse Treed	Sparse Treed: Treed (> two metres in height) area containing coniferous or deciduous species or a combination of the two. Treed sites with tall and/or low treed canopy closure between 10 and 25%. These communities are often situated on bedrock knobs, rapidly draining soils, or on raised mineral soils, deposited as beach ridges and strandlines in close proximity to Hudson/James Bay. They often exhibit a dry and very shallow substrate. Dense communities of ground lichens, graminoids and/or mosses are also common. The combination of ground cover, dry conditions and sparse canopy offer unique image tones aiding identification. Elevation information extracted from an elevation model and quaternary geology parent material also aids mapping.
Treed Upland	12	PLC2000: -	
		SOLRIS v1.2: Forest	Forest: Tree cover > 60%. Upland tree species > 75% canopy cover > 2 m in height. Perimeters visually extracted from high resolution ortho or satellite imagery. Attribute for forest type could not be derived spectrally from Landsat automated analysis due to size of feature.
		FNLC v1.3: -	

Unit Name	Code	Source Unit Name	Source Unit Description
Deciduous Treed	13	PLC2000: Forest – dense deciduous	Forest – dense deciduous: Largely continuous forest canopy composed primarily of deciduous species.
		SOLRIS v1.2: Deciduous Forest	Deciduous Forest: Tree cover > 60%. Upland deciduous tree species > 75% of canopy cover > 2 m in height
		FNLC v1.3: Deciduous Treed	Deciduous Treed: Predominately deciduous tree cover situated on varying soil depths having dry, fresh and sometimes moist conditions. Vegetation cover is typically closed and tall (greater than 10 metres in height and 60% closure). May also include open tall (greater than 10 metres in height and between 25 and 60% closure) and low (less than 10 metres in height and greater than 25% closure) communities. Upland deciduous tree species make up greater than 75% of canopy closure. Species are primarily poplar and birch.
Mixed Treed	14	PLC2000: Forest – dense mixed	Forest – dense mixed: Largely continuous forest canopy composed of both deciduous and coniferous species. In more northerly areas, a greater component of coniferous species can be expected; in more southerly areas, a greater component of deciduous species can be expected.
		SOLRIS v1.2: Mixed Forest	Mixed Forest: Tree cover > 60%. Upland conifer tree species > 25% and deciduous tree species > 25% of canopy cover > 2m in height
		FNLC v1.3: Mixed Treed	Mixed Treed: A mixture of deciduous and coniferous tree cover situated on varying soil depths that can have dry, fresh and sometimes moist conditions. Vegetation cover is typically closed and tall (greater than 10 metres in height and 60% closure). May also include open tall (greater than 10 metres in height and between 25 and 60% closure) and low (less than 10 metres in height and greater than 25% closure) communities. Upland deciduous and coniferous tree species are present and make up less than 75% of canopy closure. Species are primarily jack pine, black spruce, white spruce, poplar and birch.
Coniferous Treed	15	PLC2000: Forest – dense coniferous	Forest – dense coniferous: Largely continuous forest canopy composed primarily of coniferous species
		SOLRIS v1.2: Coniferous Forest	Coniferous Forest: Tree cover > 60%. Upland conifer tree species > 75% canopy cover > 2 m in height
		FNLC v1.3: Coniferous Treed	Coniferous Treed: Predominately coniferous tree cover situated on varying soil depths that can have dry, fresh and sometimes moist conditions. Vegetation cover is typically closed and tall (greater than 10 metres in height and 60% closure). May also include open tall (greater than 10 metres in height and between 25 and 60% closure) and low (less than 10 metres in height and greater than 25% closure) communities. Upland coniferous tree species make up greater than 75% of canopy closure. Species are primarily jack pine, black spruce, white spruce.
Plantations – Treed Cultivated	16	PLC2000: -	
		SOLRIS v1.2: Plantations – Treed Cultivated	Plantations – Treed Cultivated: Tree cover > 60%, minimum 2 m in height, linear organization, uniform tree type.
		FNLC v1.3: -	
Hedge Rows	17	PLC2000: -	
		SOLRIS v1.2: Hedge Rows	Hedge Rows: Tree cover > 60%, minimum 2 m in height, linear arrangement, minimum 10 m width, maximum 30m width.
		FNLC v1.3: -	
Disturbance	18	PLC2000: Forest Depletion – cuts; Forest Depletion – burns; Forest – regenerating depletion	Forest Depletion – cuts: Forest clearcuts estimated to be less than 10 years of age. Forest Depletion – burns: Forest burns estimated to be less than 10 years of age. Forest – regenerating depletion: Old burns supporting very sparse vegetation.
		SOLRIS v1.2: -	
		FNLC v1.3: Disturbance – Non and Sparse Woody; Disturbance – Treed and/or Shrub	Disturbance – Non and Sparse Woody: The result of natural and/or anthropogenic disturbance occurring some time over the last 20 years. Vegetation cover includes herbaceous (forbs and graminoids greater than 25%), sparse herbaceous (between two and 25%) and non vascular (lichen and or moss greater than 10%). Sparse tall and low trees along with tall and low shrub may also be present at canopy closures of less than 25%. Dead trees can exist at greater than 25% cover and can be either up rooted and horizontal on the ground or standing. Sites are most often drier upland sites with varying soil depths. This class is mapped by taking advantage of the spatial context provided by disturbance mapping and the unique image tones associated with largely dead and/or senesced vegetation.

Unit Name	Code	Source Unit Name	Source Unit Description
		FNLC v1.3: Disturbance – Non and Sparse Woody; Disturbance – Treed and/or Shrub (Cont'd)	Disturbance – Treed and/or Shrub: The result of natural and/or anthropogenic disturbance occurring some time over the last 20 years. Vegetation cover is predominately low treed (less than 10 metres in height and greater than 60% cover) and tall shrub (greater than two metres in height and 60% closure). Patches of closed tall tree cover (greater than 10 metres height and 60% cover) may also be present. Dead or dying trees can exist at less than 20% cover and can be either up rooted and horizontal on the ground or standing. Sites are most often drier upland sites with varying soil depths. This class is mapped by taking advantage of the spatial context provided by disturbance mapping and the unique image tones associated with living, dead and/or senesced vegetation.
Open Cliff and Talus	19	PLC2000: -	
		SOLRIS v1.2: Open Cliff and Talus	Open Cliff and Talus: Vertical or near-vertical exposed bedrock > 3 m in height / slopes of rock rubble at the base of cliffs. Subject to active processes / < 25% vegetative cover
		FNLC v1.3: -	
Alvar	20	PLC2000: -	
		SOLRIS v1.2: Alvar	Alvar: Level, unfractured limestone (carbonate) bedrock/ patchy mosaic of bare rock pavement and shallow substrates (<15cm) over bedrock / tree cover < 60%
		FNLC v1.3: -	
Sand Barren and Dune	21	PLC2000: -	
		SOLRIS v1.2: Open Sand Barren and Dune; Treed Sand Barren and Dune	Open Sand Barren and Dune: Exposed sands formed by extant or historical shoreline or aeolian processes. Subject to active processes / < 25% vegetative cover Treed Sand Barren and Dune: Exposed sands formed by extant or historical shoreline or aeolian processes. Subject to active processes / 25% < vegetative cover < 60%
		FNLC v1.3: -	
Open Tallgrass Prairie	22	PLC2000: -	
		SOLRIS v1.2: Open Tallgrass Prairie	Open Tallgrass Prairie: Ground layer dominated by prairie gramminoids; variable cover of open-grown trees. Tree cover < 25%; shrub cover < 25%
		FNLC v1.3: -	
Tallgrass Savannah	23	PLC2000: -	
		SOLRIS v1.2: Tallgrass Savannah	Tallgrass Savannah: Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 25% < tree cover < 35%
		FNLC v1.3: -	
Tallgrass Woodland	24	PLC2000: -	
		SOLRIS v1.2: Tallgrass Woodland	Tallgrass Woodland: Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 35% < tree cover < 60%
		FNLC v1.3: -	
Sand / Gravel / Mine Tailings / Extraction	25	PLC2000: Sand / Gravel / Mine Tailings	Sand / Gravel / Mine Tailings: Beach deposits, aggregate quarries and sand dunes; mines and mine tailings.
		SOLRIS v1.2: Extraction	Pits, quarries
		FNLC v1.3: Sand/ Gravel/Mine Tailings/ Extraction	Sand/Gravel/Mine Tailings/Extraction: These areas are dominated by exposed soil having less than 25% vegetation cover. Beach deposits, sand dunes, aggregate quarries, mines and mine tailings are all included. Also included are sand islands in larger rivers, unvegetated beach ridges, drier coastal mudflats and very shallow or dry marl lakes.
Bedrock	26	PLC2000: Bedrock	Bedrock: Exposed bedrock, lacking vegetation cover.
		SOLRIS v1.2: -	
		FNLC v1.3: Bedrock	Bedrock: Exposed bedrock with less than 25% vegetation cover.

Community / Infrastructure	27	PLC2000: Settlement / Infrastructure	Settlement / Infrastructure: Clearings for human settlement and economic activity; major transportation routes.
		SOLRIS v1.2: Transportation; Built-up Area Pervious; Built-up Area Impervious	Transportation: Highways, roads Built-up Area Pervious: Urban recreation areas, e.g. golf courses playing fields. Built-up Area Impervious: Residential, industrial, commercial and civic areas.
		FNLC v1.3: Community/ Infrastructure	Community/Infrastructure: Clearings for human settlement and economic activity; major transportation routes.

Unit Name	Code	Source Unit Name	Source Unit Description
Agriculture and Undifferentiated Rural Land Use	28	PLC2000: Agriculture – Pasture / abandoned fields; Agriculture - cropland	Agriculture – Pasture / abandoned fields: Open grassland with sparse shrubs in rural land. Agriculture – cropland: Areas of row crops and fallow fields.
		SOLRIS v1.2: Undifferentiated	Undifferentiated: Includes all agricultural features (e.g. field and forage crops and rural properties) as well as urban brown fields, and openings within forests.
		FNLC v1.3: Agriculture	Agriculture: Land cleared for agricultural use that may or may not be currently active.
Other	-99	PLC2000: Other - unknown	Other – unknown: Landcover conditions not accurately defined by any other landcover class. This class includes the following: undefined clearings in disturbed areas; small, unburned areas within recent burns; and undefined transitional areas between classes, such as some wetland boundaries.
		SOLRIS v1.2: -	
		FNLC v1.3: Other	Other: Land cover features that were not classified for a variety of reasons.
Cloud / Shadow	-9	PLC2000: Other – cloud / shadow	Other – cloud / shadow: Areas of cloud or shadow on the satellite images.
		SOLRIS v1.2: -	
		FNLC v1.3: Cloud/Shadow	Cloud/Shadow: Areas of cloud or shadow on the satellite image.

References

Ontario Ministry of Natural Resources. 2013. Far North Land Cover Data Specifications Version 1.3. Inventory, Monitoring and Assessment Section Technical Report (Unpubl.) 30p.

Ontario Ministry of Natural Resources. 2013. Far North Land Cover Version 1.3. Inventory, Monitoring and Assessment Section.

Ontario Ministry of Natural Resources. 2009. Accuracy Assessment Report: Far North Land Cover 2000 (Version 1.0). Inventory, Monitoring and Assessment Section Technical Report (Unpubl.)

Ontario Ministry of Natural Resources.. 2008. Accuracy Assessment Report 2: SOLRIS Version 1.2 (April 2008 release). Inventory, Monitoring and Assessment Section.

Ontario Ministry of Natural Resources. 2008. Southern Ontario Land Resource Information System (SOLRIS): Phase 2 – Data Specifications Version 1.2. Inventory, Monitoring and Assessment Section Technical Report (Unpubl.)

Ontario Ministry of Natural Resources. Provincial Land Cover Database (2000 Edition). Inventory, Monitoring and Assessment Section. Retrieved July 1, 2013 from the Land Information Ontario Warehouse. http://www.ontario.ca/lio

Ontario Ministry of Natural Resources. Southern Ontario Land Resource Information System (2000-2002) Version 1.2. Inventory, Monitoring and Assessment Section. Retrieved July 1, 2013 from the Land Information Ontario Warehouse. http://www.ontario.ca/lio

Spectranalysis, Inc.. 2004. Introduction to the Ontario Land Cover Database, Second Edition (2000): Outline of Production Methodology and Description of 27 Land Cover Classes.

Appendix 2: Regional Hydrological Models

Introduction

Frequency analysis is conducted for gathering inference about stream flow. To measure stream flow, hydrometric gauging stations are installed. These stations are installed along the stream reach. But, not all the locations of a stream reach are gauged. Estimates will be biased if flows are pro-rated with the nearby gauge stations, beyond +/- 25% drainage area. Hence, in order to estimate the high/low flow (n-year return level) values at any location of a stream reach, regional hydrologic models have been developed. The regional hydrologic models usually use stochastic modelling techniques. The commonly used stochastic modelling techniques are regression, transfer functions, neural networks and system identification. Mathematical and statistical theories and concepts are used to estimate the parameters. Among the above methodologies, the regression models namely the Index Method and the Multiple Regression Method are widely used in hydrology. These models resolve the problem by "trading space for time" (Hosking and Wallis, 1997). The underlying principle is to transpose the historic stream flow records of the region to the location of interest. This is achieved by building models that combine stream flow at known locations with the corresponding physio-meteriological factors. The above mentioned two methods are also recommended by WMO (1994) for frequency studies. Amongst the two, the Index method is the simplest method.

The steps involved in developing regional models are (a) Develop a Single Station Frequency Curve, (b) Delineate Homogenous Regions, (c) Develop Regional Frequency Curves that are evaluated against the methodology/scientific principles used. This is shown in Fig 1.

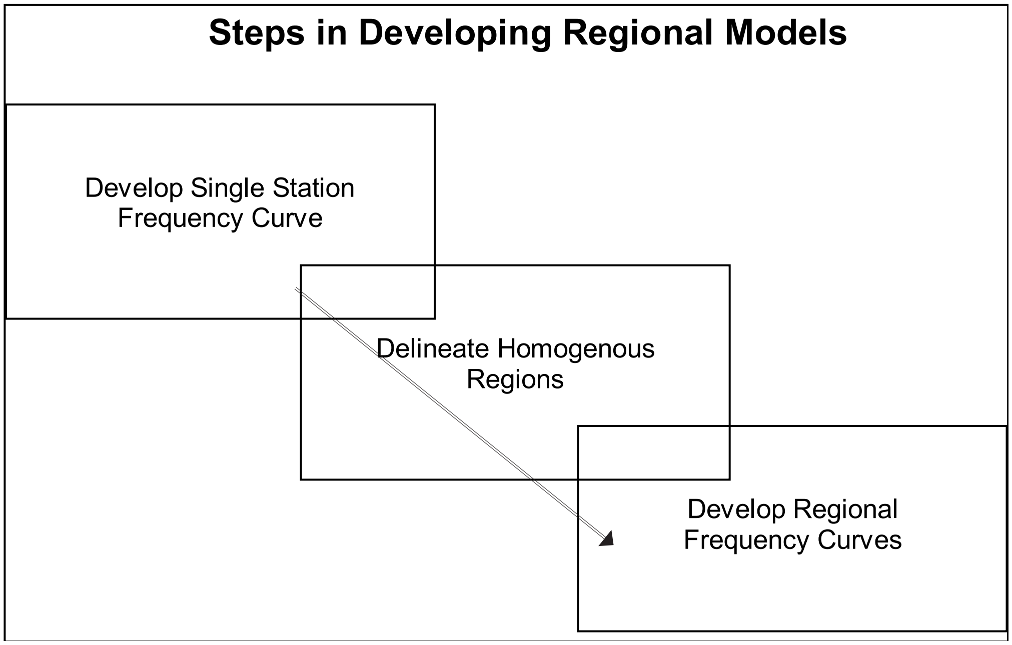


Figure 1: Steps in Developing Regional Models

Governing Equations for Return Period – Return Level

Recurrence Interval or Return Period is defined as:

An annual maximum event has a return period (or recurrence interval) of T years if its magnitude is equalled or exceeded once, on the average, every T years. The reciprocal of T is the exceedance probability, 1- F, of the event, that is, the probability that the event is equalled or exceeded in any one year (Bedient, 2002)

The probability (P) that an event (F) will occur in any year (T) is expressed mathematically as:

$$P(F) = \frac{1}{T} \quad ....(1)$$

Return Period is the reciprocal of probability and is expressed mathematically as:

$$T = \frac{1}{P} \quad ....(2)$$

Recurrences intervals (return periods) usually calculated are: 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years (annual-exceedance probabilities of 0.6667, 0.50, 0.4292, 0.20, 0.10, 0.04, 0.02, 0.01, 0.005, and 0.002, respectively). General equation for estimating the return level is in terms of the frequency factor for hydrological studies is given by Chow, 1964. The frequency factor depends on the type of distribution. It is expressed mathematically as:

$$y = \overline{y} + \sigma K \quad ....(3)$$

The Index Method

The Index method was developed by Dalrymple in 1960. A summary of this method as given in the U.S Geological survey is given below.

Initially, single hydrometric station analysis is carried out and the corresponding frequency is developed. The variable used for single station analysis is the maximum instantaneous peak flow of the annual series. Then single station frequency curves are combined to give the regional frequency curves. This is completed in two steps. The first step is the development of the dimensionless frequency curve which represents the ratio of the flood of any frequency to an index flood known as mean annual flood. The second step is the development of the relationship between mean annual floods to the drainage area of the basin.

The procedure for the development of the frequency curve for any location is: (a) find the mean annual flood corresponding to the drainage area of the watershed; (b) from the first curve select ratios of peak discharge to mean annual flood for the selected recurrence interval; (c) multiply these ratios by the mean annual flood and plot the resulting discharges of these ratios by the mean annual flood and plot the discharge of known frequency to define the frequency curve. The procedure is explained in the upcoming section.

The mean annual flood is used to make the dimensionless frequency curve. Mean annual flood (index flood) is defined as the flood having a recurrence interval of 2.33 years. The premise for using the mean annual flood as the index flood is as follows. The magnitude of the mean annual flood is affected by both physiographic and meteorological factors of the drainage basin. A method to account for the composite effect of these factors is determined by dividing the study region into homogeneous hydrologic regions and correlating it to the most significant factor, the drainage area.

The Index Method assumes that the flow is natural, or with minimum regulation, and the region is homogeneous. There is no limit to the drainage area of the homogeneous region. The recurrence intervals are computed with a minimum of 10 years of record.

The Index method is popular as it is simple and most importantly, it requires only the drainage area of the watershed, making it suitable for watersheds where physio-meteriological data are sparse. The Index method was first introduced for flood flows and then later applied for low flows. The scientific principles remain the same for both flood and low flows.

The Multiple Regression Method

Multiple linear regression (the term was first used by Person, 1908) is a multivariate statistical technique for examining the linear correlations between two or more independent variables (IVs) and a single dependent variable (DV). Multiple linear regression models are useful for: (1) predicting unobserved values of the response (y(x) for new x); (2) understanding which terms ai(x) have greatest effect on the response (coefficients aj with greatest magnitude); (3) finding the direction of the effects (signs of the ai) (4) to what extent do x1, x2, and x3 (IVs) predict y (DV). Here, the first use is being implemented. The governing equation is of the form:

$$Y = a_0 + \sum_{i=1}^{p} a_i (X_i) \quad \ldots\ldots(4)$$

where:

- y = dependent variable (T-year flood flow – actual or transformed)
- a_0 = regression constant
- a_i = regression coefficient (s)
- x_i = independent variable (s) (basin parameter – actual or transformed)
- p = no. of independent variables used

The assumption of the analysis is that the residuals are normally distributed and have a straight line relationship with predicted DV scores, and the variance of the residual about the predicted scores is the same for all predicted scores.

Flood Flow Model

In 1978, the Government of Canada and the Province of Ontario entered into "An Agreement Respecting Flood Risk Mapping and Other Flood Damage Reduction Measures". The Index Method with Expected Probability Adjustment (Moin & Shaw, 1985) and the Secondary Multiple Regression Method (Moin & Shaw, 1985) commissioned by the Steering Committee are implemented here. The flow values estimated are given in Table 1.

Name of Model	Parameters Estimated								
Index Flood Method With Expected Probability Adjustment (Moin & Shaw 1985)	$Q_{1.25}$	Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}	Q_{100}	Q_{200}	Q_{500}
Secondary Multiple Regression Method (Moin & Shaw 1985)	Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}	Q_{100}			

Table 1: Parameters Estimated in Flood Flow Models

Index Flood Method (Moin & Shaw 1985)

For the study, the province was divided into 12 regions based on the study conducted by Sangal and Kallio (1977) and a homogeneity test was conducted. The regions are shown in Figure 2. The variable used for single station analysis is annual peak instantaneous flow. Where this value is not available, the analysis uses the hydrograph method described by Sangal, 1981.

A total of 247 hydrometric stations with a record length of 10 or more years were used for the study. These stations have either natural or minimal regulation in flow. The data was fitted to the Three Parameter Log Normal Distribution. Split sample testing (Jack-Knife method) was done to validate the model. Eleven hydrometric stations from the total were kept aside. These stations were not used in developing the regional curve or in establishing drainage area versus mean annual flood relationships. The testing stations were treated treated as ungauged and the results of the single station analysis of these stations were compared with the regional model. The percentage error was tabulated and it is seen that Index Flood method gave predicted values which were quite reasonable except for two stations when compared to those obtained by the single station analysis.

The flow versus drainage area relationship is shown below in equation 5. The equations coefficients and the corresponding drainage area range are given in Table 2. This method developed two equations: drainage area greater or less than 60 square kilometres for region 1. This approach overcomes the limitation of the drainage area range to a certain extent. The dimensionless ratio of the regional frequency curves for each region is given in Table 3.

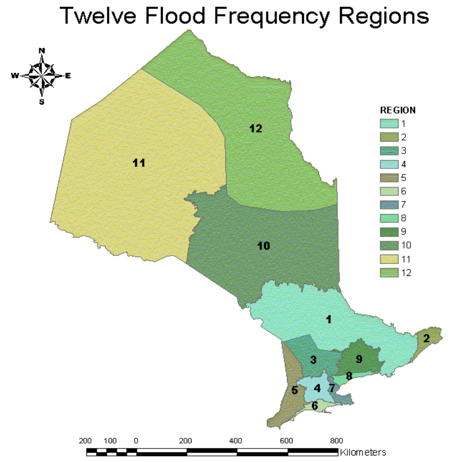


Figure 2: Twelve Flood Regions of Index Flood Method (Moin & Shaw, 1985)

General form of the equation:

$Q_2 = CA^n$ ....(5)

where:

Q_2 = 2 year return period (3PLN) flood
A = Drainage Area
C = Constant
n = exponent (slope)

Region	Constant C	Exponent n
1(a)	0.22 (A < 60 km^2)	1.000
1(b)	0.73 (A >60 km^2)	0.707
2	0.51	0.896
3	0.20	0.957
4	0.71	0.842
5	0.45	0.775
6	0.41	0.806
7	1.13	0.696
8	0.73	0.785
9	0.40	0.81
10	0.28	0.849
11	0.38	0.706
12	0.59	0.765

Table 2: Coefficients of the Regression Equations

Region	Minimum (km2)	Maximum (km2)
1	0.11	9270
2	76.1	3816
3	86.0	3960
4	2.5	5910
5	14.2	4300
6	5.2	697
7	63.5	293
8	4.9	800
9	24.3	1520
10	18.6	11900
11	0.7	24200
12	4250	94300

Table 3: Range of Drainage Area Values for the Regression Equations

Region	Q1.25/Q2	Q2/Q2	Q5/Q2	Q10/Q2	Q20/Q2	Q50/Q2	Q100/Q2	Q200/Q2	Q500/Q2
1	0.95	1.00	1.24	1.43	1.62	1.86	2.04	2.23	2.48
2	0.94	1.00	1.29	1.52	1.74	2.04	2.25	2.45	2.72
3	0.93	1.00	1.33	1.62	1.89	2.25	2.54	2.82	3.19
4	0.93	1.00	1.32	1.57	1.80	2.13	2.37	2.60	2.92
5	0.94	1.00	1.27	1.50	1.74	2.06	2.34	2.62	2.96
6	0.91	1.00	1.43	1.78	2.13	2.60	2.96	3.33	3.84
7	0.94	1.00	1.27	1.47	1.66	1.90	2.07	2.24	2.47
8	0.92	1.00	1.43	1.85	2.30	2.96	3.46	4.00	4.77
9	0.94	1.00	1.27	1.50	1.72	2.02	2.26	2.49	2.80
10	0.95	1.00	1.20	1.35	1.48	1.64	1.77	1.90	2.07
11	0.93	1.00	1.33	1.62	1.9	2.32	2.67	3.05	3.55
12	0.94	1.00	1.22	1.38	1.52	1.68	1.80	1.90	2.05

Table 4: Ratio of the Frequency Values

Another feature of this study was the introduction of the expected probability concept. The expected probability is defined as the average of the true probabilities of all magnitude estimates for any specified flood frequency that might be made from successive samples of specified size. It incorporates the effects of uncertainty in application of the curve. The Province of Ontario has adopted the policy where all frequency curves will be adjusted for the expected probability computations.

The average record length is employed to adjust the probabilities for each of the regions. N represents the number of years of record.

Exceedance Probability	Expected Probability
0.005	0.005(1+52/N1.16)
0.01	0.01(1+26/ N1.16)
0.05	0.05(1+6/ N1.04)
0.1	0.1(1+3/ N1.04)
0.3	0.3(1+0.46/N0.925)

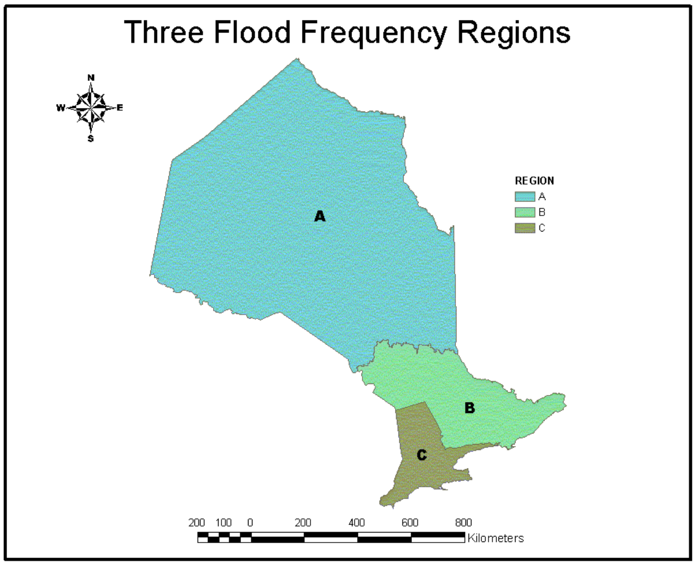
N is the number of years of record

Multiple Regression Method (Moin & Shaw 1985)

The Multiple Regression Method was also included for the flood mapping studies along with the Index Method. As in the Index Method, the variable used for single station analysis is annual peak instantaneous flow. Where this value is not available, the analysis uses the hydrograph method described by Sangal, 1981. Gauging stations in Ontario were classified according to the degree of regulation. Regulated gauging stations are included in the 50 and 100 year return period with the premise that regulation has less impact on large events. Frequency curves were developed for gauging stations with more than 10 years of historic data. For 50 and 100 year return periods, 270 gauging stations were used, and for 2, 5, 10 and 20 year return periods, 217 gauging stations with natural flow or minor regulation were used.

The main feature of this method is the delineation of homogenous regions within Ontario using the standardized residuals from the 100 year return level. Three homogenous regions where found by grouping the residuals of similar magnitude and sign. These regions are shown in Figure 3.

Regression equations were developed for each of the three homogeneous regions. The parameters significant in the regression equations in the order of importance are: Drainage Area, Base Flow Index, Slope of the Main Channel, Area Controlled by Lakes and Swamps, Mean Annual Runoff, Mean Annual Precipitation and Shape Factor.



Method (Moin & Shaw, 1985)

Regression equations developed were tested on: measure of performance as expressed as percentage in difference from the single gauge analysis, sensitivity analysis of dependent variables, regression analysis, R^2 of the equation, error analysis (same as Index method) and testing of regression equations with two stations each from each region. The test results indicated good prediction of estimates with acceptable error.

The model is calibrated for all the independent variables of the regression equation. The governing equations and the information are given below in Table 5.

Variables	Symbol
Drainage Area (km2)	DA
Mean Channel Slope (m/km)	SLP
Index of Area Controlled by Water & Wetland (%)	ACLS
Shape Factor (dimensionless) (=LNTH2/DA, where LNTH = length of main channel (km) and DA = drainage area (km2))	SF
Base Flow Index(dimensionless)	BFI
Mean annual Runoff (mm)	MAR
Mean Annual Precipitation (mm)	MAP

Table 5: Variables used in the Moin & Shaw (1985) Regression Equation

The regression equation is:

$Log(QT) = a_0 + a_1Log(DA) + a_2(BFI)^{1/2} + a_3(SLP)^{1/3} + a_4(ACLS)^{1/2} + a_5(SLP) + a_6Log(MAR) + a_7(MAR) + a_8Log(ACLS+1) + a_9(MAP) + a_{10}(SF)$ ……………………(6)

Regression co-efficients of the Multiple Regression Equations are below in the series of Tables 6.

All Ontario							
Flow m3/sec	**a0**	**a1**	**a3**	**a4**	**a7**	**SE**	**R2**
Q2	-1.5689	0.8509	0.1635	-0.0339	0.0013	0.22	0.95
Q5	-1.3629	0.8370	0.2023	-0.0341	0.0012	0.21	0.85
Q10	-1.2251	0.8261	0.2154	-0.0341	0.0012	0.21	0.84
Q20	-1.1478	0.8205	0.2353	-0.0333	0.0012	0.21	0.84
Q50	-0.8744	0.8006	0.2315	-0.0359	9.7E-4	0.21	0.84
Q100	-0.7947	0.7950	0.2424	-0.0357	9.3E-4	0.22	0.83

Region A								
Flow m3/sec	**a0**	**a1**	**a2**	**a7**	**a8**	**a9**	**SE**	**R2**
Q2	0.5473	0.9418	-2.3038	0.0011			0.13	0.95
Q5	0.4916	0.8952	-1.7518	0.0012	-0.1007		0.12	0.96
Q10	0.6927	0.8859	-1.8087	0.0010	-0.0907		0.12	0.96
Q20	0.8670	0.8767	-1.8563	8.5E-4	-0.0819		0.13	0.95
Q50	1.0335	0.9005	-2.3169			5.2E-4	0.13	0.94
Q100	1.0929	0.8889	-2.2764			5.1E-4	0.15	0.93

Region B							
Flow m3/sec	**a0**	**a1**	**a3**	**a4**	**a10**	**SE**	**R2**
Q2	0.2143	0.7464	-0.2172	-0.0194	-0.0077	0.14	0.91
Q5	0.2746	0.7443	-0.1961	-0.0198		0.14	0.89
Q10	0.3795	0.7217	-0.1799	-0.0202		0.15	0.87
Q20	0.2311	0.7461		-0.0197	-0.0081	0.15	0.87
Q50	0.3659	0.6989		-0.0275		0.15	0.85
Q100	0.4471	0.6839		-0.0276		0.16	0.83

Region C									
Flow m3/sec	**a0**	**a1**	**a3**	**a4**	**a5**	**a6**	**a8**	**SE**	**R2**
Q2	-1.7155	0.8734		-0.0167		0.5580		0.22	0.82
Q5	-1.7967	0.9031	0.1721	-0.0180		0.5424		0.21	0.83
Q10	-1.6547	0.8897	0.1841	-0.0177		0.5261		0.21	0.82
Q20	-1.5499	0.8786	0.1937	-0.0174		0.5173		0.22	0.81
Q50	-1.1793	0.8759			0.0337	0.4698	-0.0800	0.23	0.79
Q100	-1.1375	0.8676			0.0349	0.4804	-0.0811	0.23	0.78

Tables 6: Coefficients of the Secondary Multiple Regression Equations

The range of input values for the parameters of the Multiple Regression Equation are presented below in Table 7.

All Ontario				
	Q2-Q20		Q50-Q100	
Variable	Minimum	Maximum	Minimum	Maximum
DA	13.9	60100.0	13.9	395.5
BFI	0.15	1.0	0.15	0.56
SLP	0.02	9.42	0.02	1.22
ACLS	0.00	122.00	0.0	10.50
MAR	137.0	626.0	137.0	363.50
MAP	500.0	1000.0	500.0	840.0
Region A				
	Q2-Q20		Q50-Q100	
Variable	Minimum	Maximum	Minimum	Maximum
DA	62.9	60100.0	62.9	118000.0
BFI	0.36	1.0	0.36	1.0
SLP	0.02	4.14	0.02	4.14
ACLS	0.0	100.0	0.0	100.0
MAR	193.0	598.0	193.0	598.00
MAP	N/A	N/A	500.0	1000.0
Region B				
	Q2-Q20		Q50-Q100	
Variable	Minimum	Maximum	Minimum	Maximum
DA	13.9	3810.0	13.9	4770.0
BFI	0.26	0.82	0.26	0.90
SLP	0.14	5.77	0.02	5.77
ACLS	0.0	97.0	0.0	100.0
SHP	1.41	42.14	1.38	42.14
Region C				
	Q2-Q20		Q50-Q100	
Variable	Minimum	Maximum	Minimum	Maximum
DA	14.2	5910.0	14.2	5910.0
BFI	0.15	0.81	0.15	0.81
SLP	0.21	9.42	0.21	9.42
ACLS	0.0	122.0	0.0	122.0
MAR	137.0	527.0	137.0	527.00

Table 7: Range of Input Parameters for the Multiple Regression Equation

Low Flow Models

The Graphical Index Method (MOEE, 1995), and the Regression Method (MOEE 1995) implemented in OFAT III were developed by Cumming Cockburn Limited for the Ontario Ministry of Environment and Energy. The estimated outputs from the Low Flow models are given in Table 7.

Model Name	Parameter Estimated					
Graphical Index Method (MOEE 1995)	1Q2	1Q5	1Q10	1Q20	1Q50	1Q100
	3Q2	3Q5	3Q10	3Q20	3Q50	3Q100
	7Q2	7Q5	7Q10	7Q20	7Q50	7Q100
	15Q2	15Q5	15Q10	15Q20	15Q50	15Q100
	30Q2	30Q5	30Q10	30Q20	30Q50	30Q100
Regression Method (MOEE 1995)	3Q2	3Q20	3Q50	7Q2	7Q20	7Q50
	30Q2	30Q20	30Q50			

Table 8: Low Flow Models and the Parameters Estimated.

As all methods were undertaken by the same consultant; the methodology for the single gauge station analysis and the generation of homogeneous regions remains the same. A total of 344 stations with more than 10 years of record were used for the study. Variables are extracted in two steps. First the moving average low flows (n-day) were determined, and then from that extreme low values are extracted for each year of the available data base. For the Index method, for each (n-day) 1, 3, 7, 15 and 30 duration frequency curves were developed for each station. For the regression method, only 7 day duration is used. The data is fitted to the Weibull Distribution, and then frequency curves of these stations were developed. The Province was divided into six hydrological homogeneous regions by grouping similar meteorological and physiographic characteristics. These homogeneous regions are depicted in Figure 4.

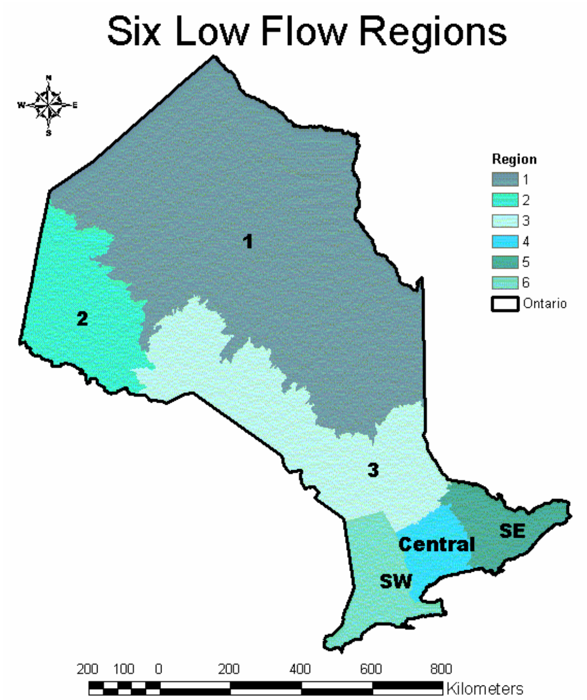


Figure 4: Six Hydrological Homogeneous Regions MOEE, 1995)

Index Method (MOEE, 1995)

Equations that relate the frequency with the drainage area, the calibrated values (range) of drainage area are given in Table 8. Application of the Index method resulted in a Nash-Sutcliff coefficient of 0.92 and 0.87 for $7Q_2$ and $7Q_{20}$ respectively.

General form of the equation:

$Q_2 = CA^n$

where Q_2 = 2 year return period (3PLN) flood

A = Drainage Area

C = Constant

n = exponent

Region	Equation
1	7Q2 = 8.681 + 0.00208 * DA
2	7Q2 = -2.494 + 0.00325 *DA
3	7Q2 = -1.341 +0.00353 *DA
Central	7Q2 = 0.383 +0.00161 *DA
Southeastern	7Q2 = -1.60 +0.00251 *DA
Combined Central and Southeastern	7Q2 = 0.118 + 0.00205 *DA

Table 8: Regression Equations of the Index Flood, 7Q2

Regression Method (MOE, 1995)

Watershed characteristics, Drainage Area, Length of Main Channel, Mean Annual Runoff, Base Flow Index and Mean Annual Snowfall were used to make the regression equations. This method also develops two equations for the regions 1, 2 and 3 for drainage areas greater or less than 17,000 km2. This approach overcomes the limitation of the drainage area range. The equations for each region, their coefficients and the calibrated watershed values are given in Table 9 through Table 17.

Sensitivity analysis of the watershed parameters show that the drainage area to be the most sensitive. Nash-Sutcliff coefficient of 0.68 and 0.86 were obtained for 7 day, 2 and 20 year recurrence intervals.

Northeastern and Northwestern Regions

Variables used in the regression equations are given in Table 9.

Variables	Symbol
Drainage Area (km2)	DA
Length of Main Channel (km)	LNTH
Mean Annual Runoff (mm)	MAR

Table 9: Variables used in the MOEE, 1995 Regression Equation for NW and NE Regions.

The general form of multiple regression equation for $7Q_2$ and $7Q_{20}$ is:

$$Y = a_0 + a_1(DA) + a_2(DA)^{1/2} + a_3(DA)^2 + a_4(LNTH) + a_5(LNTH)^{1/2} + a_0\,(MAR) + a_7(MAR)^2$$

The coefficients for the multiple regression equation for $7Q_2$ are listed in Table 10.

Region	a0	a1	a2	a3	a4	a5	a6	a7
1	-35.766		0.8628			-4.130		0.000353
2	21.65	0.00337				-4.791	0.18088	
3	7.506			1.581*10-7		0.5491	-0.0156	
1, 2, and 3, DA < 17000 km2	-3.15	0.00323			0.01898		0.00756	

Table 10: Coefficients of MOEE, 1995 Multiple Regression Equations for 7Q2

The co-efficients of the multiple equations for $7Q_{20}$ are listed in Table 11.

Region	a0	a1	a2	a3	a4	a5	a6	a7
1	-25.718		0.5587			-2.89		0.000272
2	8.124	0.00125				-0.796	-0.0104	
3	0.4185			9.777*10-8		0.3403	-0.0055	
1, 2 and 3, DA < 17000 km2	-2.45	0.0016			-0.0021		0.0047	

Table 11: Coefficients of Multiple Regression Equations

Central and Southeastern Regions

Variables used in the regression equations are given in Table 12.

Variable	Symbol
Drainage Area (km2)	DA
Base Flow Index	BFI

Table 12: Variables used in the Regression Equation

The general form of multiple regression equation for the Central Region is:

$$Y= a_0 + a_1(DA) + a_2(BFI)$$

Flow (m^3/sec)	a_0	a_1	a_2
$7Q_{20}$	-0.2134	0.00066184	0.7022
$7Q_2$	-0.7216	0.0018060	1.7386
$3Q_2$	-0.5398	0.0016260	1.2856
$3Q_{20}$	-0.1841	0.00058893	0.6295
$3Q_{50}$	-0.1331	0.00045199	0.5160
$30Q_2$	-0.7119	0.0022380	1.6806
$30Q_{20}$	-0.3275	0.00097749	0.9305
$30Q_{50}$	-0.2839	0.00087086	0.8045

Table 13: Coefficients of Multiple Regression Equations

The general form of multiple regression equation for the Southeastern Region:

$$Y= a_0 + a_1(DA)^3 + a_2(BFI)$$

Flow (m3/sec)	a0	a1	a2
7Q20	-0.5084	7.6323E-11	1.1460
7Q2	-0.9018	1.3049E-10	2.2728
3Q2	-1.0351	1.2409E-10	2.3828
3Q20	-0.6133	7.0980E-11	1.2527
3Q50	-0.6226	6.5153E-11	1.2372
30Q2	-1.0195	1.4637E-10	2.6144
30Q20	-0.5196	8.5495E-11	1.3062
30Q50	-0.4643	7.9836E-11	1.1773

Table 14: Coefficients of Multiple Regression Equations

Southwestern and West Central Regions

Table 15 shows the parameters used in the final regression equations for these regions.

Variable	Symbol
Drainage Area (km2)	DA
Base Flow Index (dimensionless)	BFI
Length of Main Channel (km)	LNTH
Mean Annual Runoff (mm)	MAR
Mean Annual Snow (cm)	MAS

Table 15: Variables used in the Regression Equation

The general form of multiple regression equation for the Southwestern and Westcentral Region:

$$Y= a_0 +a_1(DA)^3 +a_2(BFI)^2 +a_3(LNTH)^2$$

Flow m3/sec	a0	a1	a2	a3
$7Q_2$	-0.190	1.24E-10	1.67	8.35E-5
$7Q_{20}$	-0.166	9.03E-11	1.10	4.67E-5
$7Q_{50}$	-0.160	8.54E-11	1.02	3.92E-5
$3Q_2$	-0.183	1.21E-10	1.55	7.81E-5
$3Q_{20}$	-0.158	8.57E-11	0.99	4.30E-5
$3Q_{50}$	-0.150	7.92E-11	0.91	3.64E-5
$30Q_2$	-0.233	1.29E-10	2.12	1.12E-4
$30Q_{20}$	-0.227	9.58E-11	1.52	N/A
$30Q_{50}$	-0.078	1.25E-10	1.44	N/A

Table 16: Coefficients of Multiple Regression Equations

Each low flow region uses a different range of hydrologic parameters to develop models, limiting their use. Ranges of input parameters for each region is shown in Table 17.

Region 1				Region 2				Region 3		
Variable	**Min**	**Max**		**Variable**	**Min**	**Max**		**Variable**	**Min**	**Max**
MAP	500	830		MAP	695	790		MAP	695	790
MAS	190	305		MAS	190	230		MAS	190	230
MAR	108	456		MAR	154	406		MAR	154	406
EVA	340	450		EVA	490	515		EVA	490	515
DA	401	94300		DA	744	50200		DA	744	50200
BFI	0	1		BFI	0.68	0.99		BFI	0.68	0.99
LNTH	25	476.3		LNTH	4	238.1		LNTH	4	238.1
ACLS	0	100		ACLS	0	100		ACLS	0	100
Region 4 (Central)				**Region 5 (Southeastern)**				**Region 6 (Southwestern)**		
Variable	**Min**	**Max**		**Variable**	**Min**	**Max**		**Variable**	**Min**	**Max**
MAP	780	1000		MAP	800	920		MAP	780	1020
MAS	120	300		MAS	170	200		MAS	90	350
MAR	189	527		MAR	260	540		MAR	137	516
SLP	0.02	9.434		SLP	0.14	12.19		SLP	0.00034	0.00747
EVA	665	830		EVA	635	790		EVA	14.2	3960
DA	24.3	1520		DA	7	4120		DA	0.1	0.8
BFI	0.17	0.82		BFI	0.3	0.88		BFI	6.1	190.5
LNTH	9	94.3		LNTH	5	112.4		LNTH	1	100
ACLS	0	100		ACLS	0	100		ACLS	1	100

Table 17: Range of Values for the Regression Equations

Mean Annual Flow (MAF) Model

Currently, OFAT contains the Isoline Method (Environment Canada, 1986) to estimate mean annual flow (cms). The original provincial isoline map for mean annual runoff (mm) was first digitized and then a continuous surface (a map) with 1km * 1km cell resolution was created from the isolines. The mean annual runoff (mm) for the watershed is calculated by averaging all the cell values within the watershed boundary, which can be converted into mean annual flow (cms).

Appendix 3: Provincial Application Areas of OFAT III

Permit To Take Water (2007)

Sections 34: Ontario Water Resources Act, R.S.O. 1990 and Water Taking Regulation O. Reg. 387/04

Permit to Take Water Guideline recommendation for Surface Water Taking of Category 2 is *"River and Streams (3rd order or higher order) takings less than 5% of 7Q20."*

Approval of Sewage Works (2010)

Sections 53: Ontario Water Resources Act R.S.O. 1990

a. Industrial Sewage Works

Under the Environmental Impact Analysis of Surface Water Impact states the limiting conditions as "Limiting conditions within the receiving water body, including: Low flow conditions in the receiving water body, e.g., the 7Q20 for a stream, i.e., the 7-day average low flow occurring once in 20 years".

b. Municipal and Private Sewage Works

Under the Environmental Impact Analysis of Surface Water Impact states the limiting conditions as "Limiting conditions within the receiving water body, including: Low flow conditions in the receiving water body, e.g., the 7Q20 for a stream, i.e., the 7-day average low flow occurring once in 20 years".

Approval under the Lakes & Rivers Improvement Act (2010)

Sections 14 and 16: Lakes and Rivers Improvement Act (LRIA) 1927 and Ontario Regulation 454/96

The range of minimum inflow design floods are given in Table 1.

Hazard Potential Classification	Range of Minimum Inflow Design Floods			
	Life Safety		Property and Environment	Cultural - Built Heritage
Very High	Greater then 100	PMF (Probable Maximum Flood)	1/3 between the 1000 Year Flood and PMF to PMF	
	11-100	2/3 between the 1000 year Flood and PMF		
High	1-10	1/3 between the 1000 year Flood and PMF	1000 Year Flood or RF whichever is greater to 1/3 between the 1000 year flood and PMF	1000 Year Flood or RF whichever is greater
Moderate	100 Year Flood to 1000 year flood or RF whichever is greater			
Low	25 Year Flood to 100 Year Flood			

Table 1: Range of Minumum Inflow Design Floods

Flow recommendations as given in the technical guidelines are:

a. *"The design flow for fish passage should not exceed a frequency of a 1:10 year 3 day delay. This is the flow that is exceeded on average every ten years for three consecutive days".*

b. *"The PMF (probable maximum flood) is not normally used for channel design. The channel capacity may be designed for less than the 25 year flood, e.g., 10, 5, or 2 year flood, but the combined capacity of the channel and flood plain must meet the design flood criteria for small dams in the table"*

c. *"Bankfull discharge of a river natural flow channel usually corresponds to the 1:2.33 year to the 1:5 year return period depending upon the stream type and basin conditions".*

The recommendations for the road crossing are given in Table 2:

Minimum Design Floods for Road Crossings		
Road Classification	**DESIGN FLOODS**	
	Total Span (up to 6.0 m)	**Total Span (over 6.0 m)**
Freeways and Urban Arterial Roads	50 year	100 year or Regulatory Flood depending on local conditions
Rural Arterial and Collector Roads	25 year	50 year
Local (may be paved)		
Local (unpaved) Roads and Resource Access Roads	10 year	25 year
Temporary Detours	1 to 5 year	1 to 10 year

Table 2: Minimum Design Floods for Road Crossings

Flooding Hazard Limit

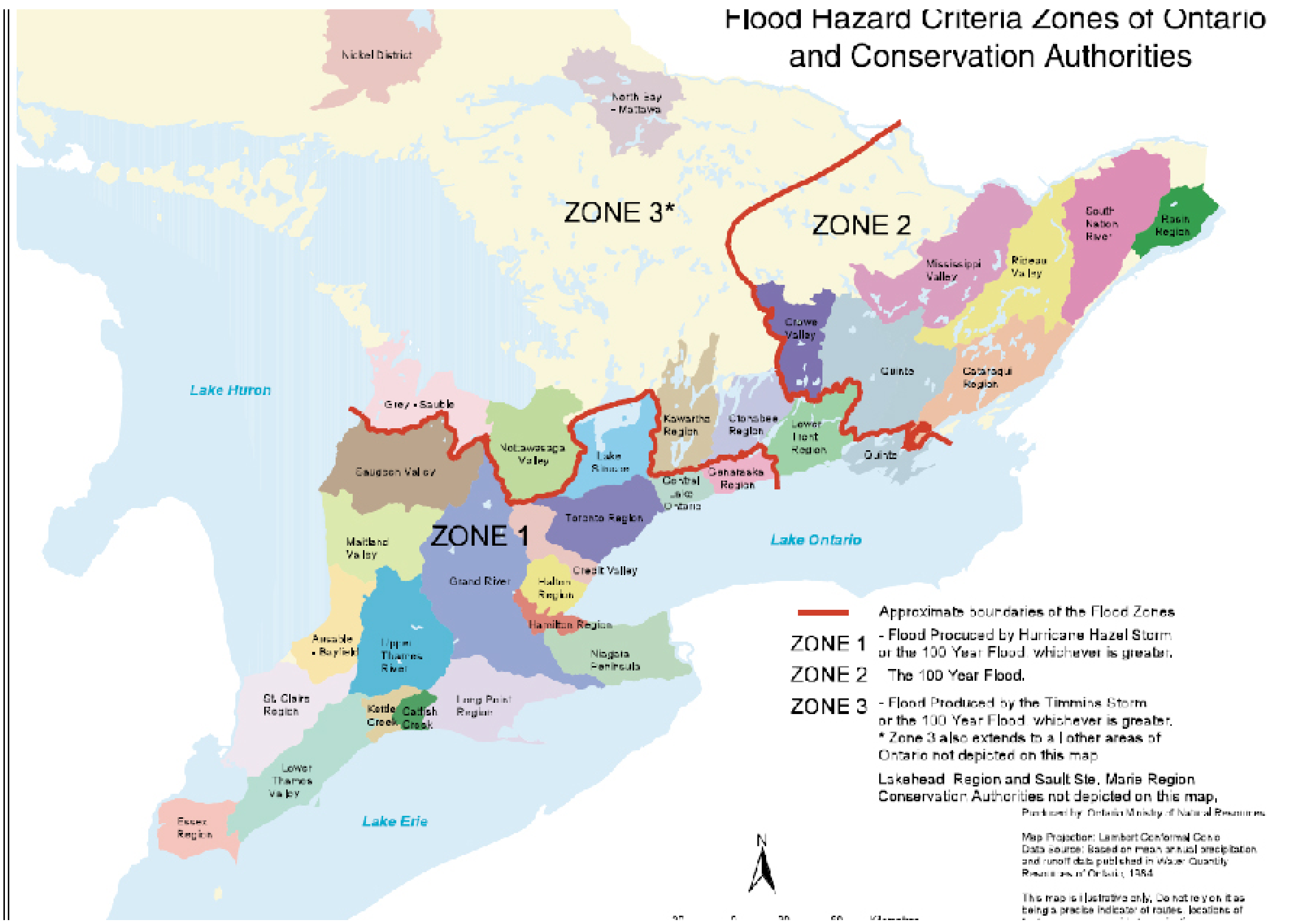
Natural Hazard Policies of the Provincial Policy Statement of the Planning Act (2002).

River System Flood Standards:

Zone 1 the peak flow resulting from the Hurricane Hazel1 Storm or the 100 year flood, whichever is greater;

Zone 2 the 100 year flood

Zone 3 the peak flow resulting from the Timmins2 Storm or the 100 year flood,whichever is greater; depending on the location in the province.



Adaptive Management

Natural Channel System: Adaptive Management of Stream Corridors in Ontario

The full regime flows should be included:

> *"Low flow - 7Q2, 7Q10, 7Q20 (biological requirements)*
>
> *Bankfull flow - 1:1.5 to 1:5 year event (geomorphology requirements)*
>
> *Riparian flow - 1:10 to 1:25 year event (biology, geomorphology)*
>
> *Valley flow/flood plain - 1:100 to Regional event"*

Design Flood for River and Stream Crossing based on Risk

MTO Drainage Management Manual (1997)

Risk is usually expressed as a probability, P that a flood will be exceeded in any one-year period and can be expressed as:

$$P = 1 - (1 - 1/Tr)\ n$$

where:

Tr = return period of the storm in years

n = life of the structure in years

Average Return Period (years)	Probability of Exceedance During: n -years of life of the structure (percent)					
	2.3	**5**	**10**	**25**	**50**	**100**
2.33	73	94	100	100	100	100
5	41	67	89	100	100	100
10	22	41	64	93	99	100
25	9	18	34	64	87	98
50	5	9	18	41	64	87
100	2	5	9	22	40	64
1000	0	1	1	3	5	10

Table 3: Risk Factors over life of structure.

Peak Flow Rate Criteria

Storm water management planning and design manual (2003)

> *"Generally, accepted criteria are that maximum peak flow rates must not exceed pre-development values for storms with return periods ranging from 2 to 100 years. Peak flow rates must be determined on a site by site basis. Existing rates can be determined utilizing computer simulation modelling or by transposing a frequency analysis of measured peak flow rates on a unit area basis to a site".*

Ontario Low Water Response

Condition	Indicator	
	Precipitation	Streamflows
Level I Voluntary Conservation	< 80 % of average	Spring: monthly flow < 100 % lowest average summer month flow Other times: monthly flow < 70 % of lowest average summer month flow
Level II Conservation and Restrictions on Non-Essential Use	< 60% of average weeks with < 7.6 mm	Spring: monthly flow < 70% of lowest average summer month flow Other times: monthly flow < 50 % of lowest average summer month flow
Level III Conservation, Restriction, Regulation	< 40% of average	Spring: monthly flow < 50% of lowest average summer month flow Other times: monthly flow < 30% of lowest average summer month flow

Table 4: Indicator thresholds for Low Water Conditions

> *"An indication of streamflow approaching the minimum needed to maintain the ecosystem is the statistical flow value, 7Q20……Comparing the value of the current flow with the historic low value will determine when the streamflow is approaching the 7Q20".*
>
> *"Streams in the headwaters or those having high width-to-depth ratio are expected to be more sensitive to low flows. An indication of streamflow approaching the minimum needed to maintain the ecosystem in these streams is the statistical flow value, 7Q2".*

Water Budget

Section 15 (2) Clean Water Act (2006)

Water Budget and Water Quantity Risk Assessment Guide (2011)

> *"Water Budget Components: ……Analyse Streamflow (QSW). The analysis will include estimates of streamflow statistical parameters (i.e.QP90, QP50, Qavg) where continuous records exist, analysis of spot flow measurements or pro-rating of data from nearby gauges.The analysis may also include baseflow separation at gauged surface water stations."*
>
> *"Surface Water Supply Estimation Methods: …….The 30Q2 flow provided by OFAT is an estimate of average annual baseflow (Pryce, 2004). This flow could be considered as the water supply for each month, as the tools in OFAT cannot provide monthly low flow estimates. OFAT cannot account for flow augmentation and regulation controls. Therefore the team must understand its limitations in estimating baseflow."*
>
> *"Tier One Surface Water Monthly Water Reserve Estimation Methods:…….. When a continuous stream gauge is available, the surface water reserve may be calculated for each month as the monthly lower decile flow (QP90), or the flow that is exceeded 90% of the time for each month."*
>
> *"Surface Water Stress Assessment:……… Water Reserve….. Surface water reserve is calculated as the monthly lower decile flow (Q90) at the outlet of the subwatershed for Tier Two. The water reserve estimate may be the same in Tier One where a reliable surface water gauge is located at the outlet of the subwatershed."*

"Significant Risk Circumstances – Groundwater:…….. Under scenario G (existing plus committed plus planned demand), the municipal takings result in measurable and unacceptable impacts to other uses. For coldwater streams, an unacceptable impact is defined by a circumstance where groundwater discharge is reduced by more than 20% as compared to the existing estimated monthly streamflow Qp80 (the flow that is exceeded 80 percent of the time) or the average monthly baseflow of the watercourse or another threshold that has already been defined as a condition in an existing permit. In situations where another threshold has been defined, that threshold would be used to identify a significant risk."

Climate Change

Guide for Assessment of Hydrologic Effects of Climate Change in Ontario, 2010

"Summary of hydrologic change metrics…… Mean Flows: Mean annual flow, Mean monthly flows, Mean seasonal flow…. Peak Flow Statistics: Recurrence Interval peak flows (e.g., 2-Year, 100-Year)…… Flow Distribution: Flow frequency-duration curve……. Low Flow Statistics: 1Q10 , 7Q10 , 7Q20."

"After selecting the hydrologic metrics, the study team must decide how to compare the climate change impacts to the reference regime. The following methods can be used to compare the estimated impacts with each metric: Absolute Change. Estimate the absolute change in the hydrologic metric (e.g., 7Q10 decreases from 10 L/s to 7 L/s). Relative Change. Estimate the percent change in the hydrologic metric (e.g., 7Q10 decreases 30%).Frequency Change. Estimate the change in the frequency of exceedance for a metric (e.g., frequency of overbank flow increases from 2.5 times per year to 2.8 times per year)."

Other Areas Indirectly Connected to Sreamflow

"Average Annual Water Yield: the amount of freshwater derived from unregulated flow (m3 s-1) measurements for a given geographic area over a defined period of time. Used to estimate stocks of water assets for the Water Accounts component of Statistics Canada's environmental accounting framework, the Canadian System of Environmental and Resource Accounts"

"….yearly runoff surfaces were then averaged to produce the thirty-year surface and scaled back to a volume based on the resolution (100 km2) of the surfaces, producing the water yield estimate."

References

Government of Ontario, Ministry of the Environment, Stormwater Management Planning and Design Manual, 2003. http://www.archive.org/details/stormwatermanage00torouoft

Government of Ontario, Ministry of Transportation, MTO Drainage Management Manual, 1997. http://www.mto.gov.on.ca/english/engineering/drainage/hydrology/ndex.shtml

Government of Ontario, Ministry of Natural Resources, Technical Guidelines and Requirements for Approval under the Lakes & Rivers Improvement Act.
http://www.ontla.on.ca/library/repository/mon/9000/246477.pdf

Government of Ontario, Ministry of Environment, Guide to Permit to Take Water Application, 2007.
http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079452.pdf

Government of Ontario, Ministry of Natural Resources, Adaptive Management of Stream Corridors in Ontario (2001).
http://www.conservationontario.ca/resources/natural_channels_stream_corridor/2FILES/00STREAM.PDF

Government of Ontario, Ministry of Natural Resources, Technical Guide River and Streams Hazard Flood Limit (2001) http://people.trentu.ca/rmetcalfe/PDFs/P0FLDHZD.PDF

Government of Ontario, Ministry of Environment, Guide for Applying for Approval of Sewage Works, 2010.
http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079525.pdf

Government of Ontario, Ministry of Natural Resources, Ministry of Environment, Ministry of Agriculture and Food, Ministry of Municipal Affairs and Housing, Ministry of Enterprise, Opportunity and Innovation, Association of Municipalities of Ontario, Conservation Ontario, Ontario Low Water Response, 2003.http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@water/documents/document/mnr_e002322.pdf

Statistics Canada. 2009. Technical Paper. The Water Yield for Canada as a Thirty-year Average (1971 to 2000): Concepts, Methodology and Initial Results, Robby Bemrose, Laura Kemp, Mark Henry and François Soulard.
http://www.statcan.gc.ca/pub/16-001-m/16-001-m2009007-eng.pdf

Government of Ontario, Ministry of Natural Resources, Ministry of Environment, Water Budget and Water Quantity Risk Assessment Guide Drinking Water Source Protection Program, 2011.
http://www.waterbudget.ca/waterbudgetguide

The Ontario Ministry of Natural Resources and Ministry of the Environment in partnership with Credit Valley Conservation. Guide for Assessment of Hydrologic Effects of Climate Change in Ontario, 2010. http://www.waterbudget.ca/climatechangeguide

Appendix 4: Other References

IDF Curves

An Intensity-Duration-Frequency curve (IDF curve) is a graphical representation of the probability that a given average rainfall intensity will occur. It characterizes the rainfall pattern of the area. Usually 2, 5, 10, 25, 50 and 100 year return periods are shown on IDF curves.

Rainfall Intensities for the province of Ontario can be found in:

MTO-IDF Curve Lookup
http://www.mto.gov.on.ca/IDF_Curves/

Duration: 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hr, 2 hr, 6 hr, 12 hr, 24 hr

Recurrence Interval: 2, 5, 10, 25, 50, 100 years

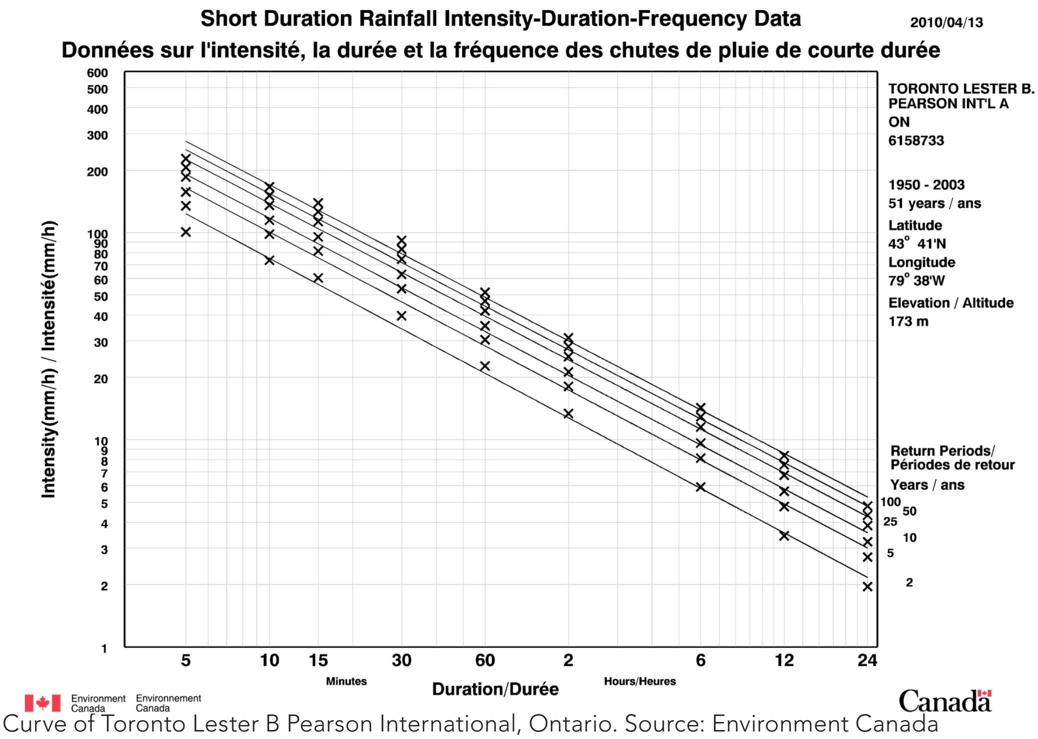
Environment Canada, National Climate Data Archive
http://climate.weatheroffice.gc.ca/prods_servs/index_e.html

Free download FTP site; **ftp://arcdm20.tor.ec.gc.ca/pub/dist/IDF/**

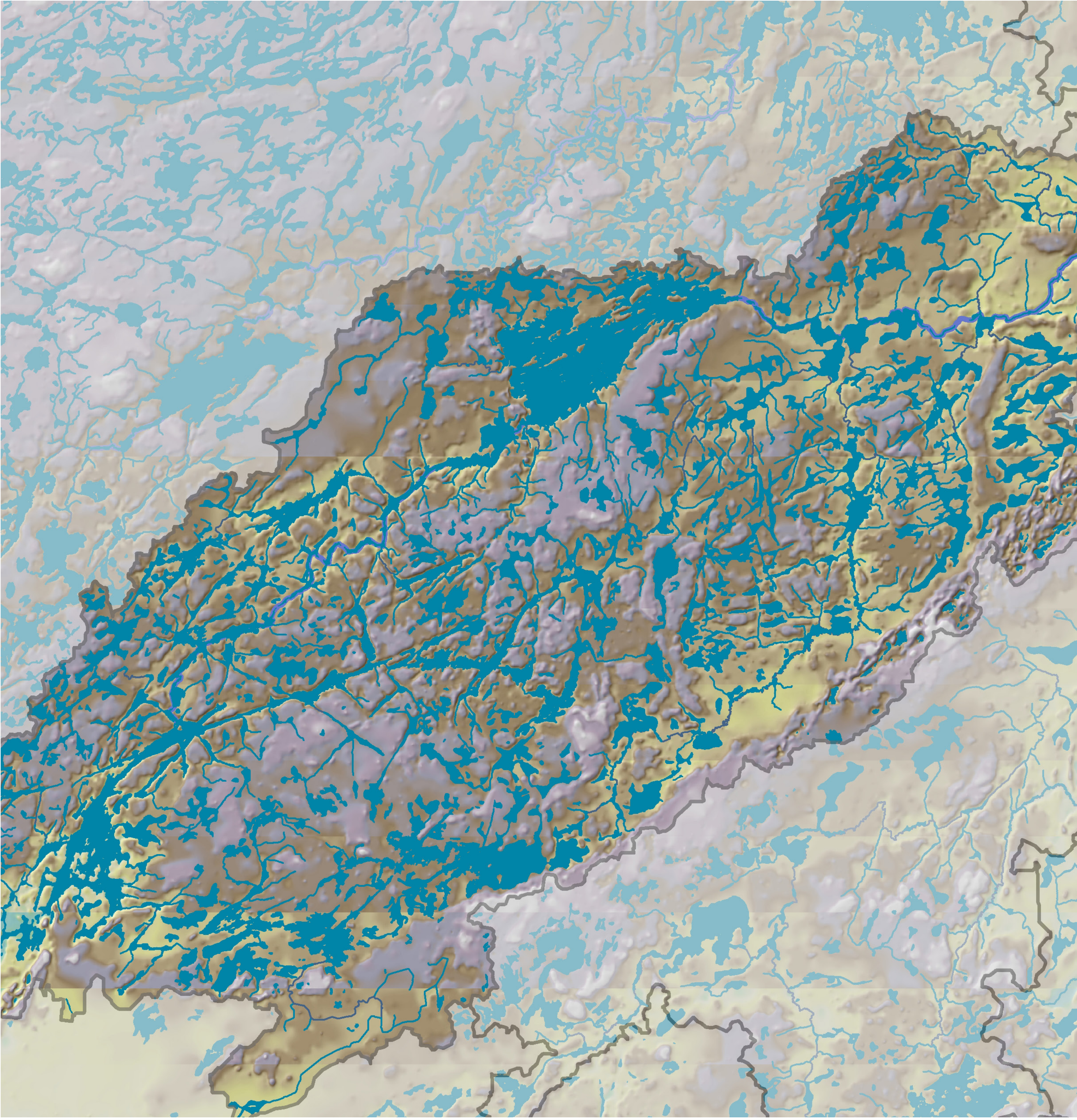
Duration: 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hr, 2 hr, 6 hr, 12 hr, 24 hr

Recurrence Interval: 2, 5, 10, 25, 50, 100 years

IDF Curve Example:



IDF Curve of Toronto Lester B Pearson International, Ontario. Source: Environment Canada



More Information

If further help is required, persistant problems occur with the application or the data that OFAT III uses, or if anything is omitted from this Help document, please email, Spatial Data Infrastructure, Ontario Ministry of Natural Resources; sdi@ontario.ca.

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