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Contract No. 13-2024 (45330471)
October 2013

Gull River Flood Review

Trent-Severn Waterway National Historic Site of Canada

Final

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October 15th, 2013

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Dear Ms. Robinson:

Project No: **60304845**

Regarding: **Gull River Flood Review**
Trent-Severn Waterway National Historic Site of Canada,
Final Version
Contract No. 13-2024 (45330471)

AECOM is pleased to provide Parks Canada with the Final Version of the Gull River Flood Review Report. The study was conducted in general conformance with the Statement of Work, Gull River Flood Review dated July 15th, 2013 and with our Project Proposal dated July 22nd, 2013.

We express our appreciation to Parks Canada staff for providing valuable input and assistance throughout the course of the study. We are available to elaborate on any aspect of the report, and to assist in any further study, at your request.

Sincerely,

AECOM Consultant Inc.

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	Annie Dumas	2013/10/15	Final Report

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Executive Summary

On April 18th, 2013, water levels started to rise, then on April 19th, 2013, localized flooding and road washouts began to be reported to the Haliburton Sector Office of the Trent-Severn Waterway (TSW) National Historic Site of Canada. Warming weather and heavy rain resulted in the rapid melting of the existing snowpack and generated very significant inflows into the lakes and rivers within the Trent and Severn River basins. Some lakes increased by approximately 30 cm overnight.

The current study provides Parks Canada Agency (PCA) with a fact based review of flooding that occurred between the period of April 18th and May 15th, 2013 in the Gull River sub-watershed.

The analysis showed that heavy rainfalls in April combined with snowmelt were sufficient to generate large runoff volumes, and therefore large flood flows, resulting in a flood exceeding the 200 year flood in the Gull River:

- On April 17th, Moore Lake Dam (Elliott Falls) and Gull Lake Dams, the two reservoirs immediately downstream of Minden Hills, were fully open (all stoplogs out).
- On the evening of April 17th, when the heavy rainfall started, water levels and flows were within usual level range for most of the reservoir lakes, and started to increase on April 18th.

With all the stoplogs out at Moore Lake Dam and Gull Lake Dams, for any flow increase entering these lakes, water level had no other option than to increase. The only option that PCA had to avoid additional flooding in Minden Hills and downstream of Minden Hills was to retain water in the upstream reservoir lakes to decrease the flow entering Gull Lake.

Considering potential public safety issues to the permanent community of Minden Hills and downstream to Coboconk, the decision to put back stoplogs in the reservoir lakes upstream of Minden Hills to prevent greater downstream flooding was taken. On April 21st, addition of stoplogs occurred and continued the two following days.

In general, the management decisions contributed to reduce the peak flood flow on April 25th and therefore avoided additional flooding in Minden and downstream to Coboconk, without endangering public safety in upstream reservoir lakes.

The flood was not caused by poor decisions. The management staff at the Trent-Severn Waterway did an exemplary job. Other alternative water management decisions would not have led to a reduced overall flooding.

In summary, the flood event analysis showed that:

- The management of the reservoir lakes did not contribute to the flooding near Minden Hills. Furthermore, the management succeeded in avoiding additional flooding on April 25th by retaining water in the upstream reservoir lakes.
- The management in reservoir lakes was performed adequately within the recognized operational procedures in order to meet the prioritized water management objectives.

A review of legislation, policies, guidelines, emergency response plans and other texts was performed to identify the roles and responsibilities of PCA. In light of the review performed:

- PCA is responsible for the management of water levels within the TSW.
- PCA is responsible for the safe management of its structures and for ensuring the structures remain in compliance with regulations.
- PCA has the responsibility to operate its dam-reservoirs to mitigate flood impacts.
    - Upstream flooding is an acceptable practice to prevent greater downstream impacts, especially if public safety is jeopardized.
    - PCA's management of the April 2013 flood has not differed from its policies and operational procedures.

Recommendations

The management staff should eventually have a management tool to support decision making. This tool would help in better management for extreme weather events by the TSW.

It is also recommended that dam safety reviews continue to be carried out for all sites to analyse structural stability of all dams, to provide inundation mapping in case of a dam failure and to have emergency preparedness and response plans available to better assure public safety under large flood conditions.

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List of Abbreviations

AECOM	Consultant
CA	Conservation Authority
EMCPA	Emergency Management and Civil Protection Act
EMO	Emergency Management Ontario
ERP	Emergency Response Plan
EPP	Emergency Preparedness Plan
IDF	Inflow Design Flood
LRIA	Lakes and Rivers Improvement Act
MNOL	Maximum Normal Operating Level
MNR	Ministry of Natural Resources
NRC	Natural Resources Canada
OPG	Ontario Power Generation
PCA	Parks Canada Agency
PEOC	Provincial Emergency Operations Centre
PWGSC	Public Works and Government Services Canada
PMF	Probable Maximum Flood
PPE	Personal Protective Equipment
PMP	Probable Maximum Precipitation
PMSA	Probable Maximum Snow Accumulation
TSW	Trent-Severn Waterway

1. Introduction

1.1 Background

On April 18th, 2013, water levels started to rise, then on April 19th, 2013, localized flooding and road washouts began to be reported to the Haliburton Sector Office of the Trent-Severn Waterway (TSW) National Historic Site of Canada. Warming weather and heavy rain resulted in the rapid melting of the existing snowpack and generated very significant inflows into the lakes and rivers within the Trent and Severn River basins. Some lakes increased by approximately 30 cm overnight.

Parks Canada Agency (PCA) was able to respond to the situation with additional crews to monitor and manipulate dams to mitigate as much as possible the impacts of increasing water levels and river flows.

After the period of flooding, questions were raised as to the cause of the flooding not seen like this in the recent past. Subsequently, a request for a review was made and on May 10th, 2013, Member of Parliament, Barry Devolin announced publically that the Minister of the Environment Peter Kent was supportive of a review.

As such, PCA mandated AECOM to carry out a review of the 2013 spring freshet flooding within the Gull River sub-watershed to better understand the context of the flood event.

1.2 Objective of the Study

The objective of the study is to provide Parks Canada with a fact based review of flooding that occurred between the period of April 18th and May 15th, 2013 in the Gull River sub-watershed.

1.3 Scope of Work

The Gull River Flood Review is related specifically to the Gull River and is intended to support the understanding of the 2013 spring freshet flooding within the Gull River Watershed.

The scope of the work is to analyse and compare the natural circumstances, conditions and the water levels in the reservoir lakes within the Gull River sub-watershed immediately prior to the flood and during the flood event. Furthermore, it is required to understand the actions taken by PCA regarding dam operations during the flooding and its responsibilities in this specific case. Finally, the peak flows on the Gull River and its catchment area are compared with those of adjacent/nearby watercourses under similar weather conditions or events.

The Gull River Flood Review is divided into three parts:

Pre-flood analysis:

- A summary of the original purpose of the reservoir dams within the Gull River system and the original intent of their construction as part of the TSW.
- The natural circumstances and conditions immediately prior to the flood (i.e. weather events including air temperature and local precipitation, ground conditions including moisture and frost conditions, snow accumulation and maturation etc.), including a comparison of these circumstances with the historical record. An examination of inflows is also performed.
- The water levels in the reservoir lakes within the Gull River sub-watershed leading up to the event and the rationale for dam operations of the TSW that may have altered them, along with comparisons to historic water levels at this time of year.

During the flood event analysis:

- The actions taken by PCA regarding dam operations during the flooding along the Gull River sub-watershed.
- PCA's responsibilities in this specific case, based upon federal and provincial legislation and policies, within the broader context of the roles of other jurisdictions in the areas of public communications, flood forecasting and emergency planning and response.

Comparison of adjacent watersheds:

- In order to scale the flood event on the Gull River, a comparison of the peak flows on the Gull River with flows in adjacent/nearby watercourses impacted by the same weather event and under similar conditions will be carried out. Adjacent watersheds are the following:
    - Burnt River near Burnt River
    - Black River near Washago
    - East River near Huntsville
    - York River near Bancroft
    - South Branch Muskoka River at Baysville.

1.4 Study Content

The report includes the following:

- Section 2 - Background Information
- Section 3 - Pre-Flood Analysis
- Section 4 - Flood Event Analysis
- Section 5 - Summary of Stakeholders Concerns
- Section 6 - PCA Responsibilities
- Section 7 - Comparative Analysis with Adjacent Watersheds
- Section 8 - Conclusions

2. Background Information

2.1 General

2.1.1 Trent-Severn Waterway

The TSW is a National Historic Site of Canada. It runs 386 km from the Bay of Quinte on Lake Ontario at the City of Quinte West (Trenton) to Port Severn, located in the south of Georgian Bay (Lake Huron). The Ontario Waterways Unit of Parks Canada Agency manages and operates the Trent Severn Waterway National Historic Site, including its 44 locks and 143 dams.

There are three key components to the Waterway: the Trent River watershed, the reservoir lakes, and the Severn River watershed. The Gull River sub-watershed is part of the reservoir lakes (a.k.a. Haliburton reservoir system). Located in the northern part of the Trent River watershed, the reservoir lakes act as reservoirs, flowing into the Kawartha Lakes, to help manage water levels within the TSW.

The Trent River basin, which drains more than 12,000 km^2, encompasses some 218 lakes in the Haliburton Highlands region, 37 of which are directly managed by Waterway dams. For water management considerations, Parks Canada divides the Trent River watershed into six sub-watersheds, three of which are considered part of the reservoir lakes.

- Gull River watershed: 1,356 km^2, 21 operable dams, part of the reservoir lakes.
- Burnt River watershed: 1,300 km^2, 13 operable dams, part of the reservoir lakes.
- Nogies Creek, Mississauga River, Eels Creek and Jack Creek watersheds: 544 km^2, 5 operable dams, part of the reservoir lakes.
- The Kawartha Lakes: 4,862 km^2, flowing into Rice Lake and the Trent River.
- Rice Lake and the Trent River: 4,348 km^2, flowing into Lake Ontario.
- Crowe River watershed, managed by the Crowe River Conservation Authority, flowing into Trent River.

The TSW, including its tributary lakes and rivers, is an important economic, environmental and recreational resource used by thousands of boaters, shoreline residents, businesses and vacationers every year. It also provides water for power generation, municipal water supplies and agriculture and supports a tremendous variety of fish and wildlife.

Appendices A and B show watersheds of the TSW and detail the Trent River Watershed.

2.1.2 Gull River Sub-Watershed

The Gull River sub-watershed is part of the Haliburton Highlands region. It is located at the very top of the Trent River basin. It drains more than 1,356 km^2, making up about 10 % of the total drainage area of the Trent River Basin. It includes 17 reservoir lakes controlled by 21 dams.

The surface areas of the lakes within the Gull River sub-watershed are generally larger than that of neighbouring watersheds. As such, they are more suited for flood management and to act as reservoirs. Because of their role, acting as reservoirs for the TSW, the lakes of the Gull River sub-watershed are known as reservoir lakes.

The reservoir lakes to be considered in the Gull River watershed are the following:

1- Kennisis Lake (Map 1)
2- Red Pine Lake (Map 2)
3- Nunikani Lake (Map 3)
4- Hawk Lake (Map 4)
5- Halls Lake (Map 5)
6- Sherborne Lake (Map 6)
7- Kushog Lake (Map 6)
8- Percy Lake (Map 7)
9- Oblong Lake (Map 8)
10- Eagle Lake (Map 9)
11- Redstone Lake (Map 10)
12- Twelve Mile Lake (Map 12)
13- Horseshoe Lake (Map 13)
14- Bob Lake (Map 14)
15- Little Bob Lake (Map 15)
16- Gull Lake (Map 16)
17- Moore Lake (Elliott Falls) (at hydrometric station) (Map 17)

The map number beside the name of each reservoir corresponds to the Map numbers in Appendix B. A flow chart of the Gull River watershed is presented in Figure A2 in Appendix A.

Appendix B present the Sub-Basins maps and physical parameters, drawn from the Book of Maps submitted in the context of the Trent River Watershed Hydro-Technical Study (Reference 2).

2.2 Operational Objectives and Purpose of the Reservoir Lakes

The construction of the TSW was completed in 1920 with the intent of providing safe navigation from Lake Ontario to Georgian Bay to open up the interior of Ontario for commercial and settlement purposes (Shoreline Policy, PCA 2011). The Haliburton reservoir lakes, which Gull River watershed is part of, were dammed to collect spring runoff and act as reservoirs, providing sufficient water for safe navigation in the TSW during dry years. The Ontario Waterways Unit of Parks Canada Agency is responsible for managing the reservoir lakes.

When the reservoir lakes were conceived, there was very little permanent settlement in the Haliburton region. Today, after many years of settlement and development, secondary water management objectives are taken into account in the management of water levels at the TSW (Ecoplans, 2007, TSW Water Management Program). These include: public safety, flood mitigation, community water supplies, water quality, the protection of natural resources, green power generation, and providing water for recreational activities.

While flood management is not the main objective of the operations at all dams in the Gull River system, the dams must nonetheless be operated to meet the dam safety requirements as per the PCA Directive and the CDA Guidelines (References 24 and 7). Therefore, while regular operation is performed to maintain navigation water levels in the TSW, the staff must be proficient and the dams must be operated to keep risks as low as reasonably practicable.

The management of water levels in the reservoir lakes is a balancing act. Water must be released from the lakes over the dry summer season to maintain navigation levels in the downstream portion of the Waterway; without this augmentation from the reservoirs, navigation would not be possible in many summers. In addition, there are several water intakes and wastewater discharges in the Waterway that require appropriate water levels to function.

Shoreline residents of the reservoir lakes, however, prefer a more stable water level regime and respond negatively when water levels decrease too quickly. To mitigate the impact of the required reservoir lake drawdowns on any one particular lake, Parks Canada has long practiced an equal percentage drawdown across all reservoir lakes based on available depth. Note that many of these reservoir lakes were not lakes before the construction of the dams and would therefore be dry; recreational use is linked to the presence of the dam.

In addition to human users of the lakes, there are certain lakes and channels in the Haliburton sector that have been identified as Lake Trout or Walleye spawning habitat. These areas require different management of water levels at spawning times, which in the case of these species are the fall and over-winter period (Lake Trout) and spring period (Walleye).

Coordination with hydro utilities is an important objective of water management as well. Typically, the TSW staff will make water management decisions based on the need to provide for navigation and flood mitigation. The hydro utilities will then be informed of the available water, and will be given the option to use this water for energy production, funnelling it through the turbines and spillways owned by the hydro utility. Water that is not used by the hydro utility is conveyed through Parks Canada infrastructure. The overall amount of water conveyed downstream does not change as a result of the operation of the hydro utility.

Table 2.1 presents the six water management goals of the Trent-Severn Waterway and the applied operational objectives in the reservoir lakes.

Table 2.1 Operations to Meet Water Management Goals in the Reservoir Lakes

Water Management Goal	Operational Objective
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Provide storage attenuation of spring runoff to mitigate flooding in downstream areas while minimizing flooding impacts to shoreline residents
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Augment flows to downstream areas to maintain appropriate conditions for drinking water intakes and wastewater effluent discharges
Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway	• Provide storage of spring runoff to augment navigation water levels in downstream areas during the summer navigation season while minimizing the amount of water released
Protecting significant aquatic habitats and species	• Manage water levels appropriately during fish spawning seasons in lakes and channels identified as key aquatic habitat
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Minimize water releases from lakes, and draw down lakes on an equitable percentage basis, to maximize availability of water for shoreline residents and visitors for enjoyment of property access
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Coordinate water management with hydro power utilities without impacting water availability for other users

2.3 Operation Procedures – Haliburton Sector

The operation procedures presented in this section are drawn from the Water Management Manual for the Trent Severn Waterway (AECOM, Reference 5).

The Haliburton sector receives water level and flow information from a network of approximately 40 gauges, of which 24 are automatic gauges (19 water levels, 5 flow) and the remainder are manual level gauges. Snowpack information is collected in the winter from 4 snow survey sites. Water level information in the Haliburton sector is typically reported to the Water Management Engineer on a weekly basis, due to the time required to collect readings from the manual level gauges.

2.3.1 Spring Season

The objective of spring operations in the Haliburton sector is to manage the spring freshet (i.e., snowmelt) both to fill up the reservoir lakes in preparation for the summer navigation season, and to mitigate the impact of flooding. In most years there is more inflow than needed to fill the lakes and some surplus is released to the rest of the system, although this release is carefully coordinated with the other sectors since there typically is a reduced capacity to mitigate excessive flows in downstream areas.

As spring approaches, stoplogs are placed in the dams as the lakes are rising with runoff from melting snow. If the snowpack is measured to be smaller than expected, some stoplogs may be put in the dams earlier in the season (see winter season operations) to retain as much water as possible. As the lakes are nearing their full levels, snow survey data and all available sources of information are checked to determine remaining runoff volumes:

- If low volumes are expected then lakes levels are filled to maximums to prepare for summer; and if high volumes are expected then lakes levels are allowed to discharge more freely.
- Heavy inflows can easily result in removing stoplogs again to spill the surplus. The equal filling of lakes during extreme events is also practiced to mitigate water level fluctuations throughout the sector. Even in periods without heavy inflows, there is a requirement to maintain flows in the downstream portions of the system, and thus some water is released while the lakes are filling.
- At some of the more remote lakes in the sector, or the lakes that are difficult to fill, the stoplogs are placed at the start of the winter season to minimize the potential that runoff will be released before staff can make the necessary stoplog adjustments in the spring.

Certain rivers in the Trent Severn Waterway, including the river downstream of Drag Lake in the Haliburton sector, have been identified as Walleye spawning habitat. Walleye spawn in the spring, their preferred habitat abundant with the high spring freshet flows. Due to the requirement to maintain spawning flows in these certain rivers, the Reservoirs upstream of the rivers may not be completely filled during the freshet.

Typically, reservoirs are filled to their upper limit of storage range by May 1st for a Victoria Day waterway opening.

2.3.2 Summer (Navigation) Season

The operational objective for summer operations in Haliburton sector is to provide water to the navigable portion of the system (i.e., North, Central and South sectors) so that the average navigational water levels are achieved, based on the 25-year long-term average water levels and advertised navigational depths. This is to be accomplished while minimizing the release of water from the Reservoirs.

Water is retained in the Reservoirs for as long as possible during the summer until downstream conditions require additional flows. Typically, the Kawartha Lakes will require augmentation of flows due to the high rate of evaporation. This can occur as early as May or as late as August, depending on temperature (i.e., evaporation) and precipitation.

When required, water is drawn from each of the lakes on an equal percentage basis according to the storage range established for that lake. For example, when a lake with a relatively large storage range of 3 m is drawn down 50%, its level will drop 1.5 m, while a lake with 2 m of usable storage will be lowered by 1 m. Water is drawn from each of the reservoir lakes on an equal percentage drawdown basis according to the storage range established for each lake.

The management of the reservoir lakes is assisted by a computer model run by the Water Management Engineer. Several times a week, readings are taken of water levels at the dams. These data are input to the model, which is run each Monday afternoon or Tuesday morning. A target percentage decline in the reservoir lakes over the next two week period is set and communicated to field staff. A two week period of adjustment is used in the model to provide a smoother water level regime; using a one week period resulted in large fluctuations in water levels. Despite the two week period, the model results are updated on a weekly basis to adapt to changing conditions.

The Sector Managers are responsible for scheduling the adjustments within their sector to ensure that proportionate drawdown is achieved. Typically the adjustments are made from upstream to downstream to accommodate the lag in water level response. Most of the adjustments will have been made by the end of day Wednesday in a typical operating week. The goal is to achieve the adjustments early in the week to allow additional time to react to changing conditions. Since there are no automatic/hydraulic dams in the Haliburton sector, and the lakes are distributed over a large area, the adjustment of dam stoplog settings requires the use of several field crews.

Certain river reaches contain Bass and Muskie spawning sites. However, spawning for these species occurs in early summer and, in a normal year, there is generally not a problem in maintaining spawning depths while achieving navigational depths.

2.3.3 Fall (Post-Navigation) Season

The operating goal during the fall season is to draw down the lakes to winter settings as soon as possible. The fall season begins after the Thanksgiving holiday weekend, when the navigation season on the Waterway officially closes. In the Haliburton sector, stoplogs are removed at most dams to their winter settings, allowing excess water to drain and creating storage capacity to receive the freshet the following spring.

In addition to the need to create storage capacity, many of the dams become inaccessible in winter, and stoplog changes, often done by cutting the logs free of ice with chainsaws, is a costly and hazardous operation. As a result, the winter stoplog settings are put in place as soon as possible in the fall season. Some additional changes may be required in the downstream portions of the sector to mitigate flooding, depending on weather conditions during the season.

An emerging concern with the management of water levels in the fall season is for certain properties along the lakes that are accessible by boat only. As water levels decrease, access to these properties may be jeopardized. This is compounded as more and more residents of the Haliburton lakes adopt an extended or year-round residency, unlike the traditional summer vacationer.

The management of water levels for Lake Trout, a species that spawns in the fall months, is a significant operating objective in the Haliburton sector. Lake Trout will deposit their eggs in certain cold-water lakes in the period between September and November, depending on location. The eggs remain in the lake over the winter, until the fish hatch in the early spring. If lake levels are reduced any time after this spawning has occurred, there is a risk that the eggs will become stranded out of the water, resulting in the loss of those fish.

Therefore, in the lakes identified for Lake Trout management, it is critical that the winter water level be achieved as soon as possible at the end of the navigation season, from which no further decreases will take place. There are also existing spawning habitat requirements on all cold-water lakes.

2.3.4 Winter Season

During the winter season only minimal management of the reservoir lakes is practiced, due to the difficulty of stoplog adjustments during winter, and the difficulty of access at some of the more remote lakes. However, water management is practiced as necessary at the lakes, particularly in the Lower Gull area which often requires more active management in the winter. In addition, there is sometimes a requirement to adjust operations to accommodate hydro power users, such as at Elliott Falls.

January 1st marks the beginning of snowpack surveys at the established sites in the Haliburton sector, namely Eagle Lake, Brady Lake (Carnarvon), Little Bob Lake and Emily Park (not part of the TSW). A snowpack survey is conducted at these four sites every two weeks in January and then increasing to every week through February, March and April.

To complement the snowpack surveys, some of the lakes that are not controlled by water control structures, such as Brady Lake and 4 Mile Lake, are observed anecdotally for natural water conditions. Groundwater conditions, as evidenced by high or low lake levels, can help to indicate the proportion of spring runoff that will enter the lakes versus infiltrating. The ground condition (i.e., frozen, unfrozen) is important when predicting the volume of water that will runoff from the snowpack, and forms part of the snowpack surveys.

The low winter levels require some coordination with hydroelectric and municipal entities, for example at Norland where there is a municipal intake and hydro power plant, to ensure that these functions can continue.

The reservoir management parameters are presented in Table 2.2.

Table 2.2 Reservoir Lake Management Parameters (Source: Parks Canada)

Reservoir Lake	Drainage Area (km²)	Lake Area (ha)	Full Control (m)	Sill or Deduction (m)	Maximum Storage Volume (ha-m)
Kennisis Lake	174	1641	2.896	0.000	4,657
Red Pine	39.5	385	1.219	0.000	469
Nunikani Lake	7.4	109	3.050	0.305	299
Hawk Lake	62.5	842	4.420	0.381	2,748
Halls Lake	21.5	529	2.590	0.914	842
Trout Lake	21.5	245	1.520	0.000	372
Kushog Lake	111	915	3.200	1.219	1,722
Percy Lake	74	563	1.980	0.000	1,115
Oblong Lake	77	1094	3.050	1.067	2,169
Redstone East Lake	169	1422	3.660	0.509	4,481
Eagle Lake	44	515	2.290	0.457	944
Twelve Mile Lake	29	1161	1.980	0.457	1,666
Horseshoe Lake	46.6	556	2.440	0.457	833
Big Bob Lake	32.3	226	2.900	0.000	655
Little Bob Lake	13.5	73	1.524	0.000	111
Gull Lake	167	998	2.130	1.219	909
Moore Lake	42.2	194	1.520	0.914	118
Total	**1,132**	**11,468**			**24,110**

3. Pre-Flood Analysis

The pre-flood analysis consists of the following:

- The natural circumstances and conditions immediately prior to the flood (i.e. weather events including air temperature and local precipitation, ground conditions including moisture and frost conditions, snow accumulation and maturation etc.), including a comparison of these circumstances with the historical record. An examination of inflows is also necessitated.
- The water levels in the reservoir lakes within the Gull River sub-watershed leading up to the event and the rationale for dam operations of the Trent-Severn Waterway that may have altered them, along with comparisons to historic water levels at this time of year.
- How the spring freshet developed into flooding based on the pre-existing snowpack and rainfall.

3.1 Flood Generation

A spring flood is a flood resulting from a combination of the three following hydrometeorological conditions:

- a snowpack on the ground
- a rainfall
- a sequence of temperature allowing the maturation and melting of the snowpack.

The melt rate is a function of the temperature and rainfall amount (dry and wet melt).

A severe spring flood generally follows a critical temperature sequence:

- **Snowpack maturation period**: consists of a snowpack maturation period in order to maximize the melt rate during the spring rainfall;

- **Snowmelt period (high pressure period)**: maximum temperatures in the sequence occur when a high pressure area would make radiation energy available to the snowpack;

- **Rainfall period (low pressure period)**: high temperatures are followed by a series of colder temperatures that reflect the passage of a colder air mass over the basin associated with a low pressure system that produces heavy rainfall (reflects the synoptic meteorological conditions associated with the major storms observed during the spring season).

As an example, the critical temperature sequence used as a basis in the computation of probable maximum floods (PMF), snowmelt period and rainfall period is shown on Figure 3.1. This temperature sequence was used in the Trent River Watershed Hydro-Technical Study (Reference 2).

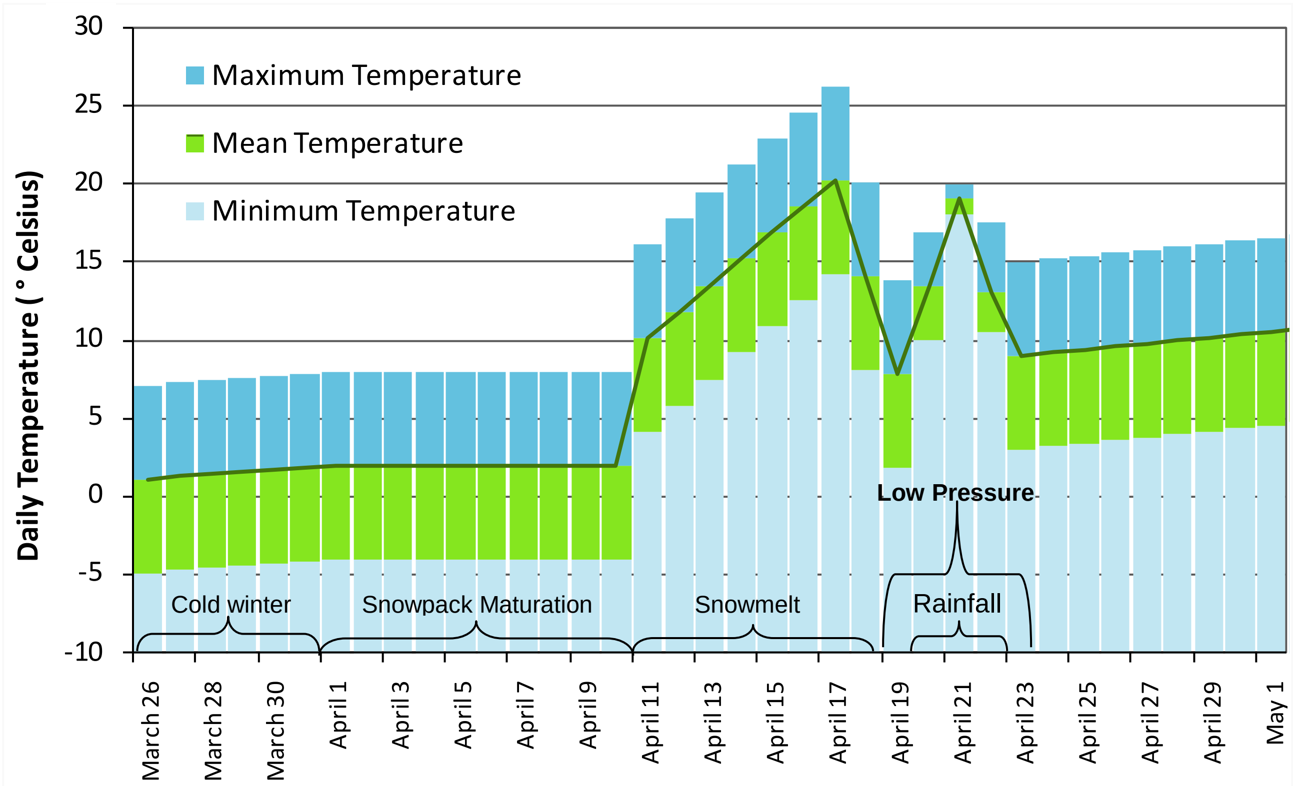

Figure 3.1 Critical Temperature Sequence for Snowmelt used for PMF Computations

3.2 Climate Data Prior to the Flood

The following sections describe the hydrometeorological conditions prior to the flood of April 2013.

3.2.1 Rainfall

Prior to the April flood event, the rainfall event occurred from in the afternoon of April 17th to the evening of April 20th 2013 (accumulations over nine periods of 6 hours), with a duration of about 48 hours.

The climate data prior to the flood were obtained from Environment Canada Information Archive (Reference 12) for the closest climate station, which is Haliburton 3 (ID 6163171). This station is however located outside the Gull River watershed, in the Burnt River watershed, at a distance of approximately 18 km from Minden Hills in the Gull River watershed. A climate station in Minden Hills, active until 2006, shows that mean annual precipitation is comparable and the Haliburton 3 station is therefore considered representative of the climate in the Gull River watershed.

Table 3.1 Climatological Stations (Environment Canada) for Spring Rainfall Analysis

Station Identification		Location		Elev.	Period of Records	Mean Annual Precipitation (mm)
No	Station Name	Latitude	Longitude	(m)		
6165195	Minden	44° 56' N	78° 43' O	274	1956 - 2006	1032
6163171	Haliburton 3	45° 02' N	78° 32' O"	330	1987 – 2013	1074

Figure 3.2 shows the daily precipitation, separated in its rain and water content of snow fall components. Values presented cover the months of March, April and May 2013, before and after the April 25th flooding. Records are taken from the Haliburton 3 climatological stations.

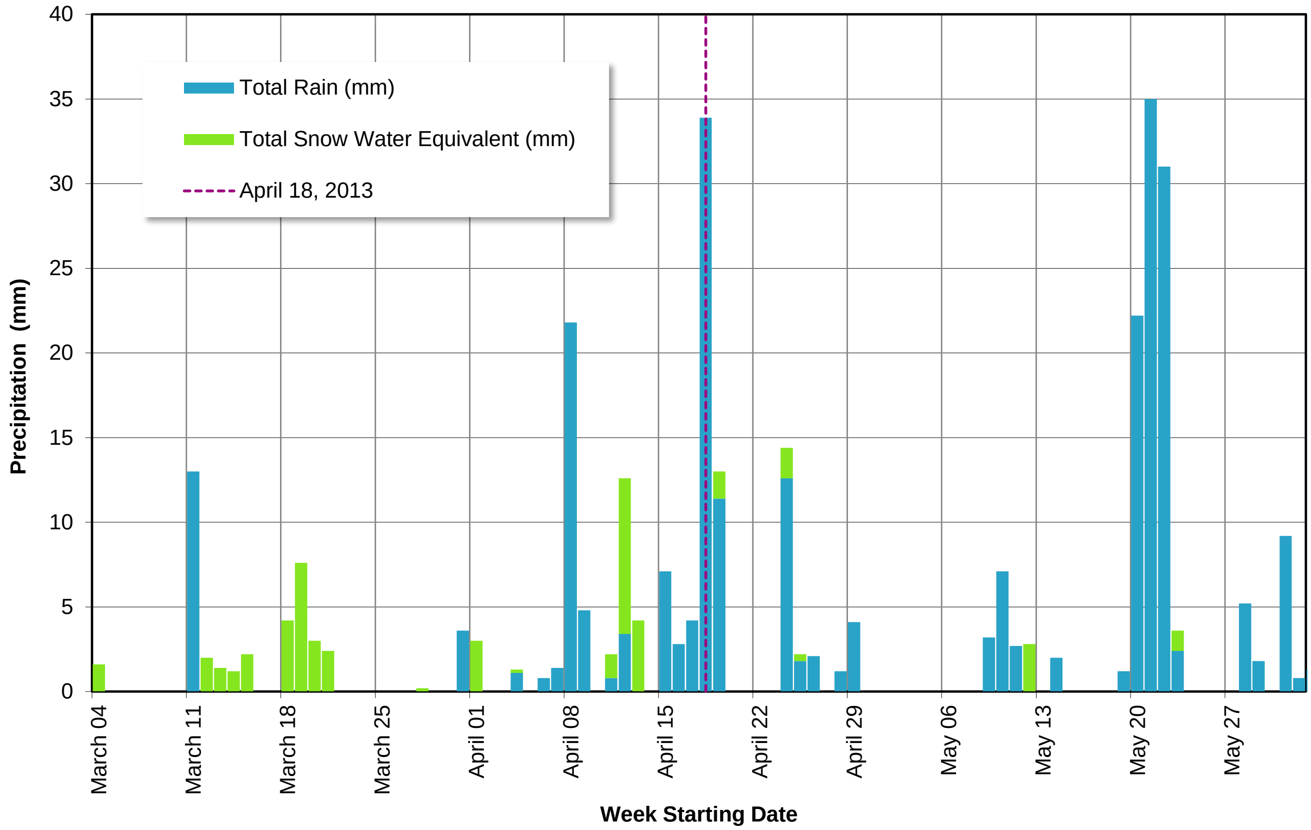

Figure 3.2 Precipitation (Rain and Snow Components) in Spring 2013 – Haliburton 3

Table 3.2 presents the daily total precipitation at the station Haliburton 3 for April 2013. Even though the precipitation had a duration of 48 hours, rainfall amounts are observed over three calendar days.

Table 3.2 Total Precipitation in April 2013 – Haliburton 3 (Environment Canada)

Days of April	Daily Precipitation (mm)	Days of April	Daily Precipitation (mm)
1	3	16	2.8
2	-	17	4.2
3	-	18	33.9
4	1.3	19	13
5	T	20	T
6	0.8	21	-
7	1.4	22	-
8	21.8	23	T
9	4.8	24	14.4
10	T	25	2.2
11	2.2	26	2.1
12	12.6	27	T
13	4.2	28	1.2
14	T	29	4.1
15	7.1	30	T
Total - April			**137.1 mm**

From April 1st to April 19th, 113 mm of precipitation was observed out of 137 mm for the entire month. A first rainfall occurred April 8th and 9th, marking the beginning of the spring freshet. The climate normal for Haliburton (Reference 12) show 75.6 mm for April. April 2013 was therefore a wet month, with 1.5 times the normal precipitation.

From April 17th to April 19th, 51.1 mm were measured at Haliburton 3.

However, it appears that the climate stations in the vicinity of the Gull River watershed did not measure the effective amount of rainfall that was observed in the Gull River watershed. A climate station is a single point precipitation measurement, which is quite often not representative of the volume of precipitation falling over a given catchment area. A dense network of point measurements can provide a better representation of the true volume over a given area. A dense network of point measurements in the Gull River watershed is not available; the only climate station available is the Haliburton 3 station, outside the watershed.

To correctly assess the effective rainfall for the April 17-19 rain event, rainfall images were provided by the Meteorological Service of Canada (MSC), Quebec regional office, Environment Canada. These images were produced using the Canadian Precipitation Analysis (CaPA)[1]. CaPA is a hybrid precipitation analysis developed at MSC that uses rain gauge data and model data. It is the best estimate of precipitation amounts in Canada at this moment. Figure 3.3 and Figure 3.4 show these CaPA rainfall images.

Figure 3.3 shows the 72 hour rainfall accumulations (12 periods of 6 hours) from 8 AM April 17 to 8 AM April 20 2013 over the Gull River watershed area. The rainfall amount for the 72 hour period ranged between 60 and 81 mm, with an approximate weighted average over the Gull River Watershed of 75 mm.

Figure 3.4 shows the 48 hours rainfall (8 periods of 6 hours) for April 18 and April 19, 2013, with rainfall accumulation ranging from 50 to 79 mm, with an approximate weighted average over the Gull River Watershed of 70 mm. This image is shown for information as city names are shown to better locate the storm center.

[1] *CaPA is available in real-time at the following web page: http://weather.gc.ca/analysis/index_e.html. For further information on CaPA, please contact by email: smclaboratoireqc@ec.gc.ca.*

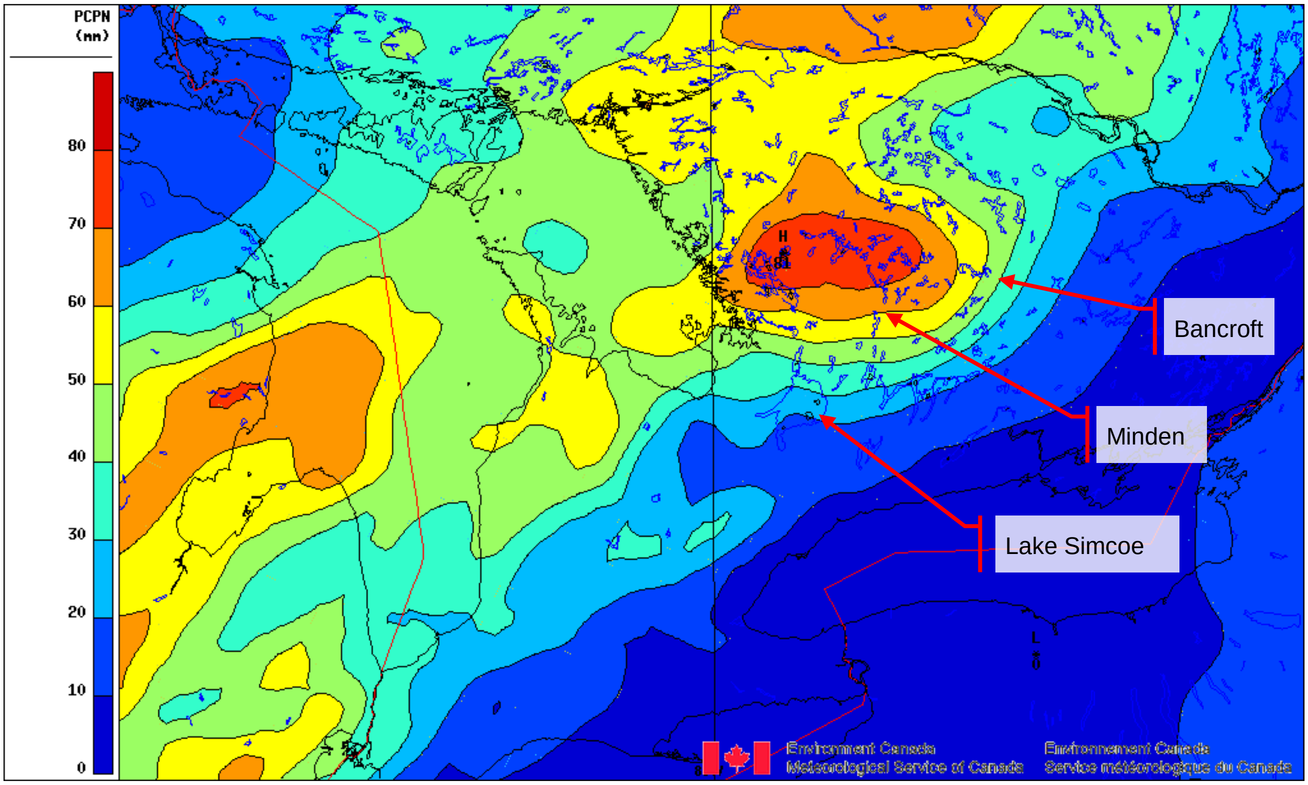

Figure 3.3 **CaPA Rainfall Image - 72-Hour Rainfall Accumulations (mm) - 8 AM April 17 to 8 AM April 20, 2013 - Reservoir Lakes Area**

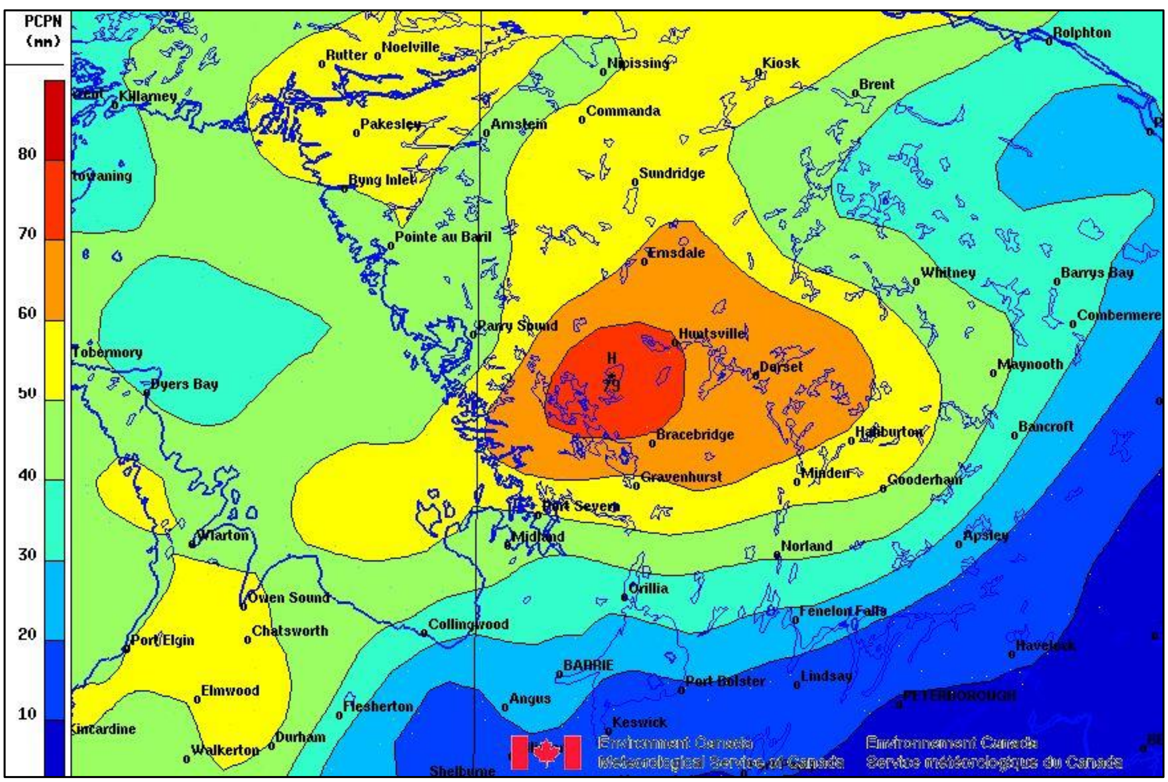

Figure 3.4 **CaPA Rainfall Image - 48-Hour Rainfall Accumulations (mm) - April 18 and April 19, 2013 - Reservoir Lakes Area**

In order to assess the severity of the rainfall event, maximum precipitations at the Minden climate station over durations of 1 day to 3 days for the spring period are presented in Table 3.3. The date represents the starting date of the rainfall event. However, since the daily precipitations used for this analysis are precipitations within a calendar day, a 48-hour event may have been measured on three calendar days.

Table 3.3 Maximum Precipitation for Various Duration (February 1st to May 1st) at the Minden Climate Station (Environment Canada) (1962 to 2006)

Year	Maximum Precipitation for Various Duration (February 1st to May 1st)					
	1 Day		2 Days		3 Days	
	P (mm)	Date	P (mm)	Date	P (mm)	Date
1962	10.4	28-Apr	20.4	13-Feb	20.4	12-Feb
1963	14.5	29-Apr	29.0	29-Apr	29.0	28-Apr
1964	22.1	21-Apr	22.6	21-Apr	22.6	20-Apr
1965	22.9	09-Feb	38.1	24-Feb	38.1	23-Feb
1966	20.3	24-Mar	22.9	28-Feb	25.9	08-Feb
1967	16.3	14-Apr	19.1	13-Apr	20.6	21-Apr
1968	45.0	01-Feb	56.4	01-Feb	56.4	31-Jan
1969	23.6	27-Apr	29.2	27-Apr	32.8	26-Apr
1970	28.2	02-Apr	38.4	01-Apr	38.4	31-Mar
1971	21.8	01-Apr	24.3	01-Apr	26.8	01-Apr
1972	17.8	03-Feb	25.7	21-Mar	28.2	21-Mar
1973	22.9	17-Mar	28.0	17-Mar	30.5	16-Mar
1974	22.9	04-Mar	24.9	03-Mar	26.7	12-Apr
1975	32.3	24-Feb	50.1	24-Feb	73.0	24-Feb
1976	25.4	12-Mar	27.9	12-Mar	33.0	12-Mar
1977	19.3	04-Mar	24.4	04-Mar	24.4	03-Mar
1978	24.4	20-Apr	28.7	19-Apr	30.0	18-Apr
1979	22.2	02-Apr	32.0	04-Apr	39.2	02-Apr
1980	51.0	21-Mar	63.0	20-Mar	63.0	19-Mar
1981	48.0	10-Feb	56.0	10-Feb	56.0	09-Feb
1982	22.4	03-Apr	30.4	02-Apr	35.4	02-Apr
1983	25.0	02-Feb	30.0	02-Feb	30.2	09-Apr
1984	30.2	13-Feb	37.0	15-Mar	37.0	14-Mar
1985	33.0	04-Mar	39.0	04-Mar	44.4	21-Feb
1986	15.0	18-Mar	20.4	18-Mar	28.6	08-Mar
1987	18.0	31-Mar	27.6	30-Mar	34.6	29-Mar
1988	19.0	23-Apr	25.0	11-Feb	28.9	23-Apr
1989	32.0	17-Mar	44.0	16-Mar	45.0	15-Mar
1990	23.2	02-Apr	33.2	02-Apr	46.6	02-Apr
1991	32.2	08-Apr	52.6	08-Apr	63.2	07-Apr
1992	22.0	10-Apr	26.2	10-Mar	34.0	09-Mar
1993	17.0	19-Apr	29.0	19-Apr	30.6	18-Apr
1994	14.4	25-Apr	25.6	25-Apr	31.6	25-Apr
1995	29.8	07-Mar	30.6	21-Apr	42.8	05-Mar
1996	20.0	25-Apr	25.8	25-Apr	33.0	23-Apr
1997	48.6	21-Feb	66.6	20-Feb	69.0	19-Feb

Year	Maximum Precipitation for Various Duration (February 1st to May 1st)					
	1 Day		2 Days		3 Days	
	P (mm)	Date	P (mm)	Date	P (mm)	Date
1998	36.6	16-Apr	37.2	30-Mar	46.4	30-Mar
1999	14.4	12-Feb	18.4	11-Feb	21.4	11-Feb
2000	29.2	20-Apr	39.6	20-Apr	39.6	19-Apr
2001	41.2	09-Feb	56.2	08-Feb	58.2	07-Feb
2002	29.2	08-Apr	34.6	07-Apr	44.4	08-Mar
2003	29.0	03-Feb	35.0	03-Feb	37.0	03-Feb
2004	37.0	05-Mar	41.0	04-Mar	46.0	05-Mar
2005	33.6	14-Feb	42.6	14-Feb	42.6	13-Feb
2006	30.8	16-Feb	40.8	16-Feb	44.8	15-Feb
MAX	**51.0**	**March 21, 1980**	**66.6**	**Feb 20, 1997**	**73.0**	**Feb 24, 1975**

From Table 3.3, it appears that the largest 2-day rainfall event (two calendar days) during the spring freshet season (February 1st to May 1st) occurred in February 1997, with 66.6 mm.

Considering a 2-day rainfall event could have occurred in three calendar days, the 3-day rainfall event is also considered to represent a rainfall event having a duration between 48 hours and 72 hours. The 3-day rainfall occurred in February 1975, with 73.0 mm.

These 2-day and 3-day events recorded at the Minden station (1962 to 2006) are both exceeded by the April 2013 rainfall event as estimated by the MSC using the CaPA. Therefore, even though the climate station provides a point precipitation measurement while the CaPA image proposes an areal precipitation estimate over the reservoir lakes area within the Gull River watershed, it appears that April 17-19 rainfall event is the largest 48 h rainfall event observed in the watershed (when compared to the measurement over the period of observations, from 1962 to 2006).

A statistical analysis was carried out based on the Gumbel distribution to assess the severity of the April 2013 rainfall event. The rainfall events associated with some return periods between 2 to 100 years are shown in Table 3.4. The April 2013 rainfall event as estimated by the MSC using the CaPA is also shown.

Table 3.4 Statistical Analysis Results on Maximum Precipitation for Various Duration (February 1st to May 1st) at the Minden Climate Station (Environment Canada) (1962 to 2006)

Year	Precipitation for Various Return Periods and Durations (February 1st to May 1st)					
	1 Day		2 Days		3 Days	
	P (mm)	Date	P (mm)	Date	P (mm)	Date
Results from the statistical analysis						
2-yr	25		32		36	
5-yr	33		43		48	
10-yr	39		50		55	
25-yr	46		59		65	
50-yr	52		66		72	
100-yr	57		72		79	
The April17th to April 19th 2013 rainfall event (a 48 hour event observed over 3 calendar days)						
CaPA	Not available		**70**		**75**	

From the statistical analysis, since a 48 hour rainfall event can be observed within 2 to 3 calendar days, the rainfall event having a return period of 100 years would be between 72 to 79 mm.

The 48-hour rainfall event of April 2013, with approximately 75 mm over the reservoir lakes area (from the CaPA) would have a return period around 100 years.

A return period is used to assess the probability of occurrence of an event. A return period of 100 years corresponds to an annual exceedance probability (AEP) of 1 % (1 % of risks to exceed the 100-year spring rainfall each year), or a recurrence interval of 100 years (in average over of long period of time).

In summary, the rainfall event of April 2013 with 75 mm of rainfall in 48 hours was the most severe rainfall observed in the Gull River watershed since 1962 (rainfall data available from 1962 to 2006 at Minden). This rainfall event has an associated return period of near 100 years and is therefore considered as a severe rainfall event.

3.2.2 Snowpack

Snow course data measured by Parks Canada were provided. Table 3.5 presents the snow course observation stations and associated mean and standard deviation of annual maximum snow course. Figure 3.5 shows the location of the snow course observation stations located within the Gull River watershed (Eagle Lake, Little Bob and Carnarvon). Numbers associated with sub-basin nodes are those presented in Appendix A.

Table 3.5 Snow Course Observation Stations (Parks Canada)

Station Identification		Location		Period of Records
No	Station Name	Latitude	Longitude	
S1	Eagle Lake	45° 07' 49"	78° 28' 50"	1977 – 2013
S2	Little Bob	44° 52' 46"	78° 46' 51"	1977 – 2013
S3	Carnarvon (Brady Lake)	45° 02' 36"	78° 47' 47"	1977 – 2013

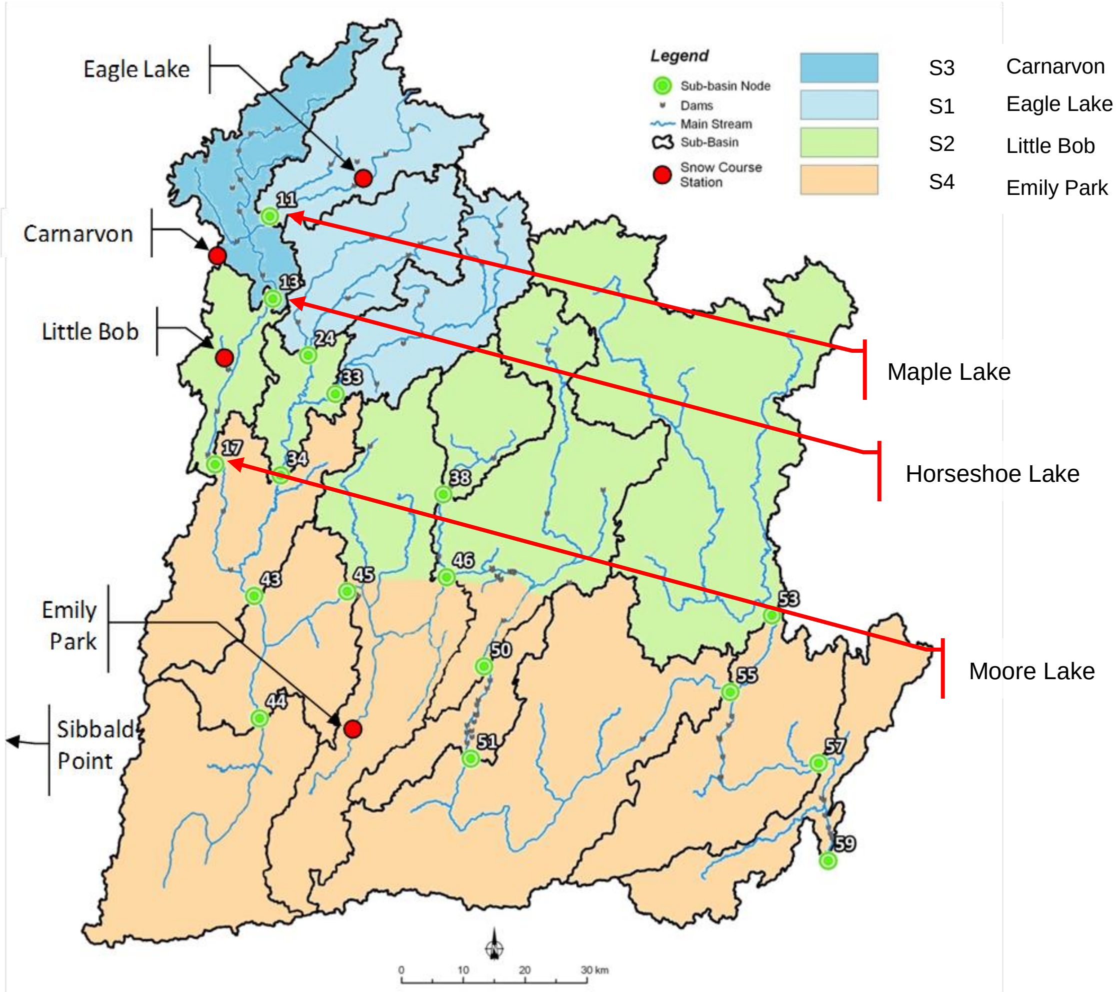

Figure 3.5 Location of the Snow Course Observation Stations

Snowpack data consists in snow depth and snow water equivalent measurements taken almost every week during the January-April period from 1977 to 2013.

Figure 3.6 shows the snowpack evolution for the winter 2013 at the three stations. Last observation for Little Bob occurred the week starting April 1st while last observations for Carnarvon and Eagle Lake occurred the week starting April 8th, where the snow course was still present.

The snowpack was still present on the ground in the highlands north of Minden when the heavy rainfall started on April 17th; however, observations were not carried out after the week starting April 8th.

It appears that the snowmelt started the first week of March (decrease in the snowpack) for one week, then the snowpack increased with additional snowfalls until the week of March 25th when snowmelt started again and lasted until the heavy rainfall of April 17th to April 19th occurred.

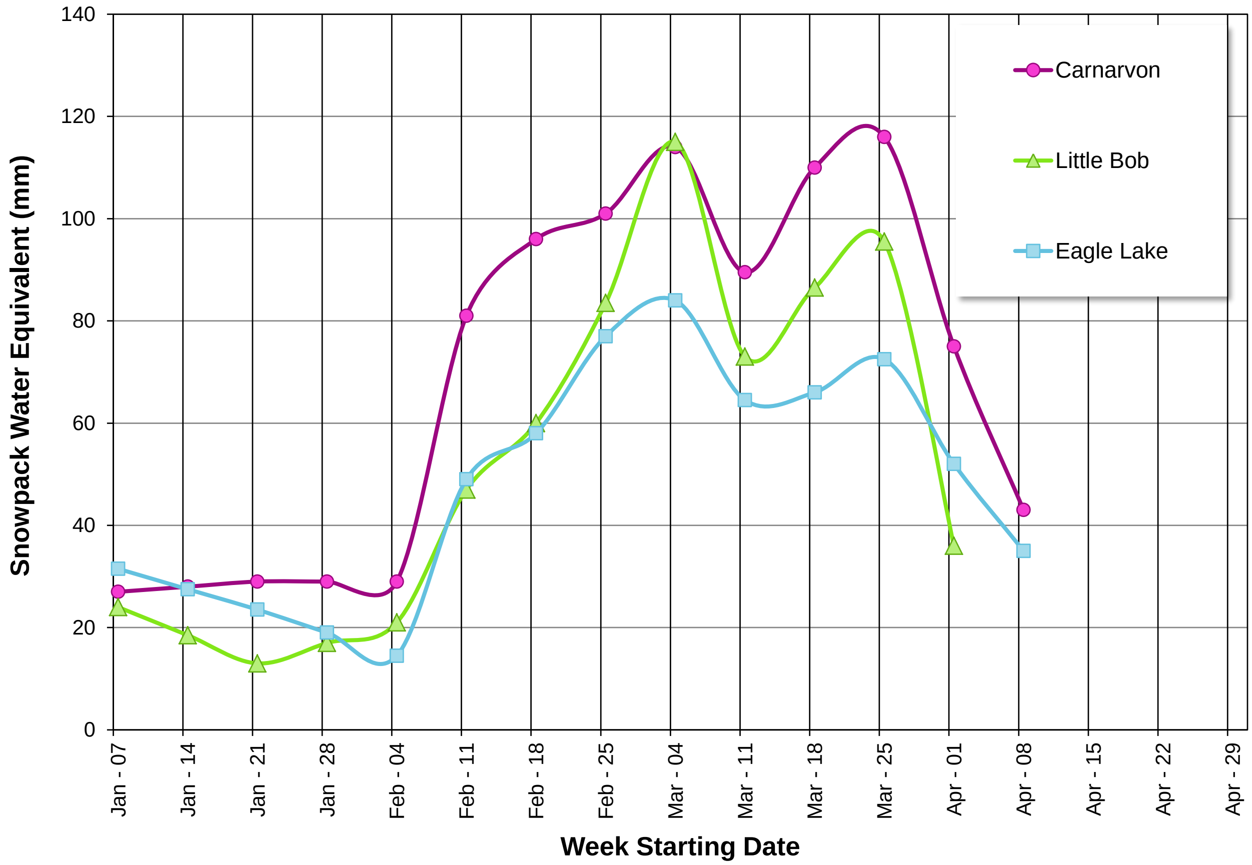

Figure 3.6 Snowpack - Winter 2013

Table 3.6 presents the maximum spring 2013 snowpack for the three stations located within the Gull River watershed.

Table 3.6 Maximum Spring 2013 Snowpack

Station Identification		Peak Snowpack Water Equivalent	Week of Peak Snowpack Water Equivalent
No	Station Name		
S1	Eagle Lake	**84 mm**	March 4 – March 10
S2	Little Bob	**115 mm**	March 4 – March 10
S3	Carnarvon (Brady Lake)	**114 mm**	March 4 – March 10

A statistical analysis was carried out on the maximum snowpack water equivalent in the context of the Hydro-Technical Study for the Trent River Watershed (Reference 1).

Table 3.7 presents the statistical snowpack at the three observation stations within the Gull River watershed.

Table 3.7 Statistical Snowpack at the three Observation Stations in the Gull River Watershed

Return Period	Station S1 Eagle Lake	Station S2 Little Bob	Station S3 Carnarvon
100 years	239	227	273
50 years	228	217	259
25 years	215	205	244
20 years	211	201	238
10 years	196	186	220
5 years	178	169	198
3 years	162	153	177
2 years	144	136	155
Spring 2013 Snowpack			
Peak Snowpack water equivalent in March 2013	**84**	**115**	**114**
Associated Return Period	<2 years	<2 years	<2 years

The peak snowpack water equivalent observed in 2013 prior to the flood event is smaller than the average maximum snowpack (less than the 1: 2-year snowpack). The snowpack was therefore not an indication of the potential severity of the flood to come.

Combined with the 113 mm of rainfall in April prior to the flooding, the snowpack added 84 to 115 mm of water equivalent to the April rainfalls, doubling the water input to the reservoir lakes.

3.2.3 Temperature and Snowmelt

The temperature obtained from Environment Canada Information Archive (Reference 12) for the Haliburton 3 climate station is shown on Figure 3.7 (daily minimum, mean and maximum). Snowpack water equivalent observed at Carnarvon is also shown. Note that snowpack was still present on the ground until the April 17-19 rainfall event, but no observation was made after the week starting April 8th.

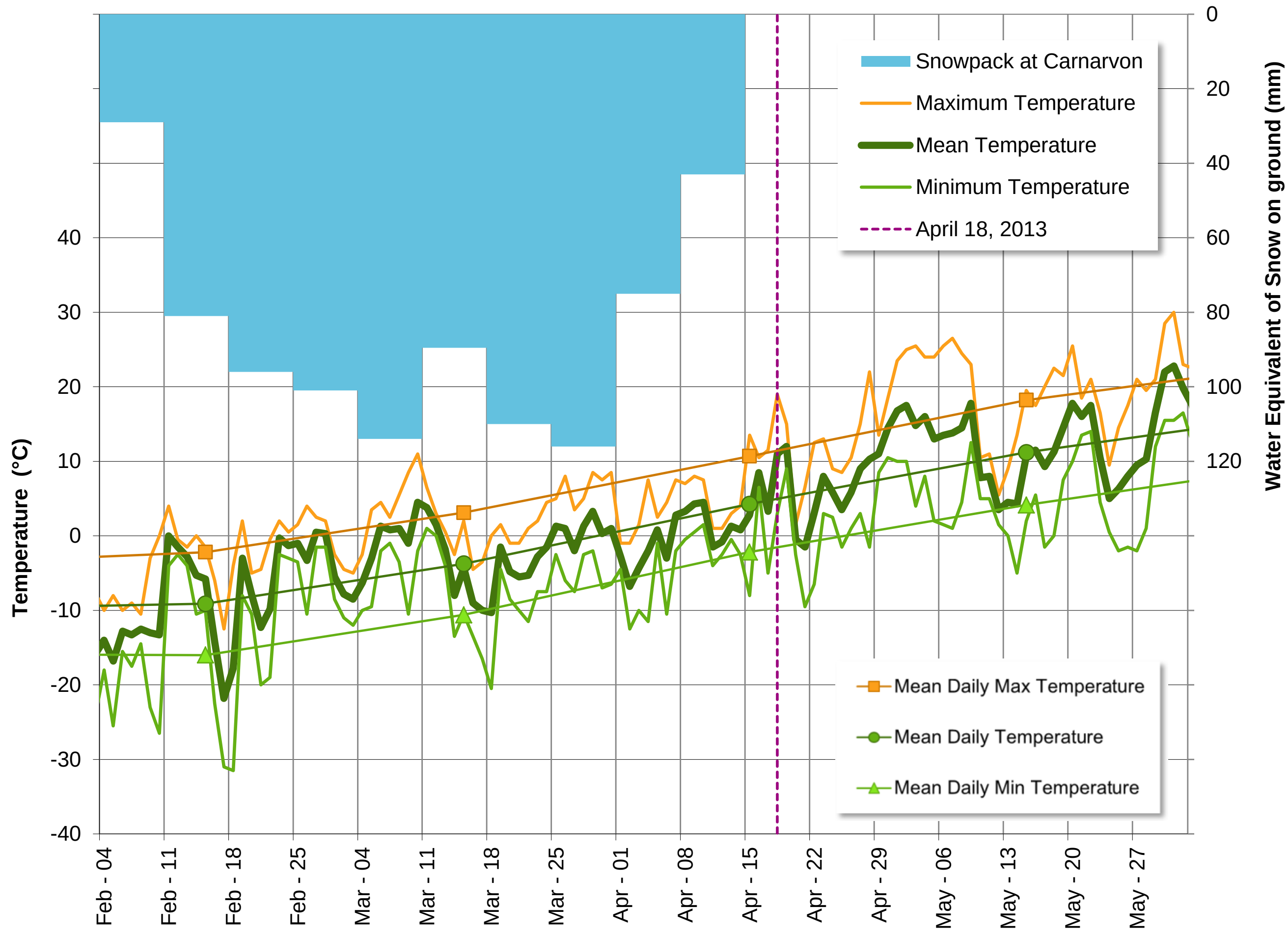

Figure 3.7 Temperature at Haliburton 3 for First Half of 2013

From Figure 3.7, it appears that the temperature sequence prior to the flood event was within the monthly maximum and minimum climate normal, also shown on the figure (for the period 1988 to 2006).

When compared to an efficient temperature sequence (as shown on Figure 3.1), similarities are found, with temperatures periods falling approximately at the same dates:

- a mild temperature period occurred for a period of more than 10 days, starting the first week of April, allowing for snowpack maturation,
- a higher temperature period occurred that lasted several days before the rainfall event, allowing efficient snowmelt.

It also appears that the snowmelt started the first week of March (decrease in the snowpack) and lasted until the heavy rainfall of April 17th to April 19th occurred. The water input from the snowmelt contributes to the soil saturation and to the runoff volume entering the reservoirs. Soil saturation leads to a higher runoff rate and a faster travel time to the reservoirs lakes.

3.3 Reservoir Levels

To perform the current Review, Parks Canada supplied the digitally recorded historical data sets, along with the stoplogs settings. Data sets cover all reservoirs lakes in the Gull River Watershed.

Note that water levels at Nunikani Lake and Sherborne Lake were not recorded due to difficult access during winter time; they were estimated based on flow estimates and discharge capacity curves, however not accurate for high water levels.

The reservoir Lakes water levels and stoplogs settings for the spring 2013 are presented in Appendix C.

Figure 3.8 to Figure 3.24 show the maximum, minimum, average and standard deviation (shaded area, representing 68 % of the recorded water levels for a specific day) of the historic reservoir levels over the periods available and the 2013 water levels.

From these figures, it appears that:

- the water levels in the reservoir lakes prior to the severe rainfall event (which started in the evening of April 17th) were within usual level range for the time of year when compared to the historic water levels (within one standard deviation from the average water level) for most of the lakes; Nunikani Lake, Hawk Lake, Sherborne Lake, Kushog Lake and Oblong Lake were almost full.
- the water levels started to increase on April 18th, reaching a peak water level within a week, on April 25th.
- the water levels on April 25th were the highest over the recorded periods for most of the dams since 1988 (length of the digital period of records).

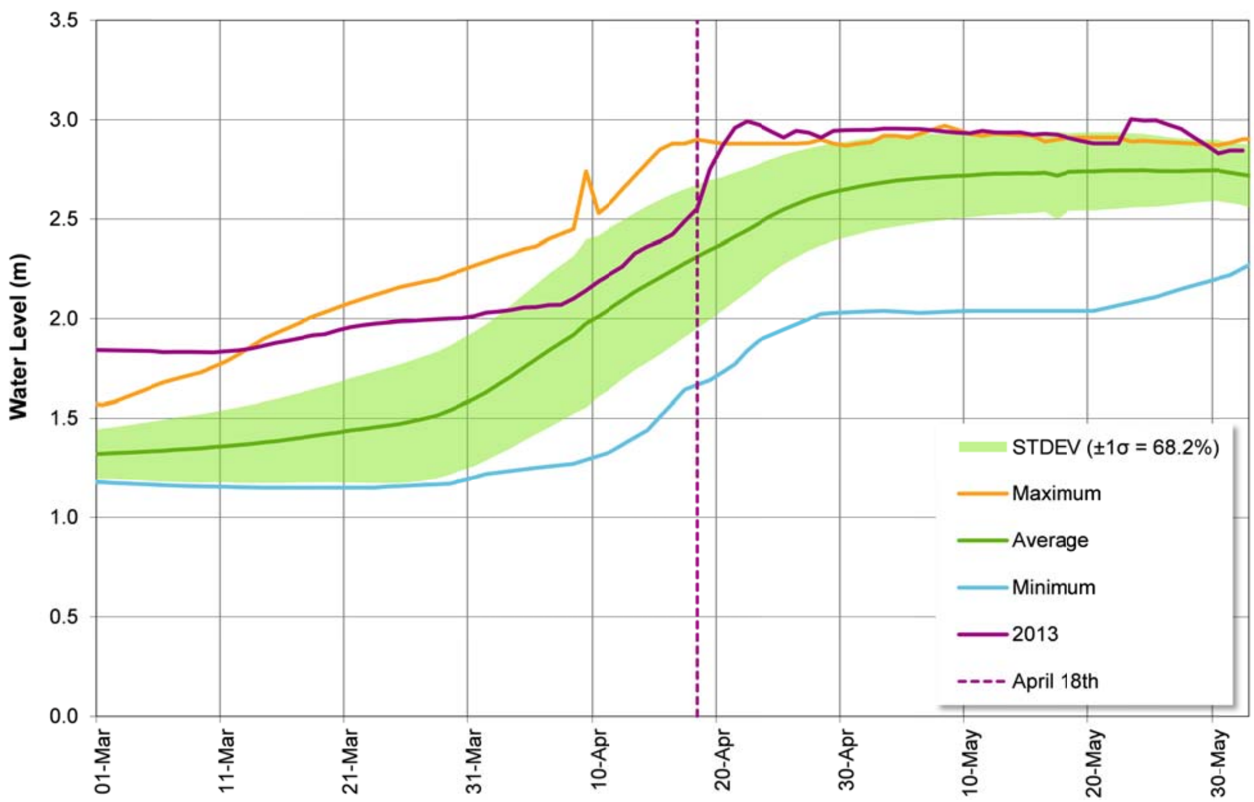

Figure 3.8 Water Levels at Kennisis Lake – 1988 to 2009 (Map 1)

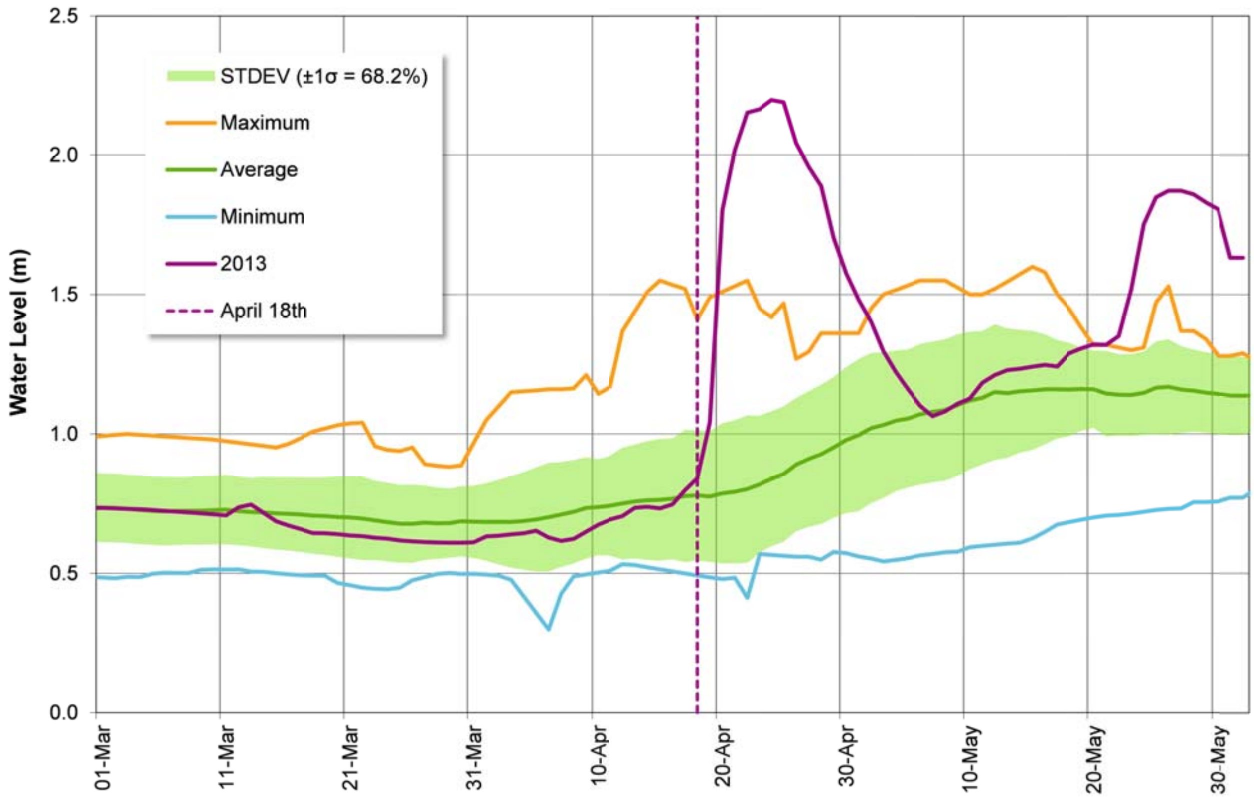

Figure 3.9 Water Levels at Red Pine Lake – 1988 to 2009 (Map 2)

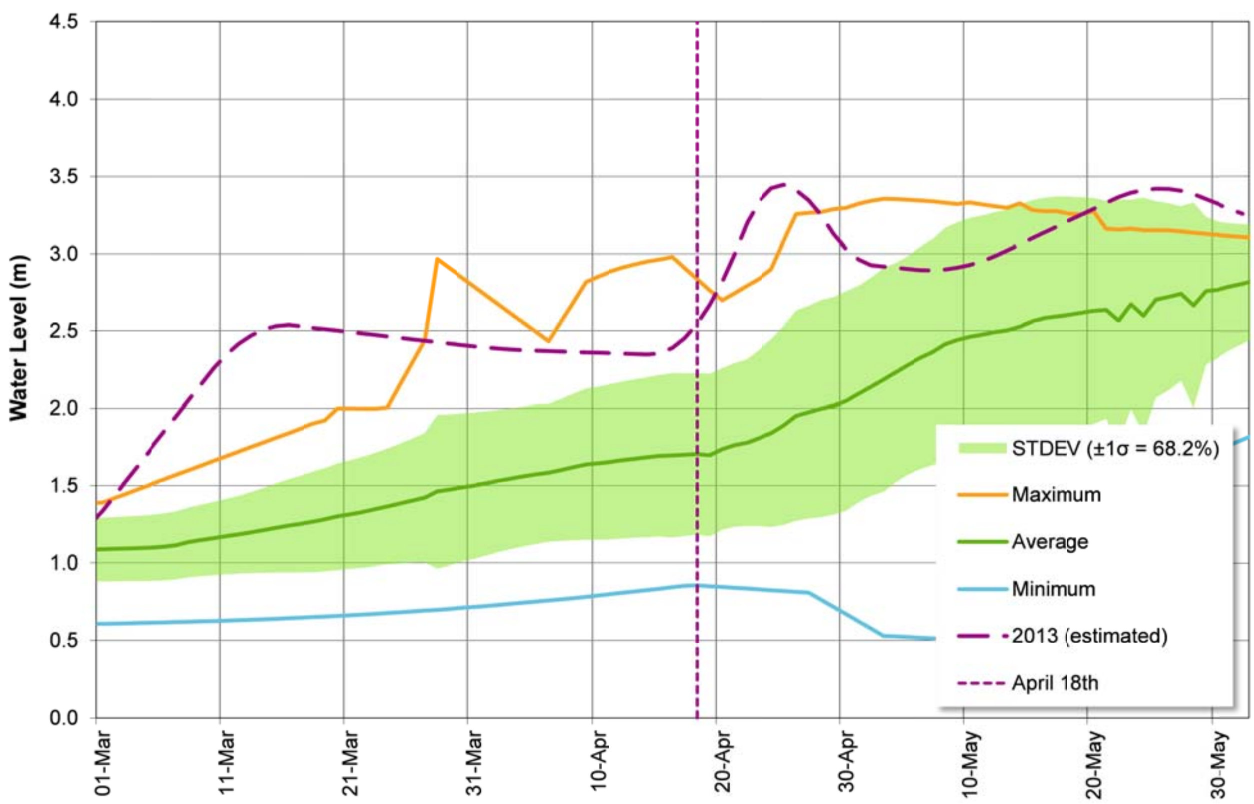

Figure 3.10 Water Levels at Nunikani Lake – 1988 to 2009 (Map 3) (Estimated)

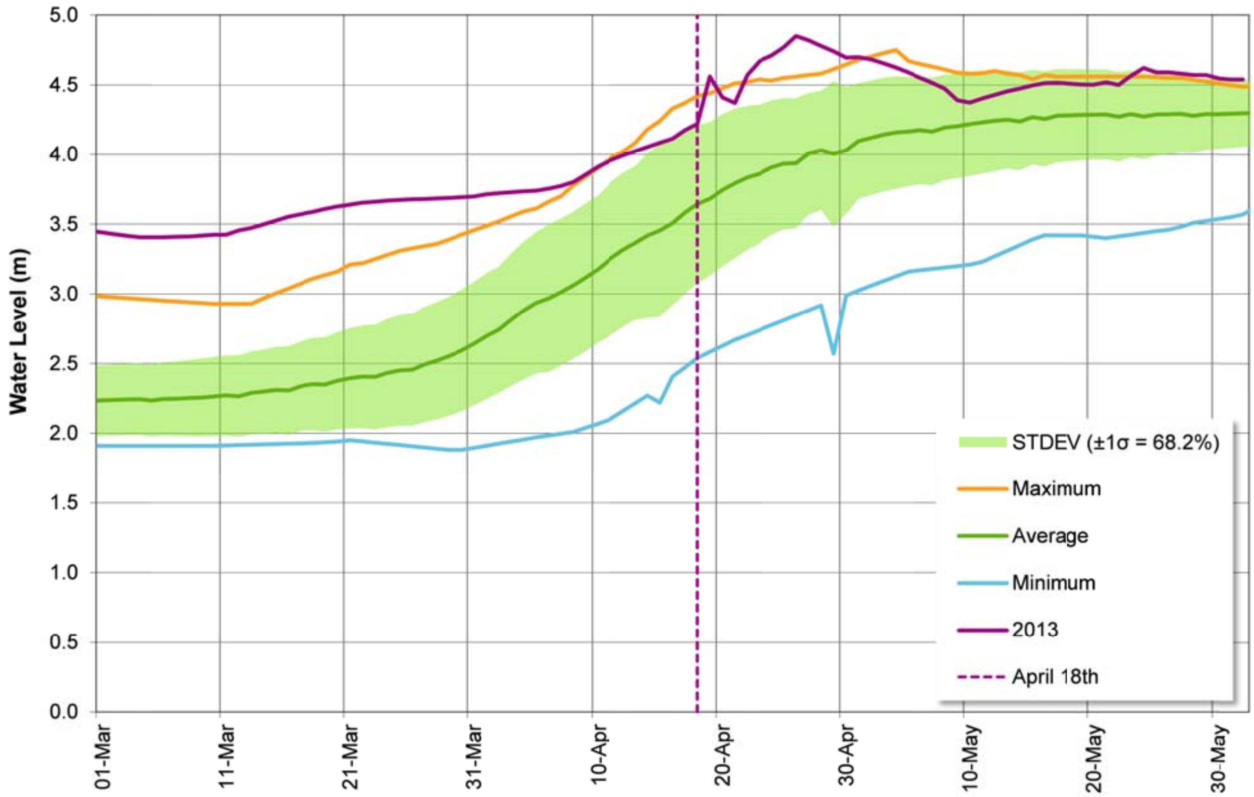

Figure 3.11 Water Levels at Hawk Lake – 1988 to 2009 (Map 4)

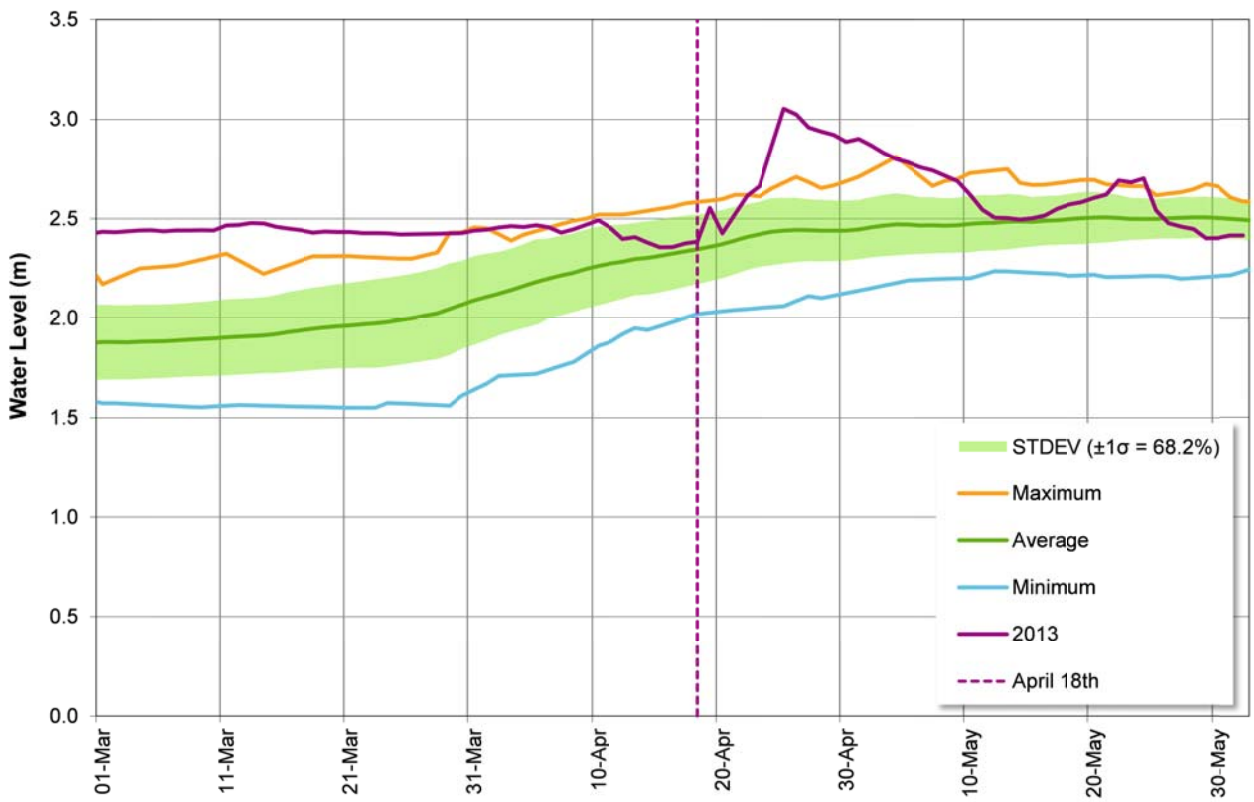

Figure 3.12 Water Levels at Halls Lake – 1988 to 2009 (Map 5)

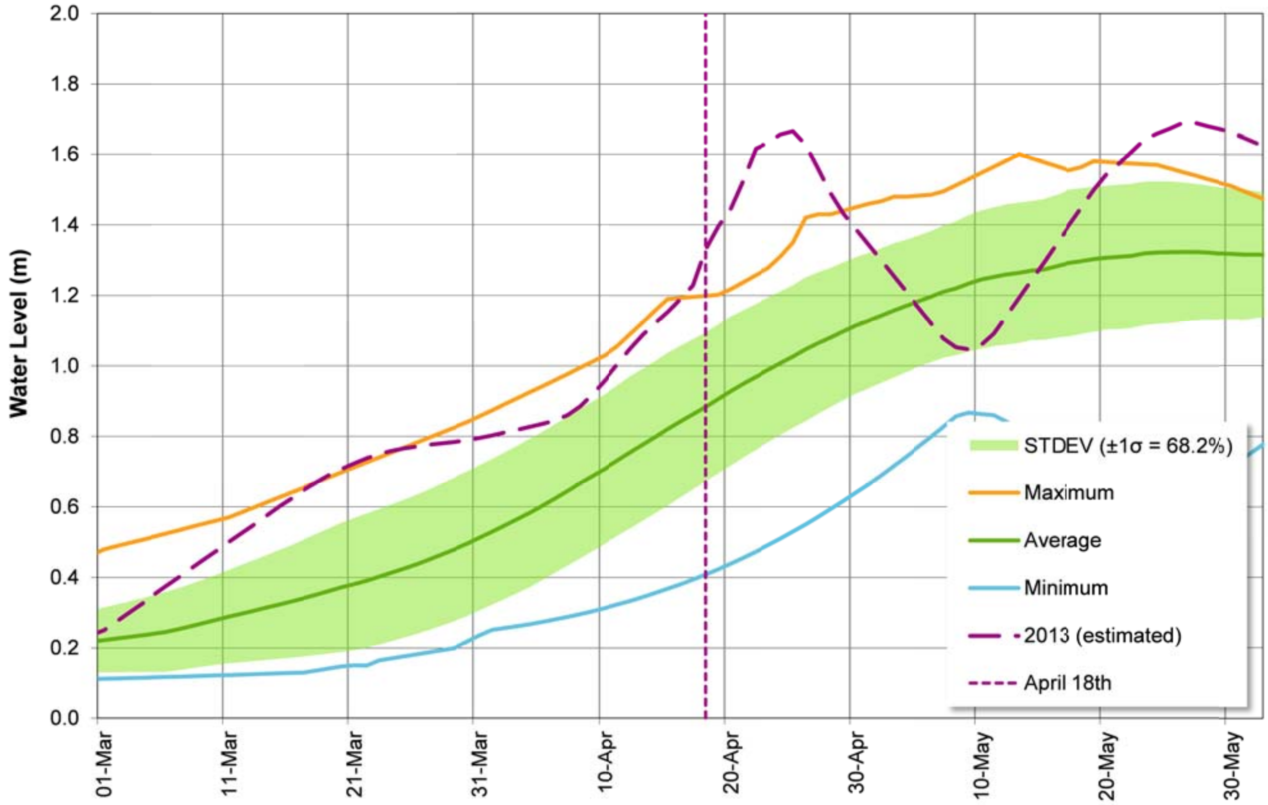

Figure 3.13 Water Levels at Sherborne Lake – 1988 to 2009 (Map 6) (Estimated)

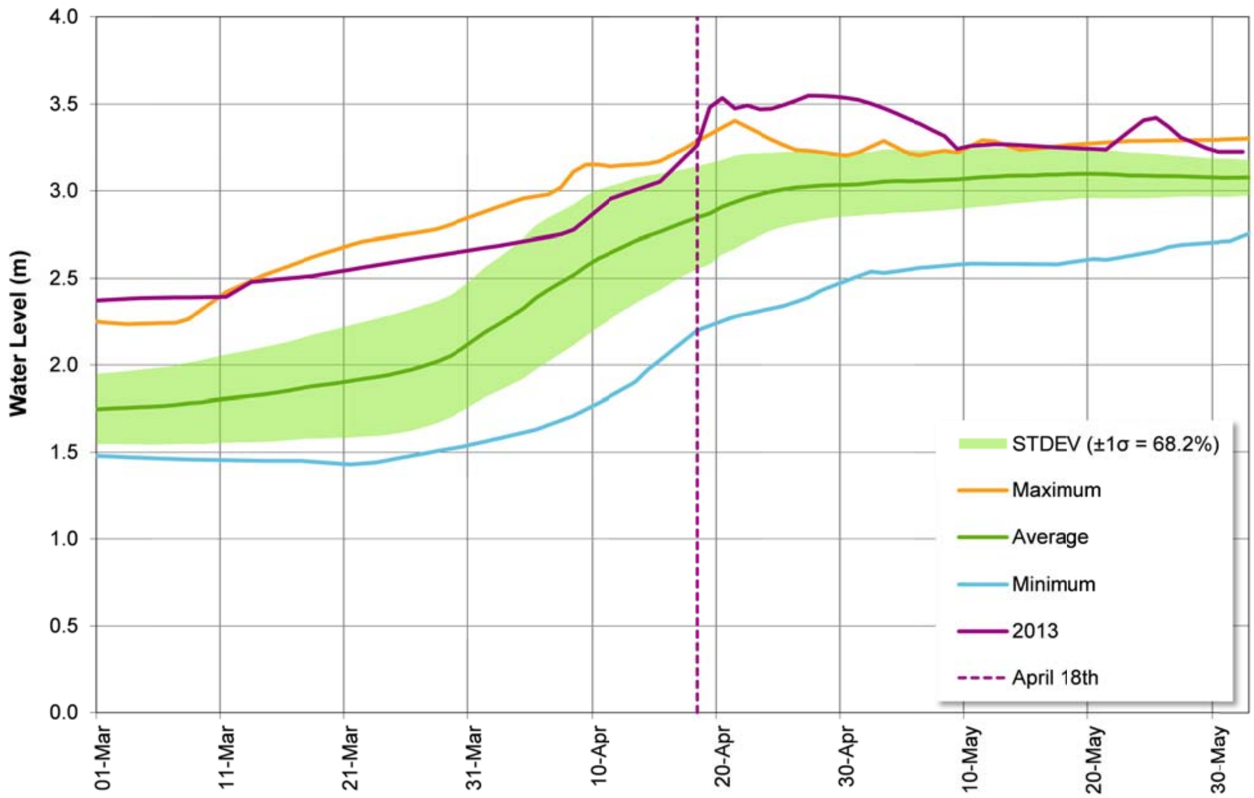

Figure 3.14 Water Levels at Kushog Lake – 1988 to 2009 (Map 6)

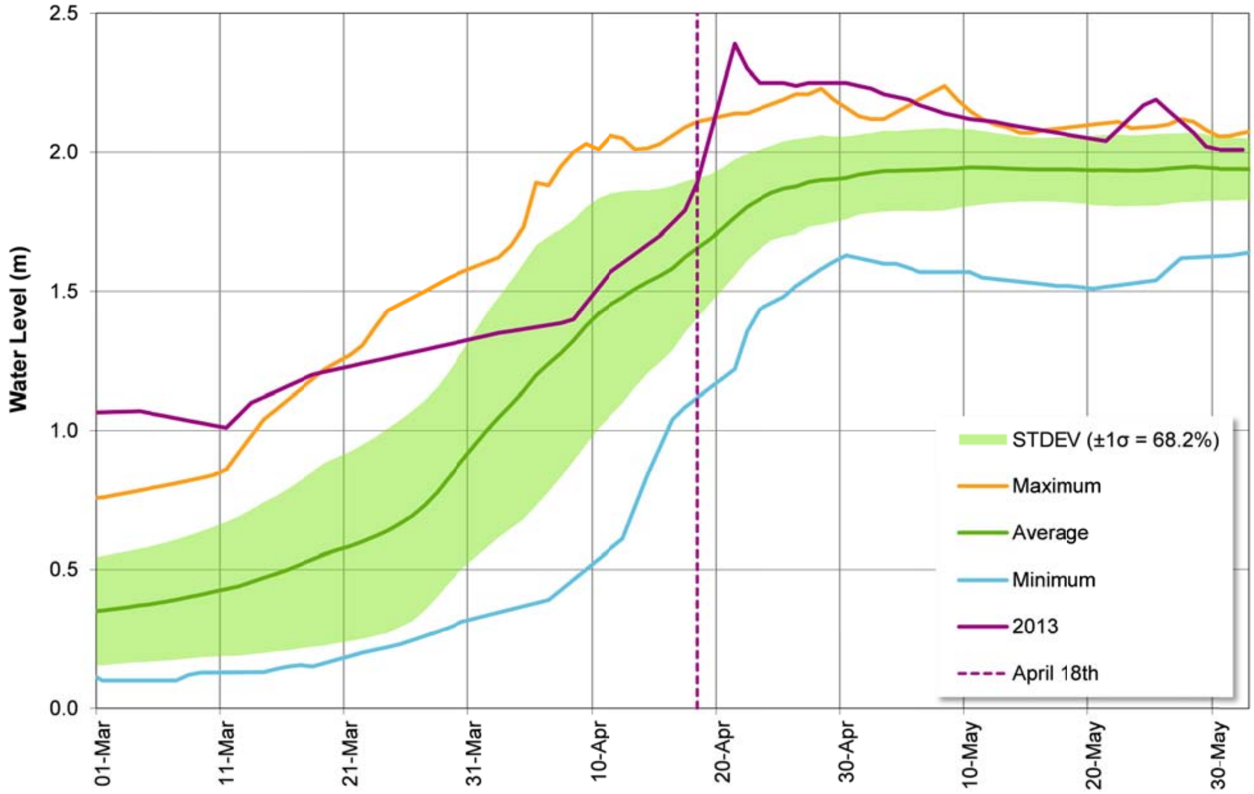

Figure 3.15 Water Levels at Percy Lake – 1988 to 2009 (Map 7)

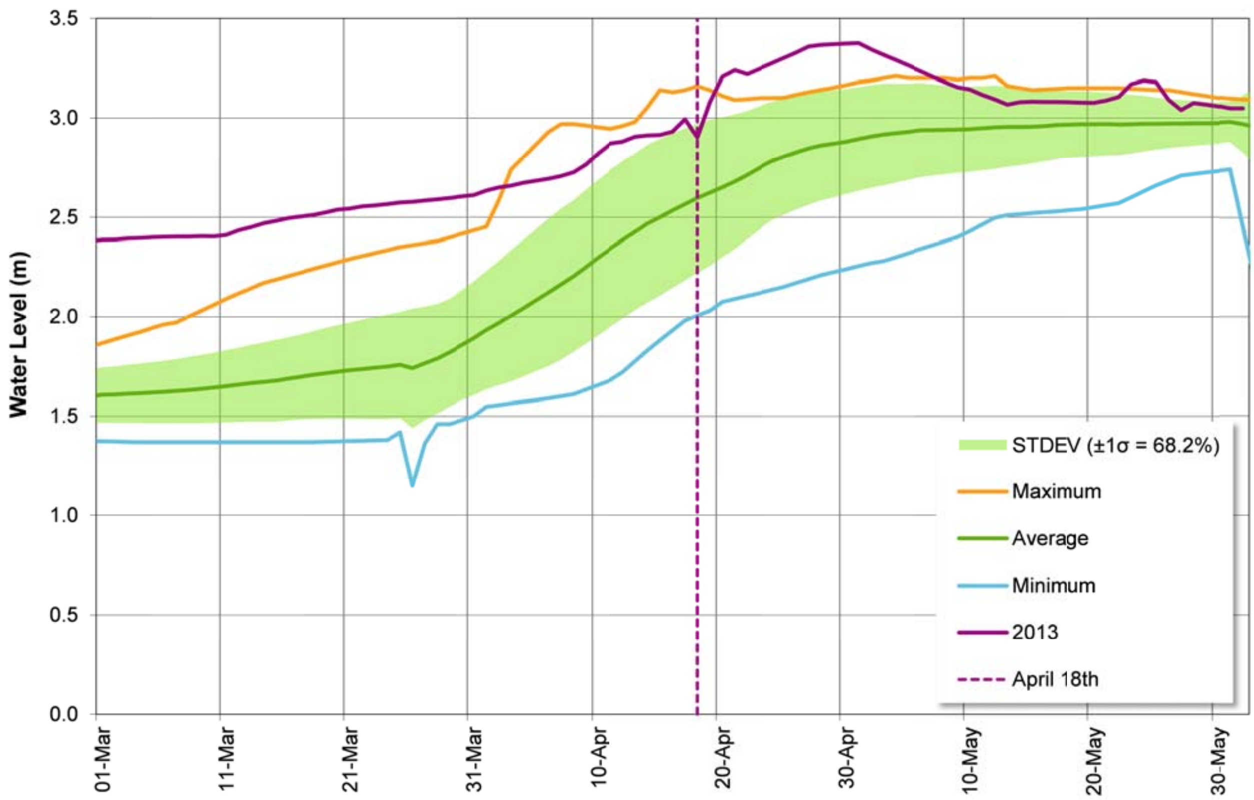

Figure 3.16 Water Levels at Oblong Lake – 1988 to 2009 (Map 8)

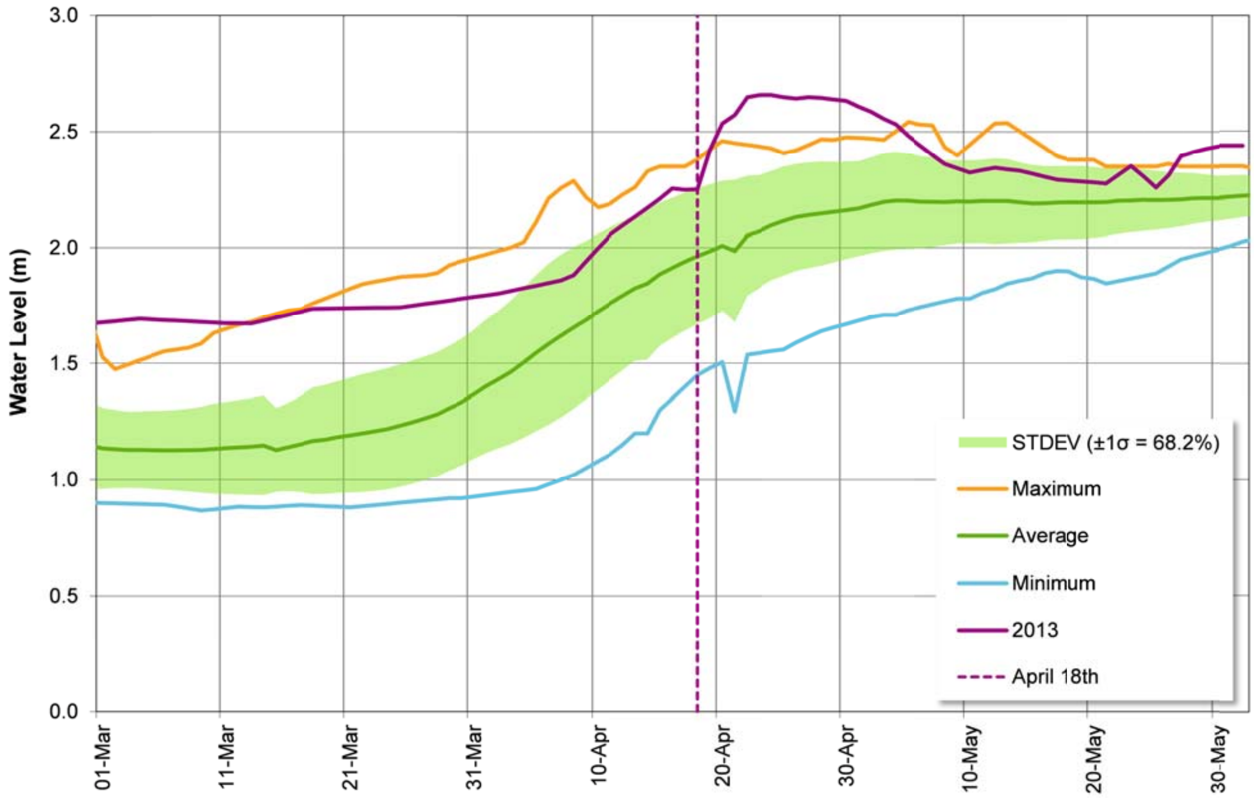

Figure 3.17 Water Levels at Eagle Lake – 1988 to 2009 (Map 9)

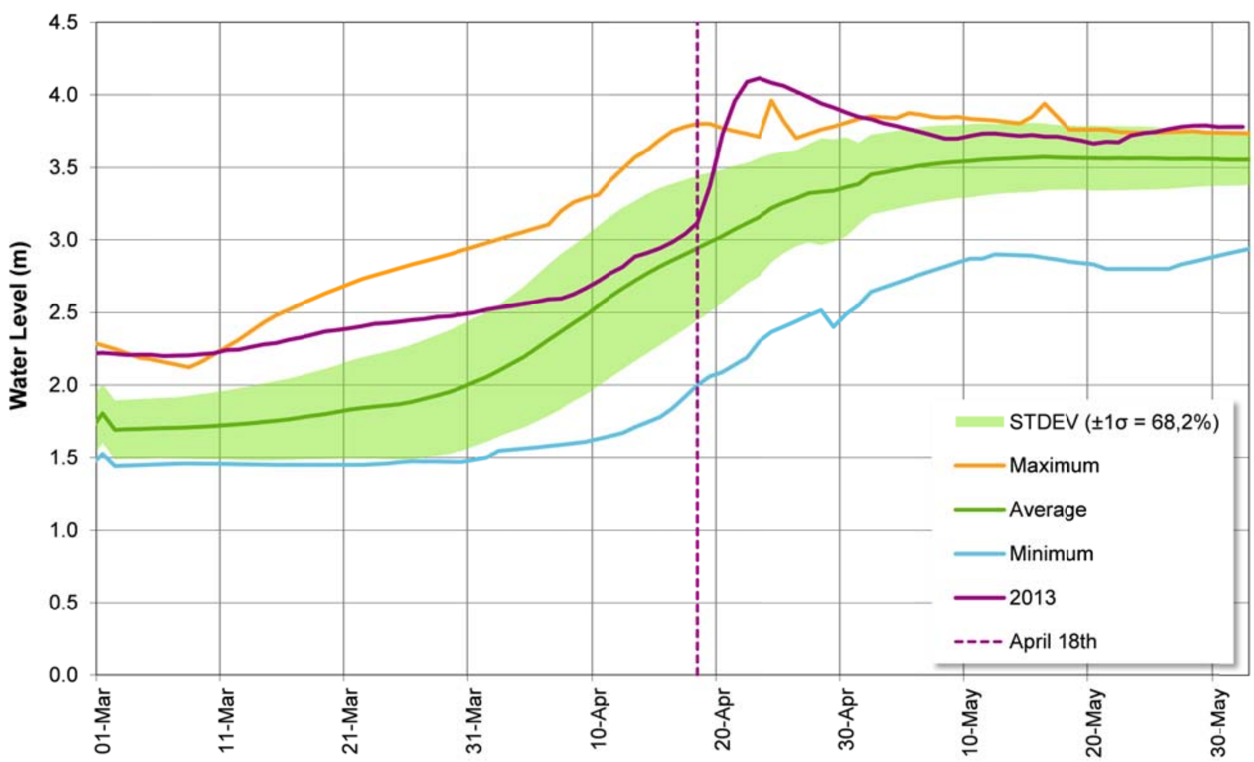

Figure 3.18 Water Levels at Redstone Lake – 1988 to 2009 (Map 10)

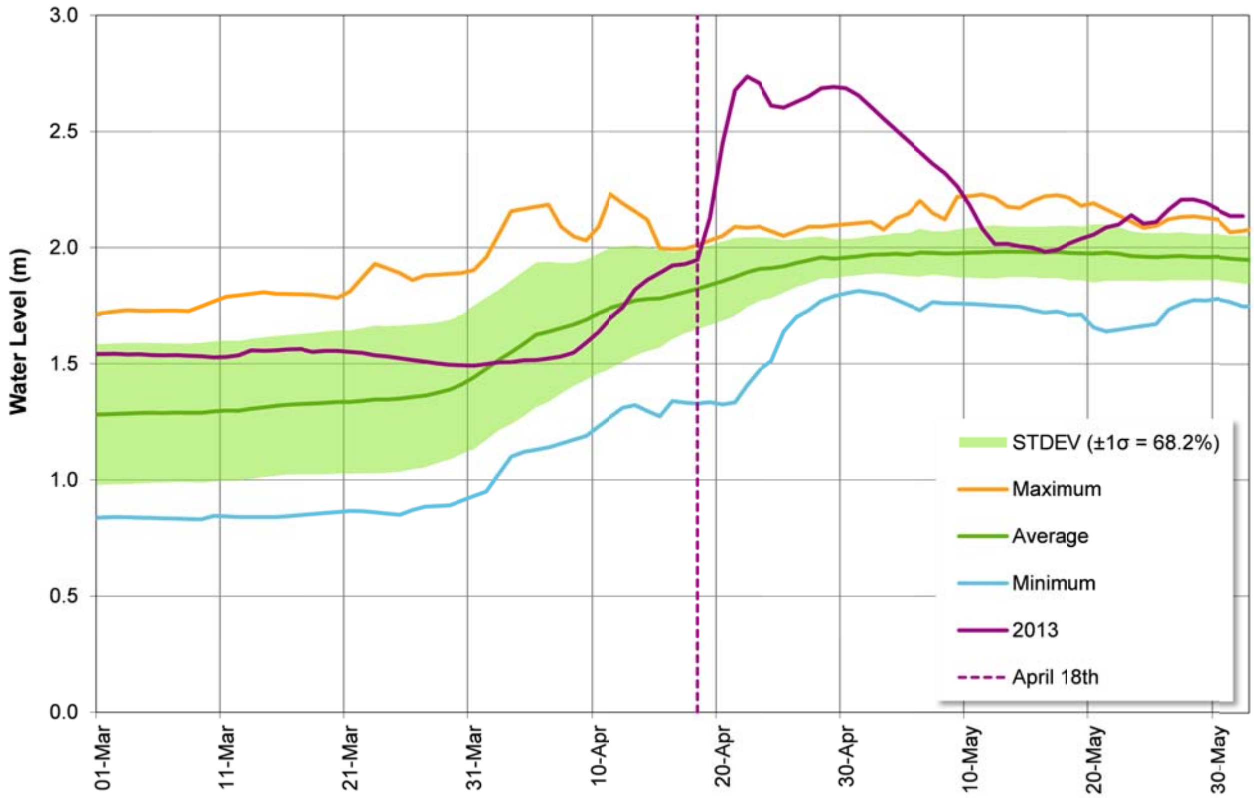

Figure 3.19 Water Levels at Twelve Mile Lake – 1988 to 2009 (Map 12)

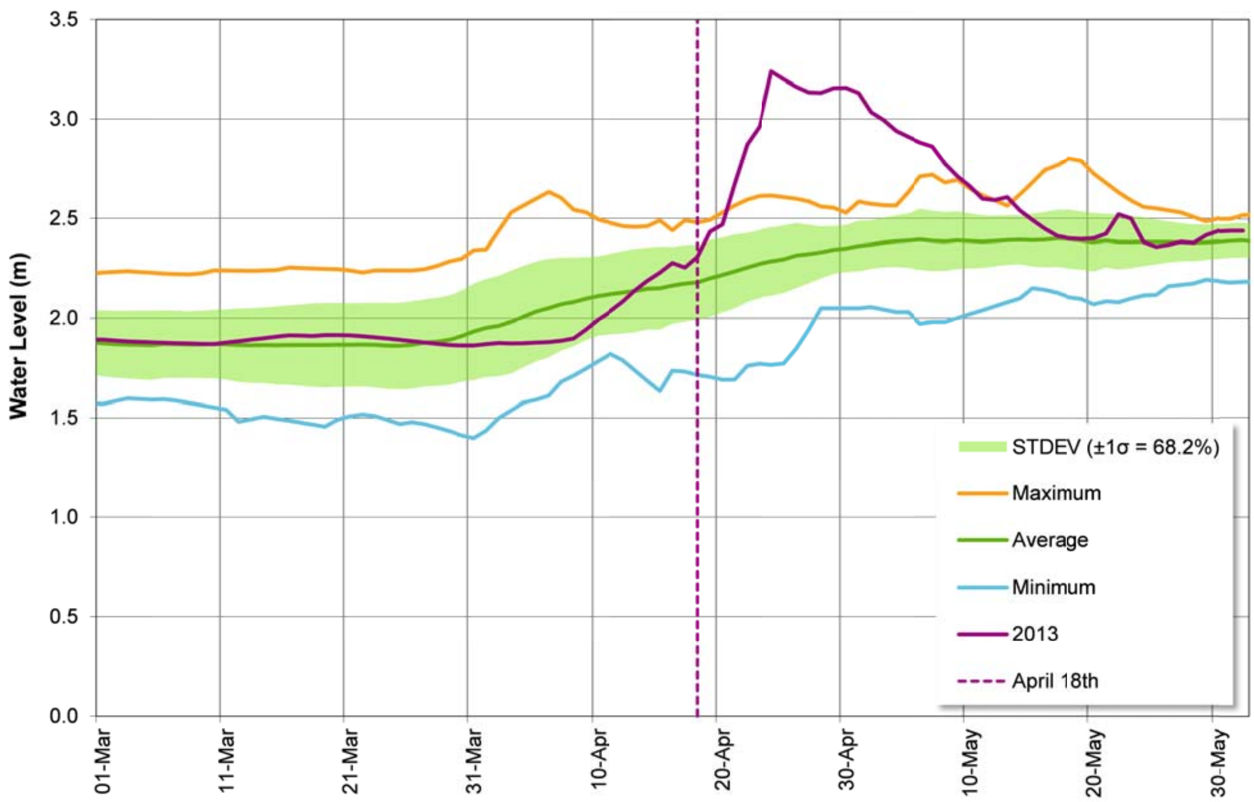

Figure 3.20 Water Levels at Horseshoe Lake – 1984 to 2009 (Map 13)

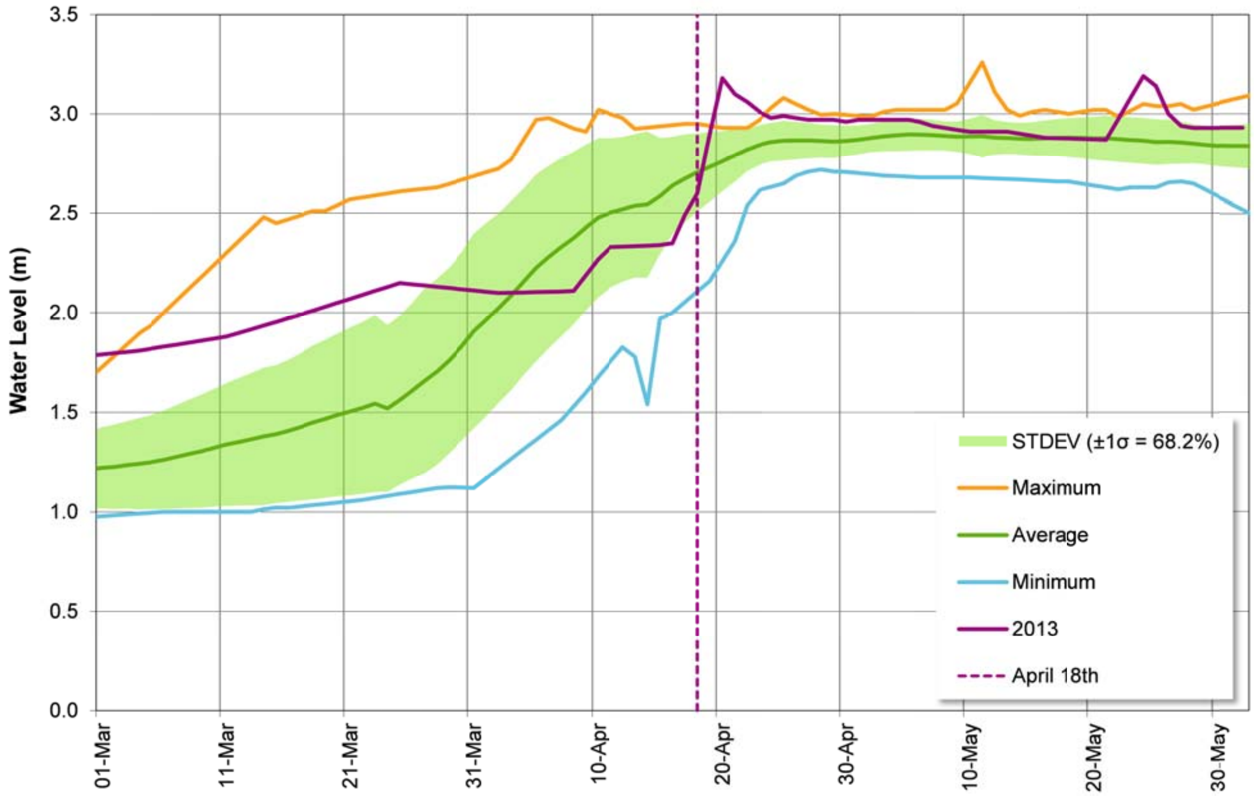

Figure 3.21 Water Levels at Bob Lake – 1988 to 2009 (Map 14)

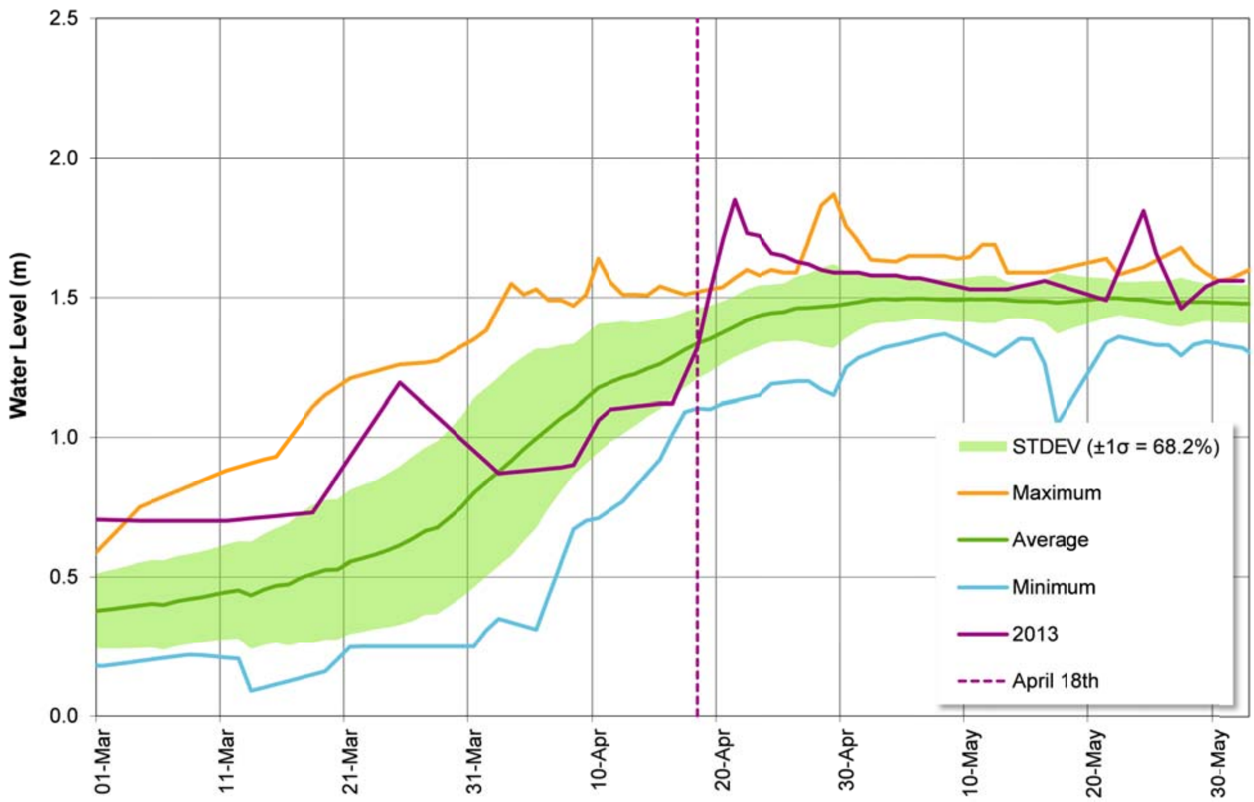

Figure 3.22 Water Levels at Little Bob Lake – 1988 to 2009 (Map 15)

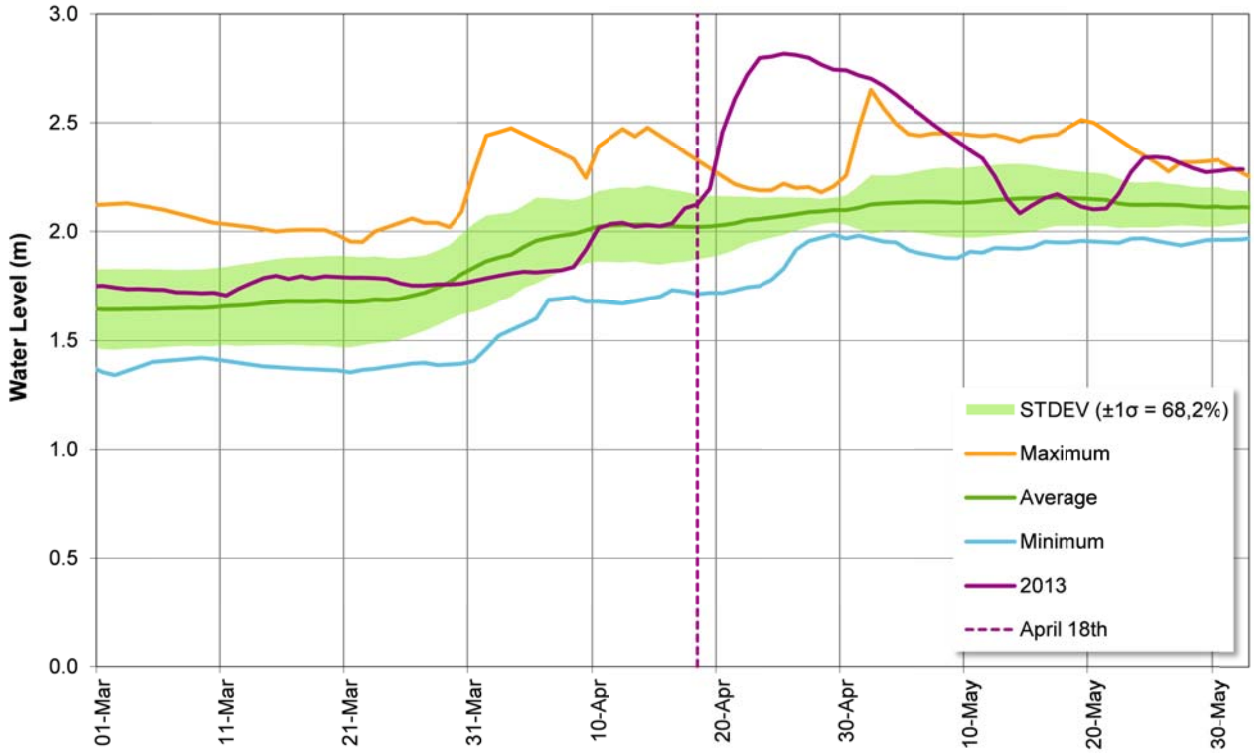

Figure 3.23 Water Levels at Gull Lake – 1988 to 2009 (Map 16)

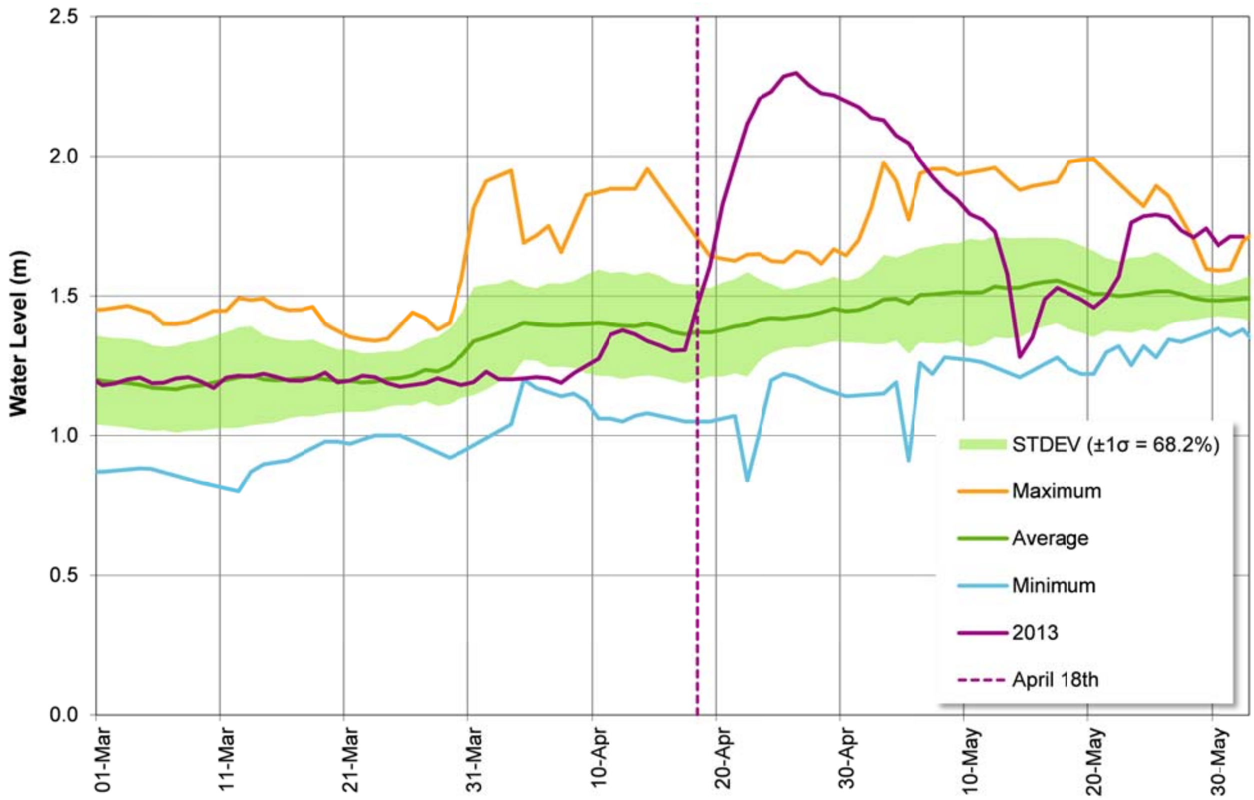

Figure 3.24 Water Levels at Moore Lake – 1988 to 2009 (Map 17)

3.4 Summary of the Pre-Flood Analysis

The pre-flood analysis showed that:

- **April Rainfall**: April 2013 was a wet month, with 1.5 times the normal precipitation.
- **Snowpack**: The peak snowpack water equivalent of 84 to 115 mm observed in 2013 prior to the flood event is smaller than the average maximum snowpack (less than the 1: 2-year snowpack).
- **Combined Snowpack and Rainfall**: With the 113 mm of rainfall in April prior to the flooding, the snowpack added 84 to 115 mm of water equivalent to the April rainfalls, doubling the water input to the reservoir lakes.
- **Temperature and Snowmelt**: Temperature in April 2013 was within the monthly maximum and minimum climate normal, but allowed a rapid melting of the snowpack before the flooding. The snowmelt started the first week of March and lasted until the heavy rainfall of April 17th to April 19th occurred. The water input from the snowmelt contributes to the soil saturation and to the runoff volume entering the reservoirs. Soil saturation leads to a higher runoff rate and a faster water travel time to the reservoirs lakes, should a heavy rainfall occur.
- **The Spring Freshet started April 10th**: Snowmelt and rainfalls at the beginning of April, including the first intense rainfall which occurred on April 8th and 9th, contributed to the spring freshet that started on April 10th.
- **Reservoirs Levels**: Even under spring freshet conditions, water levels prior to the flood event were within usual level range for most of the lakes when compared to the historic water levels, until April 18th. Five reservoir lakes were almost at their maximum normal operating level.
- **Prior to the rainfall event (before April 17th): there was no evidence that severe flooding would occur**, but all the conditions were present to favor an efficient runoff rate and to increase the severity of a flooding, should a heavy rainfall occur.
- **Rainfall April 17th to April 19th**: the spring rainfall event of April 2013 with 75 mm of rainfall in 48 hours was, is the most severe rainfall observed in the Gull River watershed since 1962 (rainfall data available from 1962 to 2006 at Minden). This rainfall event occurred when the spring freshet was at its peak flow with some snow still on the ground (flow was about to decrease). This rainfall event has an associated return period near 100 years and is therefore considered as a severe rainfall event.
- **When the severe rainfall event occurred**: The severe rainfall event combined with the spring freshet that was at its peak generated severe flooding. The water levels started to increase on April 18th, reaching a peak water level within a week, on April 25th.

Overall, the spring freshet developed into flooding after the severe rainfall of April 17th to April 19th due to pre-existing snowpack and rainfall.

4. Flood Event Analysis

4.1 General

In the pre-flood analysis (section 3), it was demonstrated how the spring freshet developed into flooding based the pre-existing snowpack and rainfall

The flood event analysis is performed to provide an understanding of:

- Whether management of the reservoir lakes may or may not have contributed to the flooding.
- Whether management of the reservoir lakes was performed adequately within the recognized operational procedures in order to meet the prioritized water management objectives.

The flood started on April 18th and the peak flooding occurred on April 25th.

The flood event analysis consists of the following:

- The actions taken by the TSW regarding dam operations during the flooding along the Gull River sub-watershed.
- Comparison of the 2013 water levels with historical water levels.
- A water balance to compare the water inputs and flood flows.

4.2 Actions Regarding Dam Operations

As part of the water management program, PCA closely tracks water levels and manipulates dams accordingly to mitigate shoreline flooding. Parks Canada had a team of engineers who were called in to assist with inspections of dam conditions on the ground providing data that inform its decision-making related to water management and dam condition during the spring flood of April 2013.

The stoplogs settings and water levels in the reservoir lakes are detailed in Appendix C. Appendix D presents a summary of the removal and addition of stoplogs at the 17 operable dams of the Gull River watershed for the period leading up to the significant flood event and as the water levels receded after.

In summary, it can be seen that:

- Winter settings were respected. As of January 1st, 61 stoplogs were in place.
- In accordance with the Water Management Program, because of the limited snow cover, stoplogs were added during winter.
- The spring freshet started on April 10th. Rapid and efficient log removal (44 logs in 10 days) allowed water levels to remain within usual ranges for most of the reservoir lakes when compared to the historic water levels, until April 18th.
- On the April 17th, the last stoplogs were removed at Moore Lake Dam (Elliott Falls) and Gull Lake Dams, the two reservoirs immediately downstream of Minden Hills; these two dams were fully open.
- No alert had been issued by Environment Canada related to heavy rainfalls near the Gull River watershed, only regular weather forecast.
- On the evening of April 17th, when the heavy rainfall started, water levels and flows were within usual level range for most of the reservoir lakes when compared to the historic water levels, and started to increase on April 18th.
- Moore Lake Dam and Gull Lake Dams, remained fully open from April 17th to May 13th when PCA started to put back stoplogs when the water levels dropped below the maximum normal operating level after the passage of the flood.

Management Decisions

At this point, with all the stoplogs out at Moore Lake Dam and Gull Lake Dams, the maximum discharge capacity is provided. For any flow increase entering Moore Lake and Gull Lake after April 17th, water level had no other option than to increase.

April 19th, 2013

Even though all stoplogs were out at Moore Lake Dam and Gull Lake Dams, severe flooding started to occur in Minden Hills, just upstream of the two foregoing dams. On April 19th, before the end of the severe rainfall, the water levels increased by about 30 cm in Moore Lake and Gull Lake, and continued to increase by approximately the same amount on April 20th. On April 19th, localized flooding and road washouts began to be reported to the Haliburton Sector Office of the Trent-Severn Waterway (TSW) National Historic Site of Canada. Evacuation of some residents started on the evening of the 19th.

The Ministry of Natural Resources issued a flood warning for the Gull River, Burnt River and Irondale River watersheds on April 19th outlining the fact that water levels have been rising quickly and continue to rise and that this trend is expected to continue in to early the following week (week starting April 22nd) with even more rain in the forecast. Experts are warning this will prove to be a problem for Minden where local lakes have risen 15-25 cm overnight (from April 18th to April 19th).

Increasing water levels above the maximum operating level while the maximum discharge capacity was provided at downstream dams revealed that the April 2013 flood had a severity exceeding the discharge capacity of these dams. Severity of the flood is presented in section 7.

April 20th, 2013

It became clear on April 20th that public safety had been jeopardized. PCA was in contact with communities within the TSW area that are experiencing flooding to advise on dam operations and to assist with information to help their emergency planning. The community of Minden Hills declared a state of emergency. The City of Kawartha Lakes also declared a state of emergency due to flooding in the Burnt River, Black River and Gull River watersheds.

The only option that PCA had in order to avoid additional flooding in Minden Hills and downstream of Minden Hills was to retain water in the upstream reservoir lakes to decrease the flow entering Gull Lake. However, retaining water upstream would cause additional flooding in the upstream reservoir lakes. A decision had to be made based upon available information.

The sources of information available for the decision making was the staff on the ground, media reports, photos, more than daily contacts with the community emergency management coordinator (CEMC) who is the fire chief of the community of Minden Hills, public communications (incoming calls and through staff on the ground) and the team of engineers carrying out inspections of dam conditions.

The various risks to public safety that could escalate to emergencies were identified.

The public safety issues noted in the community of Minden Hills and downstream were the following:

- The fire department was flooded and evacuated,
- The sewage treatment plant was surrounded by water,
- The electrical sub-station was surrounded by water,
- The integrity of the main bridge on Bobcaygeon Rd. in the centre of town was questioned. A closure of the bridge would divide the town in two, increasing the response time for EMS (Emergency Management Services) for residents on the opposite bank;

- Public infrastructure was damaged – mainly road and culverts were flooded and closed, some others washed out,
- Permanent residences were flooded and evacuated.

In the northern reservoir lakes upstream of Minden Hills, the following issues were reported:

- A causeway to a residence on an island was flooded and damaged, residents were trapped and evacuated safely,
- Public infrastructure was damaged – mainly road and culverts were flooded and closed, some others washed out,
- Mostly seasonal residences, some permanent residences and recreational infrastructures were flooded. No commercial activity other than resorts and marinas are located in the area north of Minden (Horseshoe Lake and upstream),
- No issues of public safety reported.

Considering potential public safety issues to the permanent community of Minden Hills and downstream to Coboconk, the decision to put back stoplogs in the reservoir lakes upstream of Minden Hills (Horseshoe Lake, Little Bob, etc. see Appendix D for details) to prevent greater downstream flooding was taken.

April 21st, 2013

PCA proceeded with addition of stoplogs at dams upstream of Minden Hills and continued the two following days. PCA was able to respond to the situation with additional crews to monitor and operate dams to mitigate as much as possible the impacts of increasing water levels and river flows.

A comparison of the flows at Twelve Mile Lake Dam and Horseshoe Lake Dam is carried out to assess how much the peak flood flow from Twelve Mile Lake Dam was reduced by retaining water in Horseshoe Lake, just upstream of Minden Hills. The flows at the two dams are estimated based on standard discharge capacity equations (using stoplog settings, water level records and dam geometry). Note however that the estimated flows are provided for the purpose of demonstrating the effect of retaining water in the upstream reservoirs on flood flows. They are not to be considered as accurate and aim at providing the order of magnitude of the flows that would have occurred near Minden Hills if the actions were not taken at Horseshoe Lake Dam.

Figure 4.1 shows the estimated flows at both reservoir lake dams. The comparison shows that approximately 20 m^3/s were cut from the peak flood flows entering Moore Lake from April 21st to 25th due to PCA actions. Additional flooding in Minden Hills was therefore avoided.

In summary, the actions taken by PCA to retain water in the upstream reservoir lakes (at Horseshoe Lake Dam, Twelve Mile Lake Dam, etc.) and mitigate flooding near Minden Hills and downstream to Coboconk were successful.

The volume of water retained in the upstream reservoir lakes however, as foreseen, created high water levels in these reservoir lakes, without endangering public safety. PCA crews were monitoring closely the flooding to report any potential public safety or dam safety issues. An equal flooding procedure was applied in the possible extent. Sand bags were used to protect dam structures from erosion (that can occur with overtopping of earth embankment structures, therefore to prevent dam failure) when required.

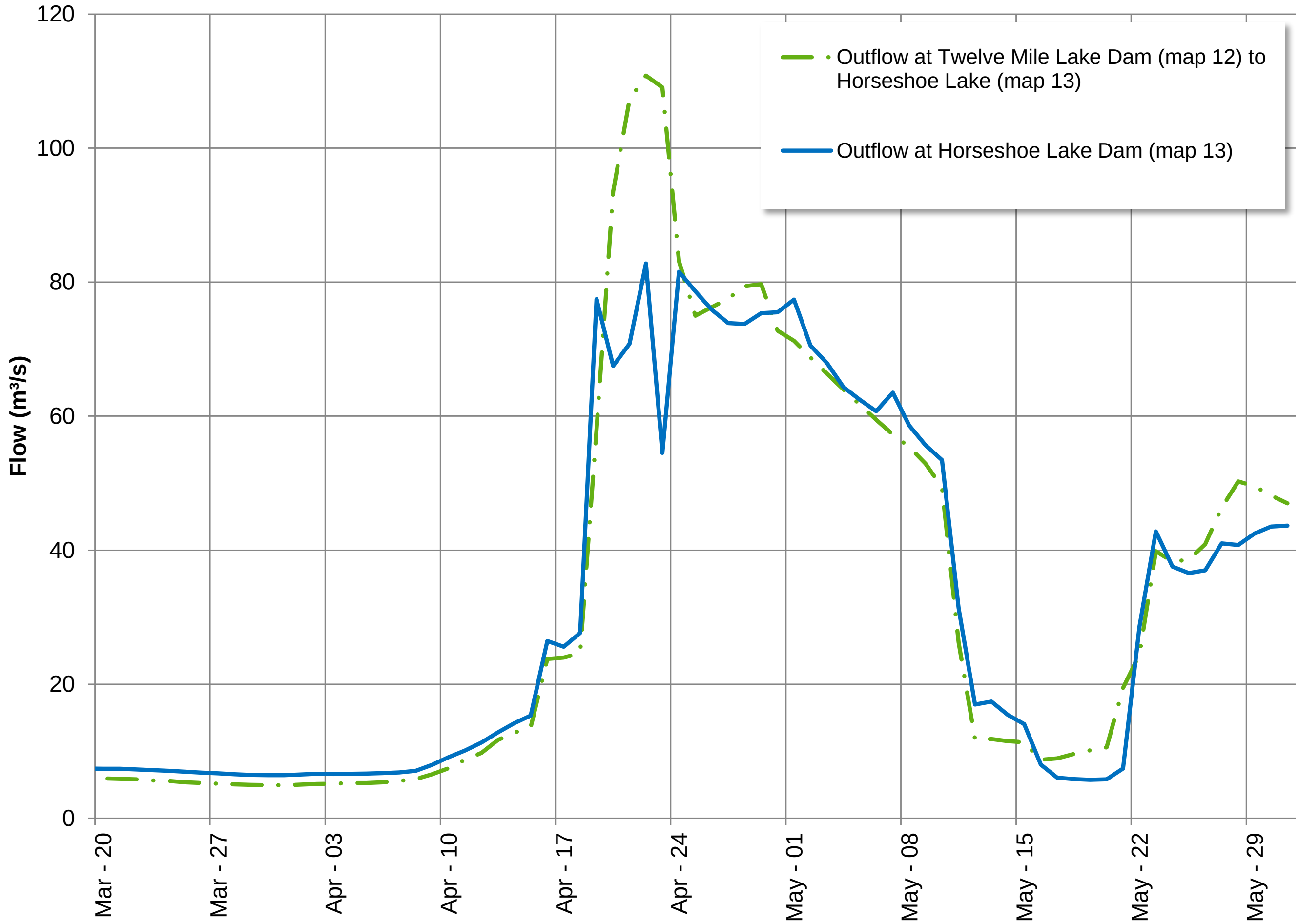

Figure 4.1 Estimated Outflows at Twelve Mile Lake and Horseshoe Lake during the April 2013 Flood

Following days

On the 25th, the flood warning from the MNR remained, as well as the state of emergency from both Minden Hills and The City of Kawartha Lakes.

In summary, the flood event analysis showed that:

- The management of the reservoir lakes did not contribute to the flooding near Minden Hills. Furthermore, the management succeeded in avoiding additional flooding on April 25th by retaining water in the upstream reservoir lakes.
- The management in reservoir lakes was performed adequately within the recognized operational procedures in order to meet the prioritized water management objectives.

4.3 Comparison of the 2013 Water Levels with Historical Water Levels

Figure 4.2 to Figure 4.4 show the sorted peak water levels from 1988 to 2009 (length of the digital period of records) and the 2013 peak water levels.

On the sorted peak water levels bar charts, it can be seen that the water levels (as well as flows) are typical of those in a reservoir system. The flood routing effects in the reservoirs and the dam operations usually allow managing the water levels within operating ranges. Approximately one year out of two (return period exceeding the 2 year flood), water levels exceed the maximum operating level by a small amount, especially if the storage capacity of the reservoir is large. But for larger floods (with a return period of more than 10 years), once the storage capacity is reached and inflows continue to increase, water levels start to increase in a marked manner.

For the Gull Lake Dam on Figure 4.2, the peak flow that occurred during the high water levels is also shown. For the 2009 and the 2013 spring floods, both water levels and flows are ranked second and first largest floods since 1988 (length of the digital period of records). High water levels were therefore linked to high flood flows.

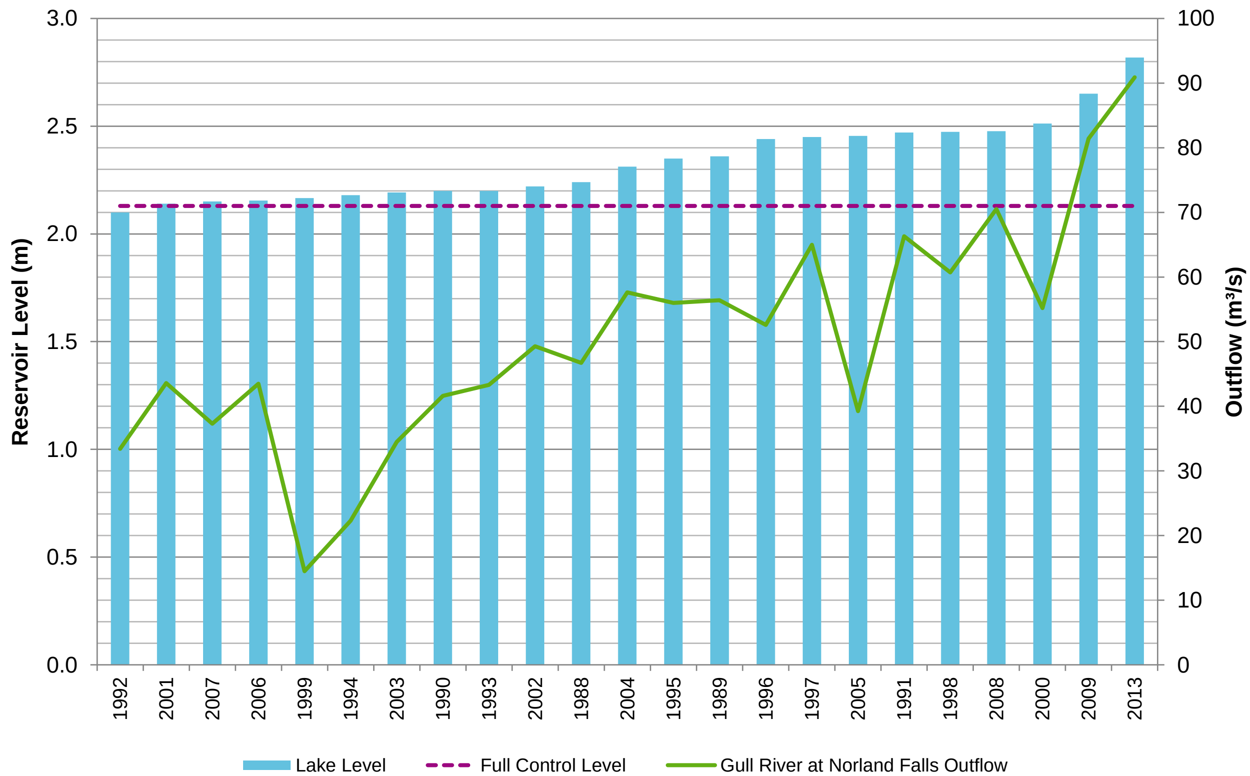

Figure 4.2 Sorted Peak Water Levels at Gull Lake Dam (m) and Corresponding Peak Flow

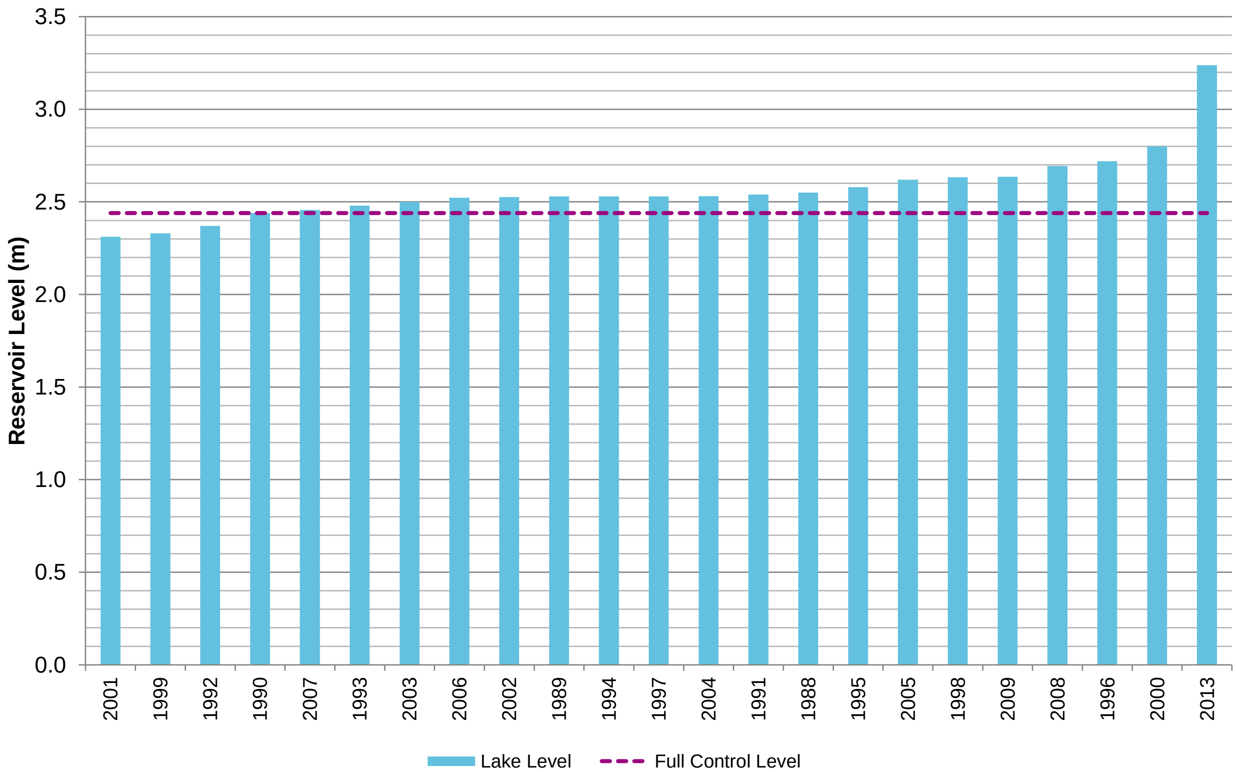

Figure 4.3 Sorted Peak Water Levels at Horseshoe Lake Dam (m)

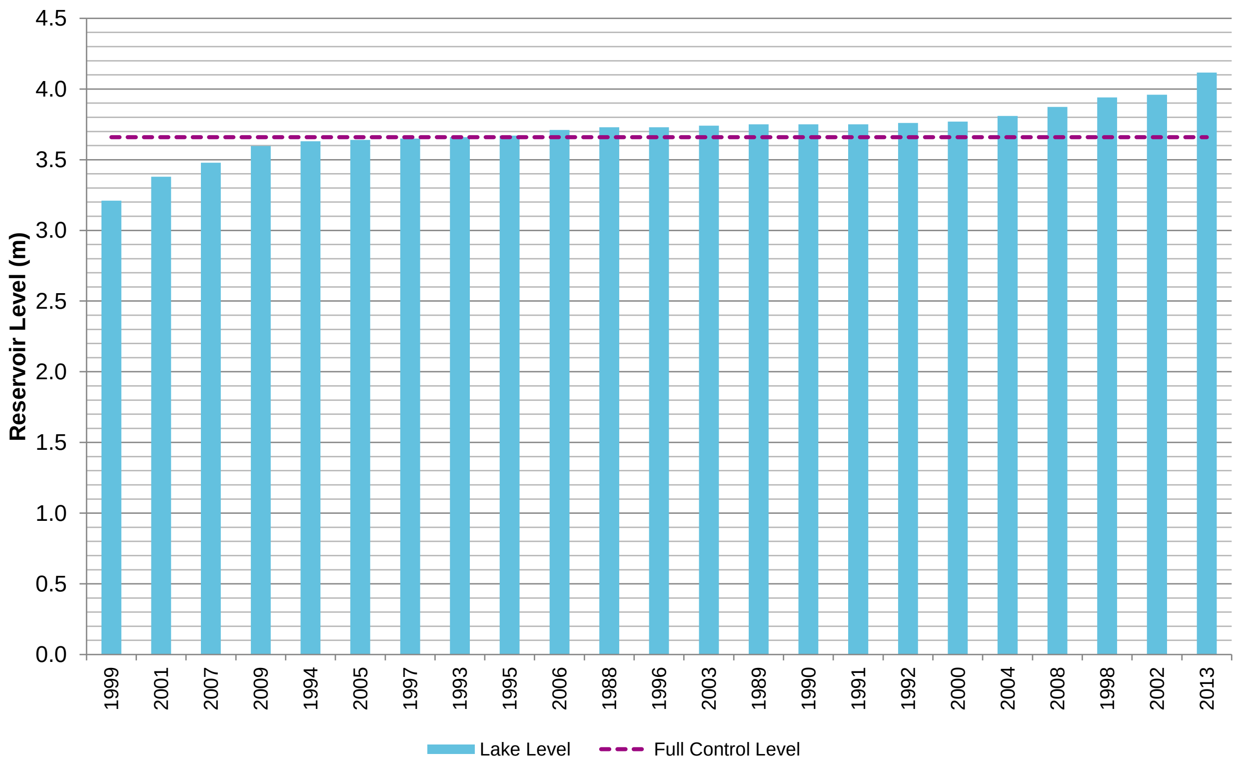

Figure 4.4 Sorted Peak Water Levels at Redstone Lake Dam (m)

4.4 Water Balance

A water balance model was developed to represent the 17 reservoir lakes in the Gull River system. The model included the following physical parameters:

- Stoplogs settings and water levels at all reservoir lake dams,
- Dam geometry (sluices dimensions, crest elevations, overflow spillways),
- Physical parameters of the sub-basins (drainage area, lake area, storage volume)
- Flows recorded at the hydrometric station Gull River at Norland,
- Hydrometeorological conditions in the watershed (outlined in section 3.2).

The model allowed assessing local inputs in all reservoir lakes, flows from upstream reservoirs, water input from snowmelt and evapotranspiration in the system.

Since estimation of discharge capacities at all reservoir lake dams was done using standard weir equations and because the discharge capacities are currently mainly used to manage storage volumes under normal conditions, these equations are not intended to estimate large flows with precision. Flows estimated using these equations under large flows conditions were not consistent throughout the system and time because potential downstream submergence effect, apron effects, upstream flow constriction under large flows, etc. have an impact on flow rates.

The water inputs in the reservoirs, evapotranspiration and observed flows at the hydrometric station were therefore used to assess the water balance on the scale of the drainage area for the hydrometric station. The water balance is done on the flood period from March 31st to May 15th and all parameters are expressed in mm. Assumption is made that water content in groundwater is the same on March 31st and May 15th.

The results obtained from the water balance model are summarized in Table 4.1.

Table 4.1 Summary of the Water Balance – Spring 2013

	Summary of the Water Balance	Gull River at Norland
		1296 km²
1	**Water Input (mm) (1a+1b-1c)**	**210**
1a	Rainfall from March 31st to May 15th	159
1b	Weighted Snowpack on March 31st	96
1c	Estimated evapotranspiration (Reference 3)	45
2	**Delta Water Stored in Reservoirs (mm)**	**63**
3	**Estimated Runoff (mm) (1-2)**	**147**
4	**Observed Runoff (mm) (from hydrometric station)**	**162**
5	**Water Balance Difference (mm) (4-3)**	+16
	Difference (%)	+11%

From Table 4.1, it appears that the water balance at Norland is respected; observed and estimated runoffs are in the same order of magnitude, considering the small amount of climate stations to provide more precision to the water input.

The water balance shows that the hydrometeorological conditions described in the pre-flood analysis (section 3) were sufficient to generate large runoff volumes and therefore large flood flows in the Gull River system.

5. Summary of Stakeholders Concerns

A review of communications addressed to various levels of government and to PCA revealed that residents of the Gull River watershed were concerned about the management of the April flood and wanted more information about the rationale behind decision making.

While many public comments were reviewed, the Coalition for the Equitable Water Flow (CEWF) captured many relevant perspectives of those on the lakes. The CEWF issued a report in August 2013. This report is reviewed hereafter.

5.1 Review of the Coalition for the Equitable Water Flow Report (CEWF) (interim Report (Reference 8)

5.1.1 Summary of the CEWF Report

In the Review of the Coalition for the Equitable Water Flow Report (CEWF), it is noted that:

It is noted that the TSW dams on the reservoir lakes were not designed primarily as a flood control system and the capacity of the TSW infrastructure to mitigate against flooding, particularly in spring when the reservoirs are filling, is far less than previously realized by most people. As a result it is concluded that Parks Canada's Trent Severn Waterway frontline water management staff are to be congratulated for their efforts to manage this unprecedented situation to the best of their ability with limited resources.

The CEWF has made a number of observations in this report relating to damages due to high water levels and high flows. The CEWF noted the lack of storage capacity in the system once the spring freshet begins and the limited discharge capacity of key control structures.

The CEWF also noted that the TSW management staff have insufficient information to understand the local consequences of some of its actions and that TSW need to have access to a modern water management model capable of simulating extreme events and balancing competing priorities: the model needs to be sophisticated enough to allow constraint-based data from individual lake associations to define preferred water levels during the navigation season and document flood impact levels.

The CEWF noted finally the need for better public education on water management issues:

- The events following the April 18-19 rains came as a complete surprise to many leading to undue criticism of the TSW and other public agencies.
- The decision to sandbag certain dams, causing upstream flooding in order to save property downstream was noted.

5.1.2 Review of the CEWF Report and Other Stakeholder Comments

Storage capacity:

Since the TSW dams on the reservoir lakes were not designed primarily as a flood management system, the reservoir lakes are not intended to mitigate against flooding. As a reminder, the primary objective of the reservoir lakes is to collect spring runoff and act as reservoirs, providing sufficient water for safe navigation in the TSW during dry years. The storage capacity, while not being the main objective, is however used to keep risks as low as reasonably practicable during the spring freshet.

Limited discharge capacity of the key control structures:

The discharge capacity of the Gull river system was exceeded during the April 2013 flood. In section 7, it is estimated that the return period associated with the April 2013 flood exceeds the 200 year flood. Therefore, it appears that the control structures in the lower Gull River do not have the discharge capacity to avoid flooding under a 200-year flood condition.

Also, the discharge capacity of a dam is largely reduced under high downstream water levels (downstream submergence). Under high water levels at all the downstream dams, the time required to drain the excess volume of water upstream and to reduce the water level requires that downstream water levels at all dams recede. Only then, the full discharge capacity of all downstream dams is recovered. Therefore, in the Gull River system, the discharge capacity of the dams is influenced by downstream constraints which must be alleviated before the full discharge capacity is available.

This explains why it took several weeks to return to the normal water level (flooding occurred from April 18th to May 13th).

Given these constraints, increasing the discharge capacity of a dam beyond the discharge capacity of all downstream dams will not reduce significantly the flooding under similar conditions than those that occurred in April 2013, unless the discharge capacity is increased to all downstream dams in the Gull River system.

It should also be noted that other types of constraints such as roads, culverts, bridges, etc. also reduce discharge capacity.

Insufficient information to understand the local consequences of the TSW actions and need for a water management tool:

Critical safety issues in Minden Hills oriented the decision making, the actions taken by the TSW management staff aimed at limiting water increases near Minden Hills by retaining water in the upstream reservoir lakes while no more actions could have been done downstream (all stoplogs were removed successfully on April 18th, the day after the heavy rainfall started in the evening of April 17th). These actions helped in reducing the flow at Minden Hills, therefore avoiding additional flooding.

The volume of water retained in the upstream reservoir lakes however created, as foreseen, high water levels in these reservoir lakes. PCA crews were monitoring closely the flooding to report any potential threat or dam safety issues. An equal flooding procedure was applied in the possible extent. Sand bags were used to protect dam structures when required.

No management tool to support decision making was used nor exists for the management of flooding in the reservoir lakes.

The management staff should eventually have a management tool to support decision making. This tool should be based on physical constraints along the Trent-Severn Waterway and in the reservoir lakes to minimize damages under flood conditions, as well as to optimize indicators of a good management in normal conditions (for example, integrated balance flood mitigation and the need to fill the reservoirs in order to feed the waterway in dry years).

Public education

Public education should be done as part of a good emergency preparedness and response plan. The MNR is responsible of developing public education on risks to public safety and on public preparedness for emergencies.

For example, flooding is not necessarily due to errors in operations. It is the result of adverse weather conditions which cannot be planned, as it was the case for the April 17th heavy rainfall. As outlined previously, flooding started the day after the heavy rainfall began.

Also, the decision to sandbag certain dams is not to reduce flood flow and save property downstream (and causing upstream flooding), but aims at protecting dam structures from erosion (that can occur with overtopping of earth embankment structures, therefore to prevent dam failure) and therefore ensure public safety.

Dam safety reviews are currently being carried out in the TSW system and emergency preparedness and response plans are underway. These dam safety reviews will help PCA to have more information about critical water levels that can trigger potential dam safety issues. The decision to sandbag earth embankment dams is part of required measures to protect the dam integrity under large flood conditions and prevent dam failure and therefore to ensure public safety downstream.

5.2 Public Comments

In general, residents within the Gull River watershed were worried about the flooding and were concerned about water levels in the reservoir lake where they live and wanted to be informed about stoplogs operation. They also wanted to know if different actions from the TSW would have led to less flooding in their lake and if the TSW or PCA were aware that the forecast would be calling for heavy rain that would affect the system to be prepared for what was to come.

The Gull River Review Report aims at addressing most of these questions.

6. PCA Responsibilities

In order to assess the responsibilities of PCA in the management of water levels and flows in the TSW, a review of the federal and provincial legislation and policies is performed. Also, other texts, while they do not have force of law, are indicative of the roles and responsibilities and are reviewed. This is done within the broader context of the roles of other jurisdictions and/or authorities in the areas of public communications, flood forecasting and emergency planning and response.

6.1 Documents Reviewed

This section presents the documents reviewed. For each document and when relevant, the responsibilities of PCA and other jurisdictions are identified. Also, other information that is relevant to the understanding of the responsibilities of PCA and other jurisdictions and/or authorities in the context of the management of water levels and flows in the TSW, public communications, flood forecasting and emergency planning and response are presented.

It is worthwhile to note, as of September 2013, only one dam safety review (DSR) was completed (Elliott Falls, completed in 2011) for the dams in the Gull River watershed and four other DSR's are currently underway. Other DSR are also completed or underway in the Burnt River watershed and at several locations along the Trent-Severn Waterway. Also, neither emergency response plans (ERP) nor emergency preparedness plans (EPP) have been finalized.

6.1.1 Lakes and Rivers Improvement Act (LRIA) and LRIA Administrative Guide

The Lakes and Rivers Improvement Act (R.S.O. 1990, c. L.3) (Reference 16) was written with the purpose of providing for:

- The management, protection, preservation and use of the waters of the lakes and rivers of Ontario and the land under them.
- The protection and equitable exercise of public rights in or over the waters of the lakes and rivers of Ontario;
- The protection of the interests of riparian owners.
- The management, perpetuation and use of the fish, wildlife, and other natural resources dependent on the lakes and rivers.
- The protection of the natural amenities of the lakes and rivers and their shores and banks.
- The protection of persons and of property by ensuring that dams are suitably located, constructed, operated and maintained and are of an appropriate nature with regard to the purposes of clauses (a) to (e).

The Lakes and Rivers Improvement Act Administrative Guide (Reference 22) was written to provide an overview of the LRIA, its application and the process for seeking Ministry of Natural Resources (MNR) approval to construction, alter, improve or repair water control infrastructure in Ontario (Reference 22).

Responsibilities:

- PCA has a mandate to protect representative areas of national natural and cultural significance.
- Owners of infrastructure are responsible for the safe management of their structures and for ensuring their structures remain in compliance with the LRIA, its associated Regulations and approvals issued there under.
- Applicants must make every effort to protect the interests of land owners who will be impacted by the proposed works. For instance, where temporary or permanent flooding of land will occur, or riparian rights will be negatively impacted, a formal land tenure document, consent or release from the affected owners must be obtained ("Applicants" refers to those who apply for construction or alteration of a dam).

Other information:

- A riparian owner is defined as an owner of land that fronts on to a water body, where the property boundary is the water's edge (not all property owners adjacent to water are riparian owners). Established in Common Law, riparian owners enjoy a bundle of rights associated with their property. These rights include:
  - Right of access to the water
  - Right of drainage
  - Rights relating to the quantity (flow and level) of water
  - Rights relating to the quality of water
  - Rights relating to the use of water and
  - Right of accretion.
- R.S.O. 1990, c. L.3, s. 6. Where land is overflowed or otherwise injured by the maintenance of a dam that was erected before the land was granted by the Crown and the grantee or any person under whom the grantee derived title obtained a reduction in the price of the land on account of, or was otherwise indemnified for, its being overflowed or otherwise injured by the dam, no subsequent owner of the land is entitled to maintain an action against the owner or occupier of the dam for damages for any overflowing or injury to the land due to the continuance of the dam.
- R.S.O. 1990, c. L.3, s. 23 (1). Regulation of water levels (1): Where a dam or other structure or work has been heretofore or is hereafter constructed on a lake or river and the Minister considers it necessary or expedient for the purposes of this Act, the Minister may order the owner of the dam or other structure or work to take such steps within the time specified in the order as may be necessary to maintain the level of the water of the lake or river or to raise or lower such level as the order provides.
- R.S.O. 1990, c. L.3, s. 23.1 (1). Plan for operation and maintenance (1): If the Minister considers it necessary or expedient for the purposes of this Act, the Minister may order the owner of a dam or other structure or work that has been constructed on a lake or river, or a person who has applied under section 14 or 16 for an approval to construct, alter, improve or repair a dam, other structure or work on a lake or river, to, in accordance with the regulations and with guidelines approved by the Minister,
  a) prepare or amend a plan for the operation and maintenance of the existing or proposed dam, other structure or work; or
  b) participate in the preparation or amendment of a plan referred to in clause (a). 2012, c. 8, Sched. 26, s. 2 (1).
- The LRIA does not bind the Crown. Dams and other works subject to the LRIA, but constructed by Provincial and/or Federal Ministries, Agencies and Departments, may not require LRIA approval.
- From Common Law, there are additional rights afforded to the public in general related to water bodies and waterways. These include the right of navigation, the right of access, and the right to fish.

Conclusions:

- LRIA's concern with water levels is that owners respect orders from the Minister, S.23 (1), and respect the plan for operation and maintenance, S23.1 (3).
- LRIA Admin Guide is concerned with applicants for construction, alteration, repair or decommissioning. It makes no mention of operational requirements others than as mentioned in the LRIA.
- The LRIA does not bind the Crown. Dams and other works owned and operated by PCA may not be subject to the LRIA.

6.1.2 Emergency Management and Civil Protection Act (EMCPA)

The primary reason for an emergency management program is to improve public safety through a coordinated and pre-identified process for responding to critical situations. A realistic emergency management program will assist in protecting lives, infrastructure, and property, protect the environment, promote economic stability, and help ensure the continuance of critical assets and government (Reference 17).

<u>Responsibilities:</u>

- All municipalities and provincial ministries are required to have an emergency management program. Requirements for these programs are set out in the EMCPA.
- Individuals and families should be prepared to take care of themselves for at least 72 hours in the event of an emergency situation.
- Municipalities are required to:
    - Develop, implement and maintain an emergency management program in conformity with regulations developed by Emergency Management Ontario (EMO). This program consists of:
        - An emergency plan.
        - Training programs and exercises for employees of the municipality.
        - Public education on risks to public safety and on public preparedness for emergencies.
        - Any other element required by standards.
    - Identify and assess the various hazards and risks to public safety that could give rise to emergencies and identify the facilities and other elements of the infrastructure that are at risk of being affected by emergencies.
    - Review and, if necessary, revise its emergency plan every year.
- EMO is responsible for:
    - Monitoring, coordinating and assisting in the development and implementation of emergency management programs throughout Ontario.
    - Supporting municipalities and ministries in implementing their programs by providing them with advice, assistance, guidelines, training, and other tools.
- Provincial Emergency Operations Centre (PEOC) is responsible for:
    - Monitoring evolving situations inside and outside of Ontario to ensure key decision makers and provincial resources are able to respond as quickly as possible if required.
    - Coordinating Ontario Government response to major emergencies. This includes providing municipalities and First Nations with a single point of contact for provincial assistance in times of crisis.
- The MNR is responsible for:
    - Declaring an emergency situation when there is an emergency that requires immediate action to prevent, reduce or mitigate a danger of major proportions that could result in serious harm to persons or substantial damage to property and, if required, implementing any emergency plans (regulating or prohibiting travel movement, evacuating, establishing facilities for care, welfare, safety and shelter, etc.).
    - Developing an emergency management program for floods.
    - Flood monitoring, notably by collecting and analyzing data and using forecast models (Surface Water Monitoring Centre (SWMC), Reference 23). Local information about flooding comes from conservation authorities and the Ministry of Natural Resources (MNR) and MNR issues provincial messages to alert local agencies and other parts of government. Current flood information is available online (Reference 20).
    - Developing training programs and exercises for public servants and other persons with respect to the provision of necessary services and the procedures to be followed in emergency response and recovery activities.
    - Developing public education on risks to public safety and on public preparedness for emergencies.

- Developing any other element required by the standards for emergency management programs set under section 14. 2002, c. 14, s. 7; 2006, c. 35, Sched. C, s. 32 (3).

Other information:

- An emergency is defined as a situation or an impending situation that constitutes a danger of major proportions that could result in serious harm to persons or substantial damages to property and that is caused by the forces of nature, [...].

Conclusion:

- Information is mostly about the power to declare state of emergency and governments' responsibilities.
- The MNR is responsible for declaring an emergency situation when there is an emergency that requires immediate action to prevent, reduce or mitigate a danger of major proportions that could result in serious harm to persons or substantial damage to property and, if required, implementing any emergency plans (regulating or prohibiting travel movement, evacuating, establishing facilities for care, welfare, safety and shelter, etc.).
- The MNR is responsible for developing an emergency management program for floods.
- This emergency management program must notably formulate procedures under and the manner in which public servants and other persons will respond to the emergency.

6.1.3 Municipal Act

Municipalities are created by the Province of Ontario to be responsible and accountable governments with respect to matters within their jurisdiction (Reference 18). They are given powers and duties under this Act and many other Acts for the purpose of providing good government with respect to those matters.

Responsibilities:

- Municipalities in Ontario can exercise their powers in the provision of "good government," which is widely interpreted to include asset management as well as the social, economic and environmental well-being of the community.
- Municipalities may establish, maintain and operate a centralized communication system for emergency response purposes.

Conclusion:

- No clear responsibility related to emergency management or communication under state of emergency.

6.1.4 Conservation Authorities Act

The Conservation Authorities Act (Reference 14) was created in 1946 in response to erosion and drought concerns, recognizing that these and other natural resource initiatives are best managed on a watershed basis (Reference 9).

Responsibilities:

- Conservation Authorities (CAs) are authorized under Section 28 of the Conservation Authorities Act to regulate certain activities within their areas of jurisdiction.
- Permission of the local CA is required for straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream or watercourse, or for changing or interfering in any way with a wetland.
- Permission of the local CA is also required for development activities if in the opinion of the CA, the control of flooding, erosion, dynamic beaches, pollution or the conservation of land may be affected.

Conclusion:

- No clear responsibility related to emergency management or communication under state of emergency.

6.1.5 Parks Canada Agency Act – Historic Canals Regulations (1993)

The objective of this act is to clearly state the regulations respecting the management, maintenance, proper use and protection of the Historic Canals administered by PCA.

Responsibilities:

- The superintendent may, on receipt of an application, issue a permit authorizing the applicant to remove, alter or destroy a cultural resource, natural resource, structure, equipment or object, where the removal, alteration or destruction is necessary for
  a) scientific purposes.
  b) the management of water levels or flows.

Conclusion:

- The TSW is a historic canal as defined in Schedule I of the Historic Canals Regulations. However, this Act is more concerned with the activities that take place within or around the canal rather than the water management at its tributaries.
- It is understood that the applicant authorized by the superintendent (i.e. PCA's water management engineer should fall within that category) can go as far as remove, alter or destroy objects to manage water levels. This may not apply to flooding of upstream third-party property but confirms that certain liberties are given to the applicant (Section 11, subsection 3).

6.1.6 Parks Canada Guiding Principles and Operational Policies

This web based resource details the guiding principles and policies of PCA. This is neither a text of law nor a series of regulations. It is intended to inform the public on the activities and responsibilities or PCA (Reference 25).

Responsibilities

- 1. - The first priority for Parks Canada is always to ensure long-term ecological and commemorative integrity of heritage areas.
- 1.1.2 - The following considerations will guide the provision of navigation: availability of adequate water levels, maintenance of public safety, preservation of heritage character, physical condition of the works, time of year, demand, and available human and financial resources.
- 1.1.3 - Where navigation is maintained, Parks Canada objectives will be to maintain adequate canal water depths, structures and navigation aids in order to provide for navigation.
- 1.1.4 - Water levels and flows required for navigation on the canals will be monitored and managed to minimize flooding and adverse resource impacts.

Other information

- 2.2.4 - Modification of a cultural resource to meet significant operational or safety purposes will be considered only after thorough review, taking into account the maintenance of this stewardship responsibility.
- 2.2.5 - Parks Canada will encourage others to protect cultural resources on lands not administered by Parks Canada that are adjacent to the canals.
- 2.3.2 - Canals will be operated and maintained in ways that seek an appropriate balance between use and environmental impacts, and comply with the Canadian Water Quality Guidelines.

Conclusions

- The first priority for Parks Canada is always to ensure long-term ecological and commemorative integrity of heritage areas.
- PCA is responsible for minimizing flooding. This does not specify the details (how, prioritization, to which extents, etc.).

6.1.7 Shoreline Policy and Regulation: Review and Recommendations

The purpose of this report is to review and analyze the current shoreline policies and regulatory tools of the many planning agencies along the TSW.

Responsibilities:

- PCA has jurisdiction over the federally owned and managed ‘bed’ of the TSW, including lakes and rivers that are part of the navigable waterway, excluding reservoir lakes (Shoreline Policy, 2011).
    - PCA has jurisdiction for all land below the UNCL (upper controlled navigation limit) of all lakes except Simcoe and Couchiching.
    - PCA has jurisdiction above the UNCL (upper controlled navigation limit) for land it owns.
- Transport Canada is responsible for navigation safety over the TSW (Department of Transport Act).
- PCA is the regulating authority for all in-water and shoreline works. CAs retain authority for permitting and regulation above the UCNL on waters of the TSW (Shoreline Policy 2011).

Conclusion:

- While PCA does not have jurisdiction over the bed of the reservoir lakes, it has jurisdiction over the land it owns, where the dams are located.

6.1.8 TSW Water Management Program

The purpose of this document is to provide background on the way Parks Canada manages water flows and levels on the Trent-Severn Waterway (TSW) and some of the challenges it faces in trying to meet the needs of various stakeholders while striving to maintain safe conditions across the system (Reference 11). Figure 6.1 shows the chain of command for the water management in the TSW.

Responsibilities:

- The Director of the Ontario Waterways of the Trent-Severn Waterway is ultimately responsible for the water management program. However, the day-to-day operation is led by the Manager of Canal Operations and coordinated by the Water Management Engineer from TSW headquarters in Peterborough.
- The Water Management Engineer communicates almost daily with Sector Managers working out of six different Waterway offices located in Trenton, Campbellford, Kawartha, Kirkfield, Severn and Haliburton and other water control agencies such as the Ministry of Natural Resources, Conservation Authorities, Ontario Power Generation, etc.
- Decisions with respect to water levels and flows are made by the Water Management Engineer using a variety of data and in consultation with the Sector Managers.
- The Sector Managers have the experience and authority to suggest modifications to the water management directions.
- The Water Management Advisory Council provides expert and stakeholder advice on how to best achieve its water management goals throughout the Trent-Severn watershed. The council is led by an independent chair and consists of representatives from Environment Canada and Conservation Authorities; citizens from the Haliburton, Severn, Kawartha and Trent River watershed areas; representatives from industry including the

Ontario Waterpower Association & the Ontario Boating Forum; in addition to representation from the TSW (Reference 26).

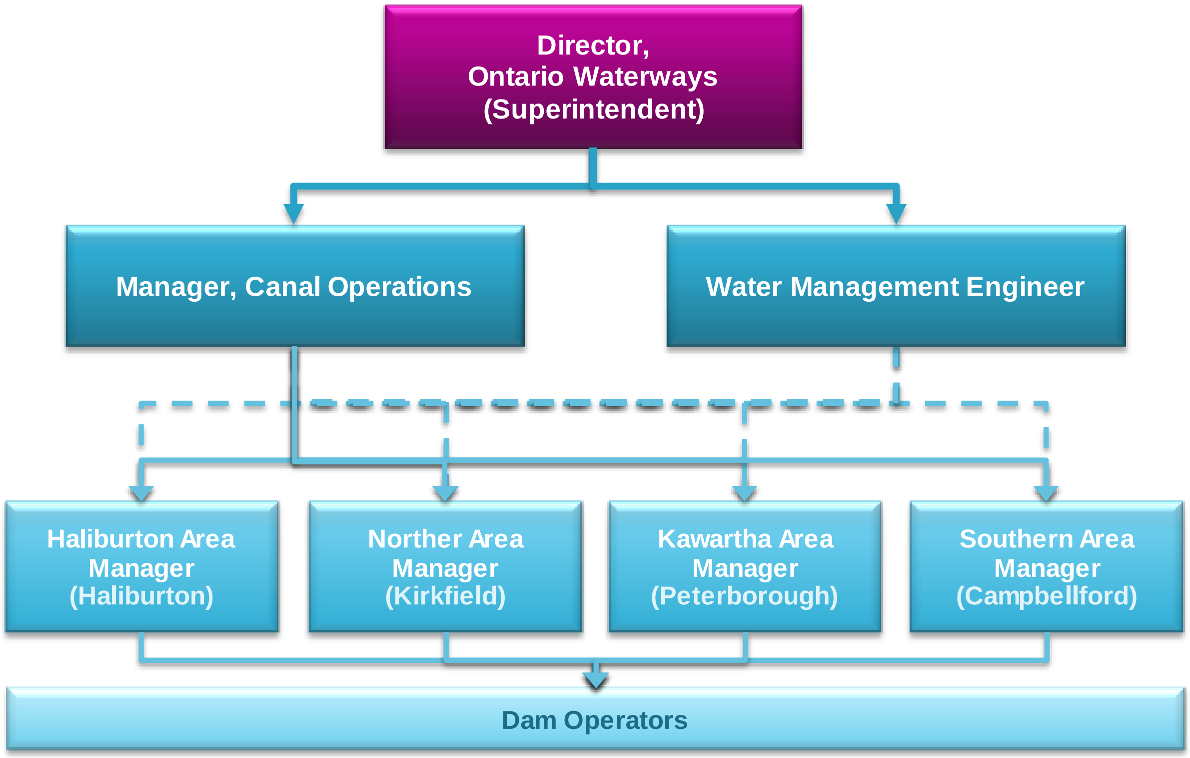

Figure 6.1 Chain of Command for Water Management in the TSW

<u>Water Level Management</u>

- The water management goal is to provide for safe navigation while trying to accommodate the other water users.
- Regular management for the reservoir lakes is done on an equal percentage basis according to the storage range established for that lake.
  - Drawdown on reservoir lakes is done by the same % for all, no matter their range (i.e. considering a drawdown of 50%, a lake with a range of 3 m would be lowered by 1.5 m while one with a 2 m range would be lowered by 1 m)
  - Water levels are lowered in the fall, notably to prepare for spring floods.
- Main spring balancing act:
  - reduce or eliminate flooding, and
  - store as much water as possible for summer use.
- As spring approaches on the Reservoir Lakes, stoplogs are placed in the dams as the lakes are rising with the runoff. Typically there is more inflow than needed to fill them and some surplus is allowed to run off. As the lakes are nearing their full levels, snow survey data and all available sources of information are checked in an effort to anticipate whether or not a larger volume of water is still coming. If only a little water is expected, then the lakes are topped up for the summer: if a lot of water is expected, then the lakes are allowed to discharge more freely. Heavy inflows can easily result in pulling stoplogs out again at dams on these lakes to expel surplus water.

Flood Management

- Once the freshet starts, some reservoir lakes and many Kawartha lakes fill or overfill even with all the stoplogs out of their dams.
- Downstream conditions are also critical considerations. It is mentioned: "*For example, during extreme flood conditions (e.g., flows of 400-450 cubic metres per second (m³/s) at Peterborough), a decision may be required to flood the Kawartha lakes above normal in order to prevent much more serious flooding downstream of Peterborough.*" Though this is a consideration for the Kawartha Lakes, there is reason to believe it would apply to the reservoir lakes. For the reservoir lakes, it is mentioned: "*High spring water levels can flood low-lying areas*."
- During flood events, it can occur that not all dams are fully open even though the lake it holds back is still rising and flooding. This can occur for one or more of the following reasons:
  - The dam has more capacity to pass water than dams upstream or downstream that already have all logs out. This is the case with the dam at Buckhorn.
  - The lake downstream is already experiencing high water, so releasing more water will only worsen conditions, e.g., Pigeon-Buckhorn Lake below Sturgeon Lake.
  - A natural obstruction such as a rock ridge in the lake or river bed upstream of the dam is controlling the flow to such an extent that releasing more water only lowers the water immediately above the dam with little or no effect on the amount of flow coming over the rock ridge.

Other information

- A.7 - Water levels and flows within the Trent and Severn watersheds are effectively managed in a manner that recognizes the diverse and sometimes conflicting needs of users while minimizing adverse environmental effects (Reference 11).
- A.8 - The potential effects of climatic change and other major emerging issues are monitored in consultation with others to ensure sound up-to-date water and ecosystem management (Reference 11).

Conclusions

- Responsibility for water level management lies solely with PCA.
- Reservoir lakes are usually managed according to the equal percentage drawdown method.
- As the facilities are managed for dam and public safety, the intent is to minimize overall incremental consequences. As such, it is suggested that flooding a given area with the intent of preventing greater incremental consequences elsewhere is an acceptable practice.

6.1.9 The County of Hallliburton Emergency Response Plan

The County of Haliburton Emergency Response Plan is intended to provide for effective coordination of human and material resources to assist their municipalities, communities and the County as a whole in mitigating the effects of emergencies (Reference 10).

Responsibilities:

- Municipalities are responsible for the management of emergencies within their own boundaries.
- The County of Haliburton's role is to assist local municipalities by providing resources and to act in a coordinating function during emergencies.

Conclusion:

- No reference to flood management and water levels and PCA responsibilities.

6.2 Summary of PCA Responsibilities

In light of the literature review performed, the following is a listing of the key elements highlighting the responsibilities of PCA as pertaining to the management of water levels and flows in the TSW, public communications, flood forecasting and emergency planning and response:

- The first priority for Parks Canada is always to ensure long-term ecological and commemorative integrity of heritage areas.
- PCA is responsible for the management of water levels within the TSW.
- Water levels are managed primarily for navigation purposes, but also for other objectives such public safety, flood mitigation, community water supplies, water quality, the protection of natural resources, green power generation, and providing water for recreational activities.
- Owners of infrastructure are responsible for the safe management of their structures and for ensuring their structures remain in compliance with the LRIA, its associated Regulations and approvals issued there under.
- As PCA is responsible for maintaining the structural integrity of its structures and manages water levels, decisions to flood certain lands in order ensure dam safety (stability) of downstream dams and public safety around downstream dams falls within PCA’s jurisdiction.
- Emergency management requires cooperation and communication between dam operators and the civil authorities. However, communication channels between dam owner/operators and levels of government are not clearly identified by law.

The MNR, not PCA, is responsible for the following.

- The MNR is responsible for flood monitoring, notably by collecting and analyzing data and using forecast models, and to issue provincial messages to alert local agencies and other parts of government.
- The MNR is responsible for declaring an emergency situation when there is an emergency that requires immediate action to prevent, reduce or mitigate a danger of major proportions that could result in serious harm to persons or substantial damage to property and, if required, implementing any emergency plans (regulating or prohibiting travel movement, evacuating, establishing facilities for care, welfare, safety and shelter, etc.).
- The MNR is responsible of developing public education on risks to public safety and on public preparedness for emergencies.

7. Comparative Analysis with Adjacent Watersheds

In order to scale the flood event on the Gull River, a comparison of the peak flows on the Gull River with flows in adjacent/nearby watercourses impacted by the same weather event and under similar conditions is carried out.

Adjacent watersheds are the following:

- Burnt River near Burnt River
- Black River near Washago
- East River near Huntsville
- York River near Bancroft
- South Branch Muskoka River at Baysville

To place the flow conditions of the Gull River and adjacent watersheds in a historical context, a statistical analysis is performed on the flood flows at these hydrometric stations.

7.1 Flow Data

The flow data are obtained from the Water Survey of Canada of Environment Canada (Reference 13) for all adjacent watersheds and for the Gull River at Norland.

The characteristics of the hydrometric stations are presented in Table 7.1 and location of the stations is shown on Figure 7.1. Flow records are daily values. The Gull River station is highlighted in yellow.

Table 7.1 Hydrometric Station Characteristics

Station ID		Station Name	Location		Drainage Area (km²)	Period of Records
Project	WSC [1]		Latitude	Longitude		
Gull River						
H4	02HF002	Gull River at Norland	44°43'54"N	78°49'05"W	1,296	1962 - 2013
Burnt River						
H5	02HF003	Burnt River near Burnt River	44°42'35"N	78°40'39"W	1,265	1962 - 2013
Black River						
	02EC002	Black River near Washago	44°42'49"N	79°16'53"W	1,510	1916 - 2013
East River						
	02EB013	East River near Huntsville	45°23'33"N	79°09'35"W	610	1973 - 2013
York River						
	02KD002	York River near Bancroft	45°03'07"N	77°50'45"W	844	1915 - 2013
South Branch Muskoka River						
	02EB008	South Branch Muskoka River at Baysville	45°08'52"N	79°06'48"W	1,403	1941 - 2013

[1] Station identification from WSC - Water Survey of Canada, data available online (http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm).

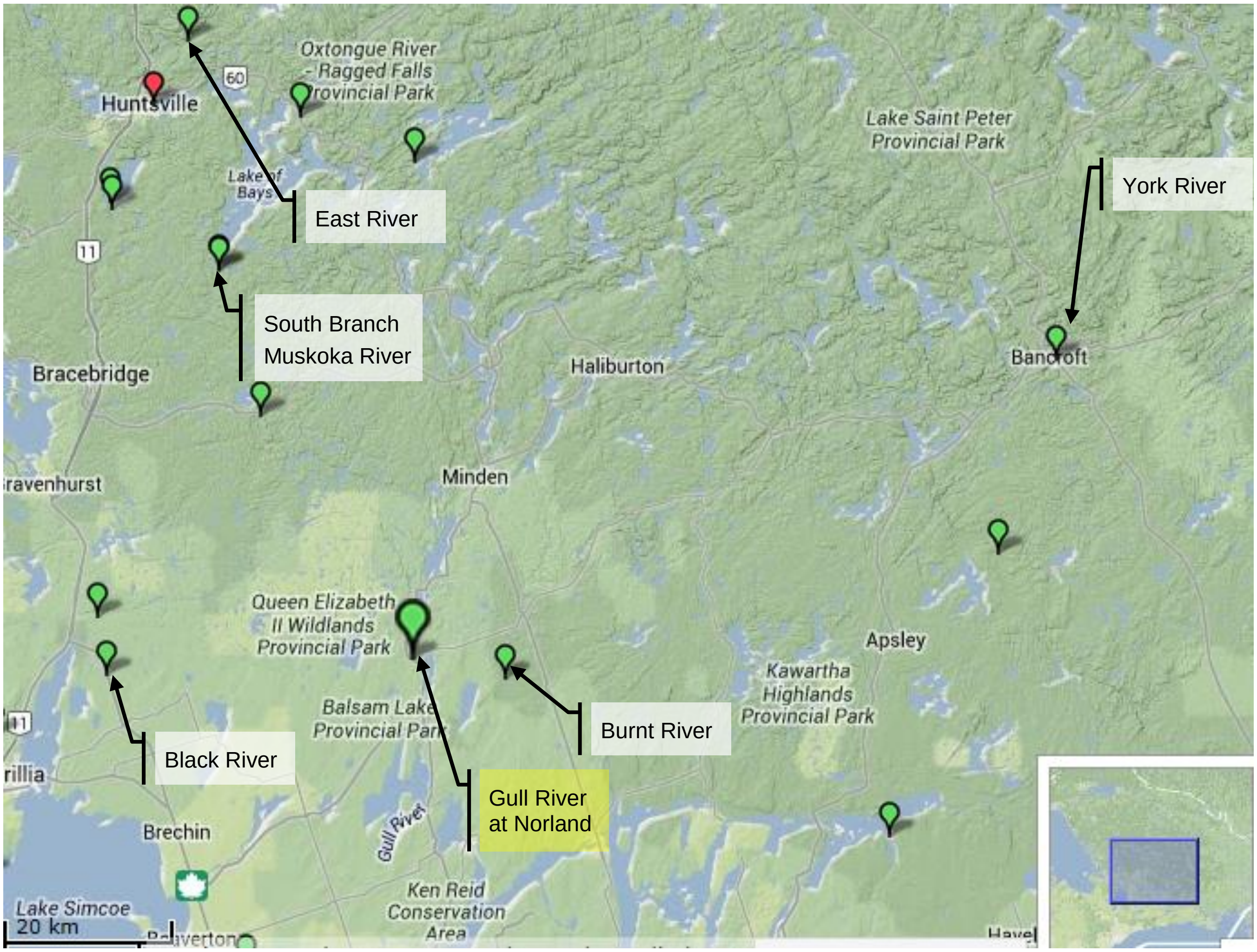

Figure 7.1 Location of Hydrometric Stations

Figure 7.2 shows the Flood Hydrographs in the Adjacent Watersheds and in the Gull River.

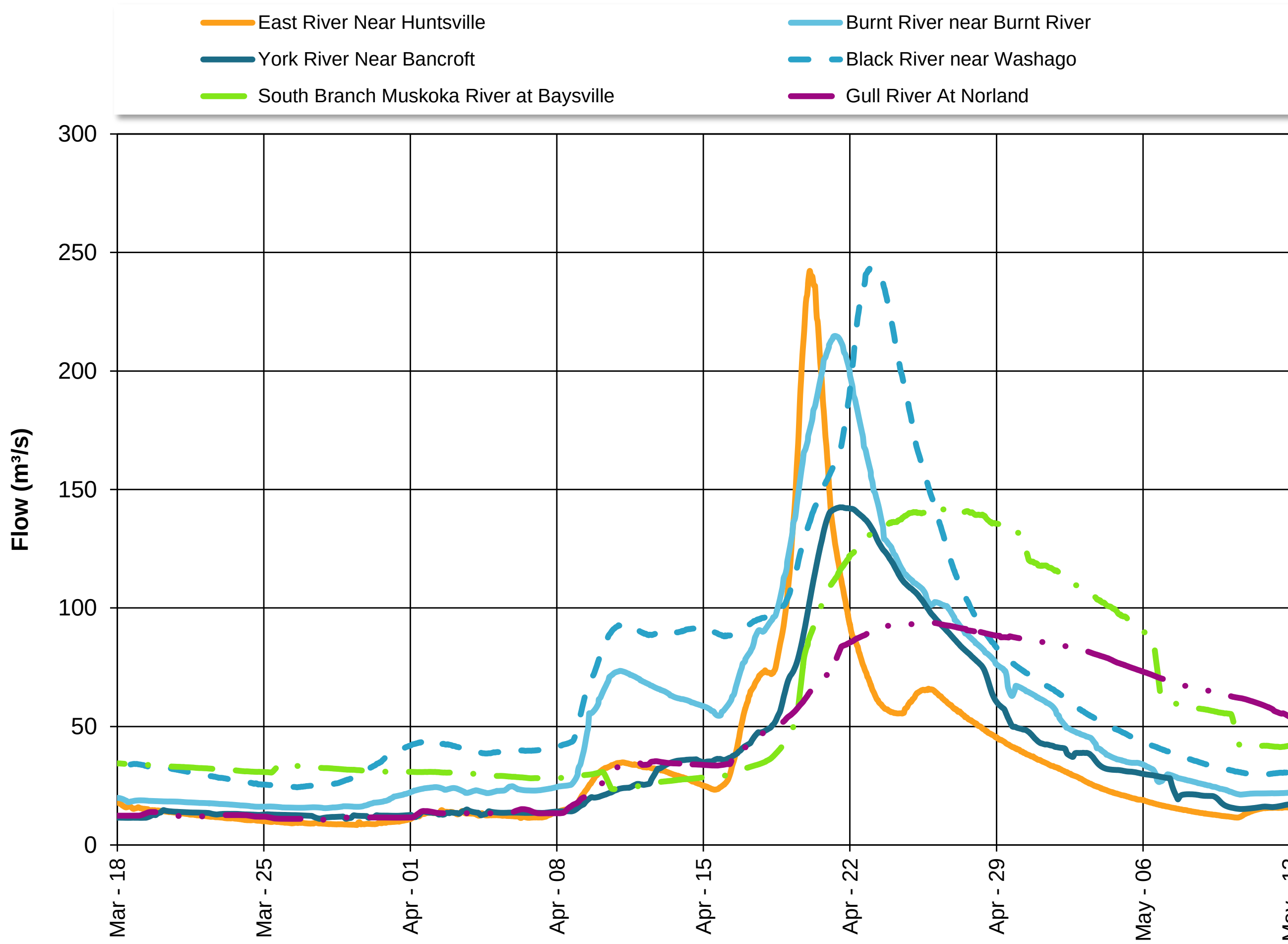

Figure 7.2 Flood Hydrographs in the Adjacent Watersheds and in the Gull River

7.2 Statistical Analysis on Spring Flood Flows

This section presents the results of the statistical analysis carried out on the daily peak flows for the adjacent watersheds and for the Gull River, for a common period from 1981 to 2010, for 30 years of spring floods, except for the York River, for which flows are missing from 1994 to 2006.

A short period of 30 years has been selected for the statistical analysis to represent the same recent period for all stations to better represent floods for the current use of lands and for the current management of the systems.

The frequency analysis is undertaken with HYFRAN (Hydrological Frequency Analysis), statistic software developed by INRS-ETE (Institut National de la Recherche Scientifique - Eau Terre et Environnement) of Quebec.

The daily peak discharges for various return periods are presented in Table 7.2 for all studied rivers. Results for each hydrometric station are presented in the following sub-sections.

Table 7.2 Daily Peak Flood Discharges at Hydrometric Stations for Various Return Periods

Sub-Basin Node Description	Peak Flood Flows (m³/s) 2 yrs	5 yrs	10 yrs	20 yrs	50 yrs	100 yrs
Gull River at Norland	49.1	61.6	68.2	73.6	79.7	83.8
Burnt River near Burnt River	107	142	162	179	198	211
Black River near Washago	126	157	174	188	204	214
East River near Huntsville	251	330	372	406	444	470
York River near Bancroft	73.6	91.8	101	109	118	124
South Branch Muskoka River at Baysville	74.6	94.2	104	113	122	129

7.2.1 Gull River at Norland

Based on the information criteria and using the Decision Support System of HYFRAN, the Normal distribution is selected to fit the observations for the Gull River at Norland.

Figure 7.3 shows the results of the statistical analysis.

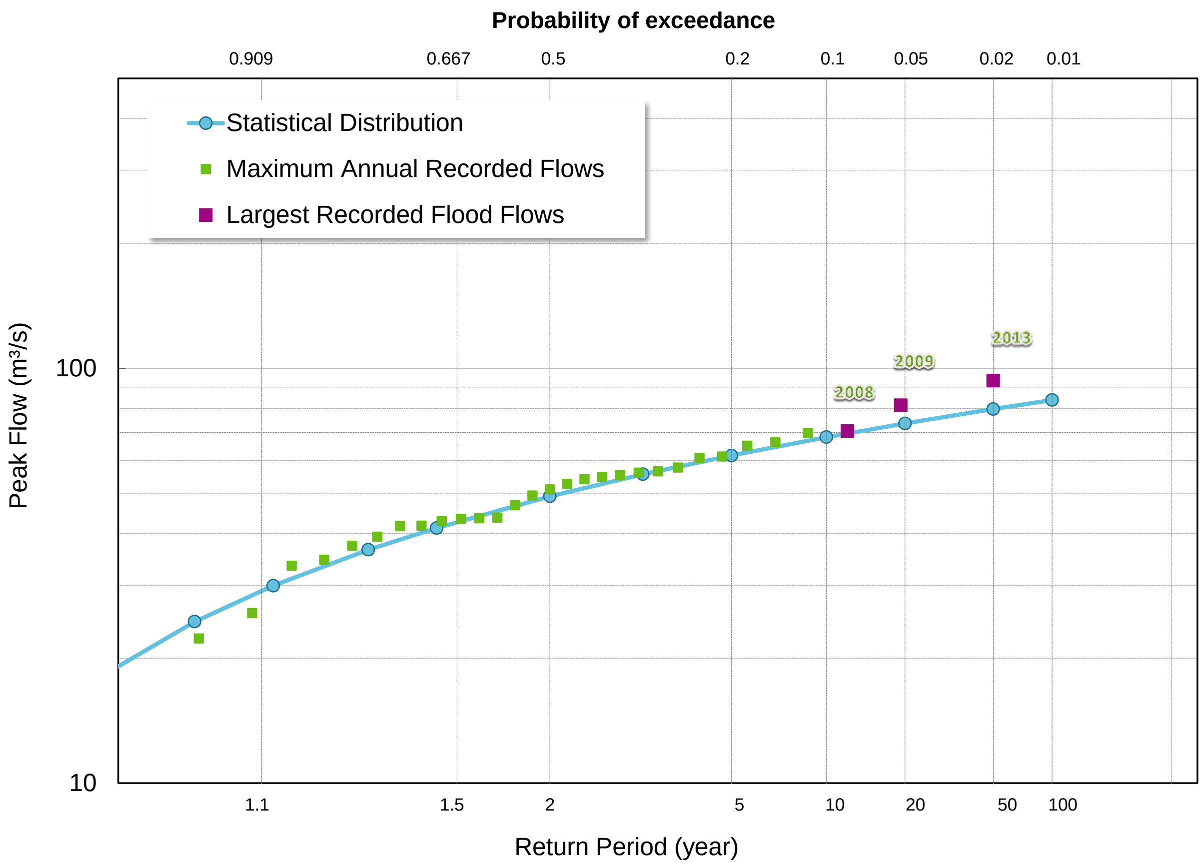

Figure 7.3 Statistical Analysis Results – Daily Peak Flood - Gull River at Norland

Historical flood flows are presented in Table 7.3 with the associated return period.

Table 7.3 Historical Flood Flows and Associated Return Periods – Gull River at Norland

Description	Maximum Recorded Peak Flood		
	Year	Flow	Associated Return Period [1]
	Data	(m^3/s)	(years)
Gull River at Norland	2008	70.5	15
Gull River at Norland	2009	81.4	70
Gull River at Norland	2013	93.4	> 200

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.3 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period that should be associated with the 2013 spring flood of 93.4 m^3/s on the Gull River at Norland, considering that the 100 year flood is estimated to 83.8 m^3/s in Table 7.2, should have a return period larger than 100 years. However, the theoretical limit of validity of a statistical analysis corresponds to approximately twice the sample size. Therefore, the 100-year peak flood flows estimated based on the statistical analysis fall outside the validity range for all stations and care should be brought when associating a larger return period for a flood.

The return period for the 2013 flood on the Gull River at Norland, based on the distribution curve, is larger than the 200 year flood.

7.2.2 Burnt River near Burnt River

Based on the information criteria and using the Decision Support System of HYFRAN, the Log Pearson III distribution is selected to fit the observations for the Burnt River near Burnt River.

Figure 7.4 shows the results of the statistical analysis.

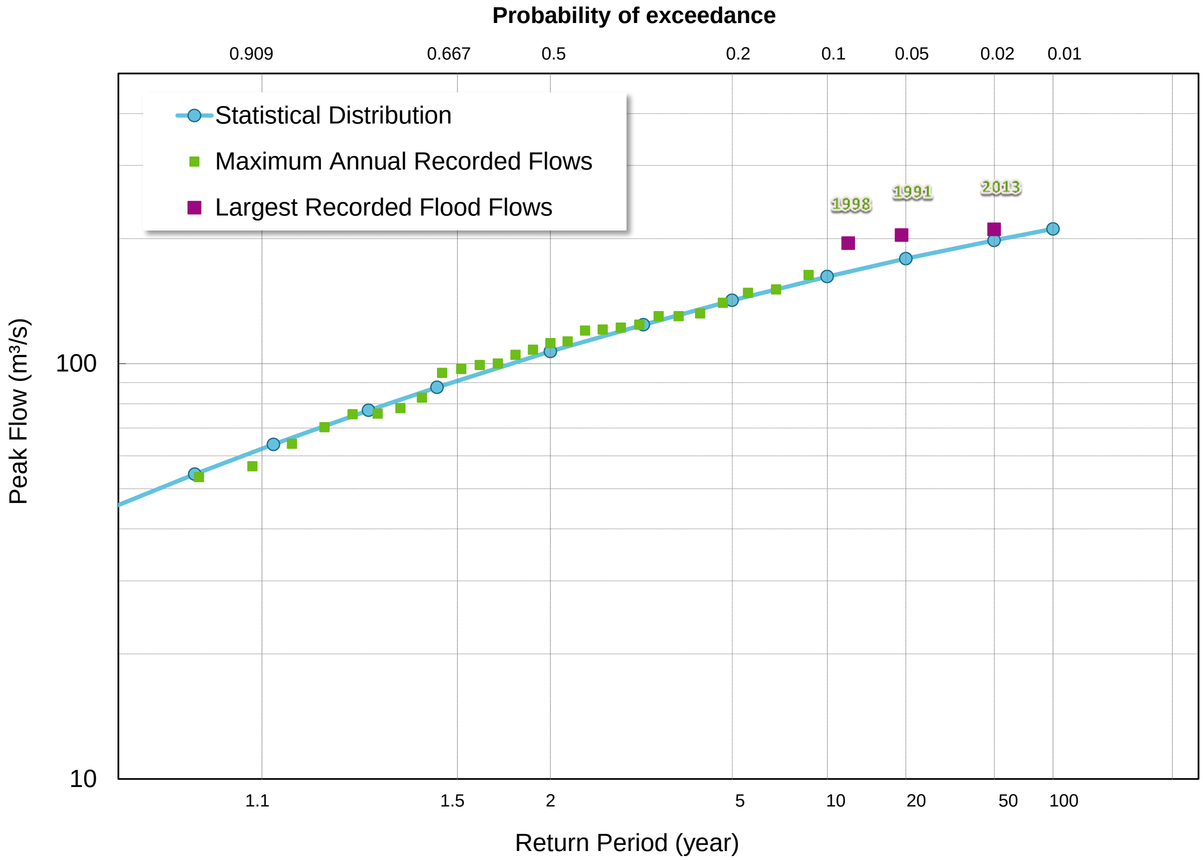

Figure 7.4 Statistical Analysis Results – Daily Peak Flood - Burnt River near Burnt River

Historical flood flows are presented in Table 7.4 with the associated return period.

Table 7.4 Historical Flood Flows and Associated Return Periods – Burnt River near Burnt River

Description	Maximum Recorded Peak Flood		
	Year Data	Flow (m^3/s)	Associated Return Period [(1)] (years)
Burnt River near Burnt River	1991	204	70
Burnt River near Burnt River	1998	195	43
Burnt River near Burnt River	2013	211	95

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.4 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period for the 2013 flood on the Burnt River near Burnt River, based on the distribution curve, would be of 95 years.

7.2.3 Black River near Washago

Based on the information criteria and using the Decision Support System of HYFRAN, the Normal distribution is selected to fit the observations for the Black River near Washago.

Figure 7.5 shows the results of the statistical analysis.

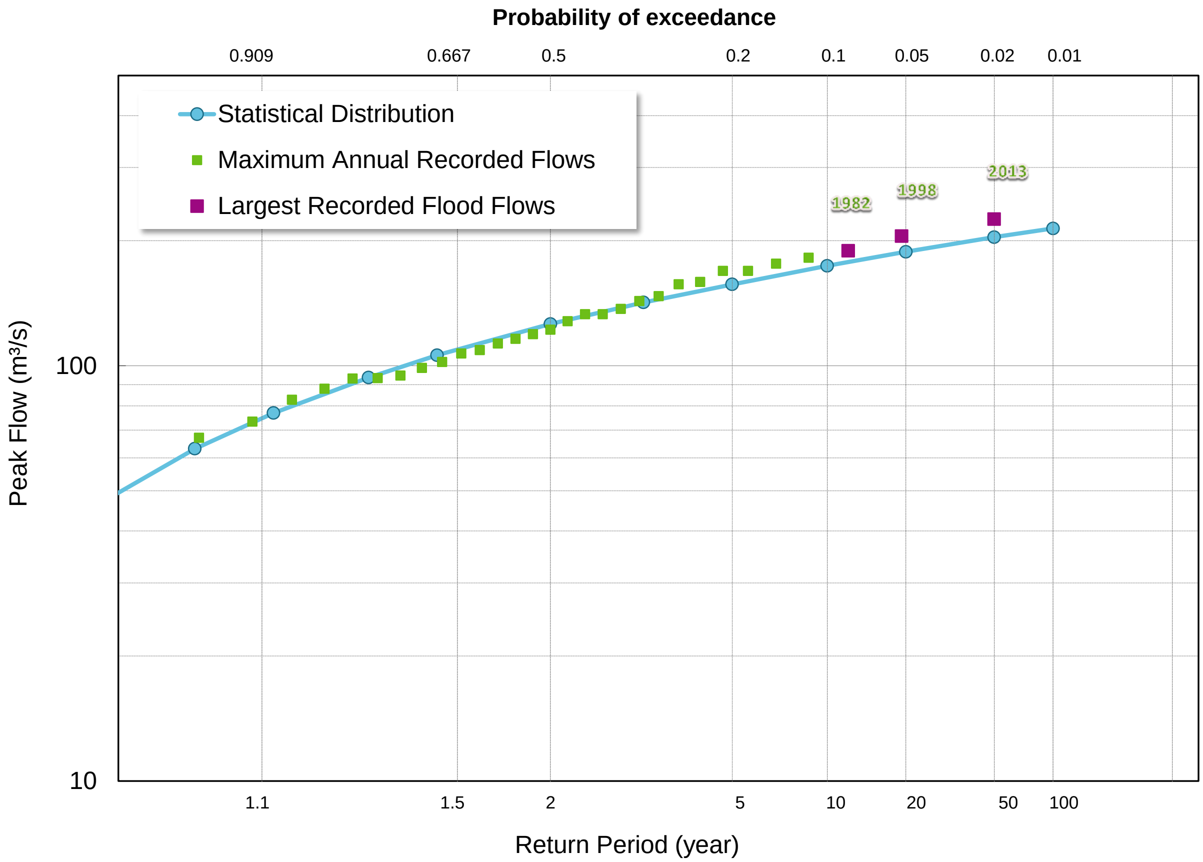

Figure 7.5 Statistical Analysis Results – Daily Peak Flood - Black River near Washago

Historical flood flows are presented in Table 7.5 with the associated return period.

Table 7.5 Historical Flood Flows and Associated Return Periods – Black River near Washago

Description	Maximum Recorded Peak Flood		
	Year Data	Flow (m^3/s)	Associated Return Period [(1)] (years)
Black River Near Washago	1982	189	21
Black River Near Washago	1998	205	55
Black River Near Washago	2013	225	> 200

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.5 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period for the 2013 flood on the Black River near Washago, based on the distribution curve, would be larger than the 200 year flood. This return period however falls outside the validity range of the analysis.

7.2.4 East River near Huntsville

Based on the information criteria and using the Decision Support System of HYFRAN, the Normal distribution is selected to fit the observations for the East River near Huntsville.

Figure 7.6 shows the results of the statistical analysis.

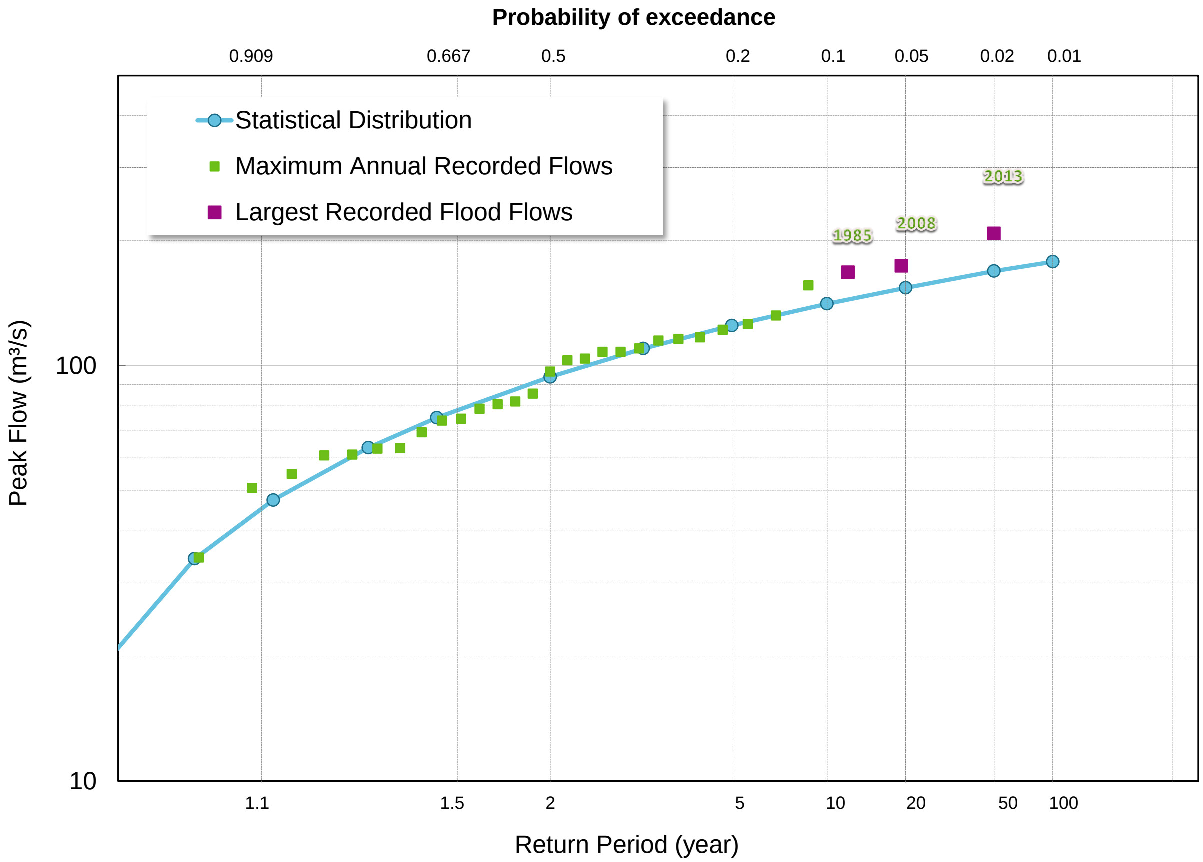

Figure 7.6 Statistical Analysis Results – Daily Peak Flood - East River near Huntsville

Historical flood flows are presented in Table 7.6 with the associated return period.

Table 7.6 Historical Flood Flows and Associated Return Periods – East River near Huntsville

Description	Maximum Recorded Peak Flood		
	Year Data	Flow (m^3/s)	Associated Return Period [(1)] (years)
East River near Huntsville	1985	168	47
East River near Huntsville	2008	174	75
East River near Huntsville	2013	208	> 500

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.6 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period for the 2013 flood on the East River near Huntsville, based on the distribution curve, would be larger than the 500 year flood. This return period however falls outside the validity range of the analysis.

7.2.5 York River near Bancroft

Based on the information criteria and using the Decision Support System of HYFRAN, the Normal distribution is selected to fit the observations for the York River near Bancroft.

Figure 7.7 shows the results of the statistical analysis.

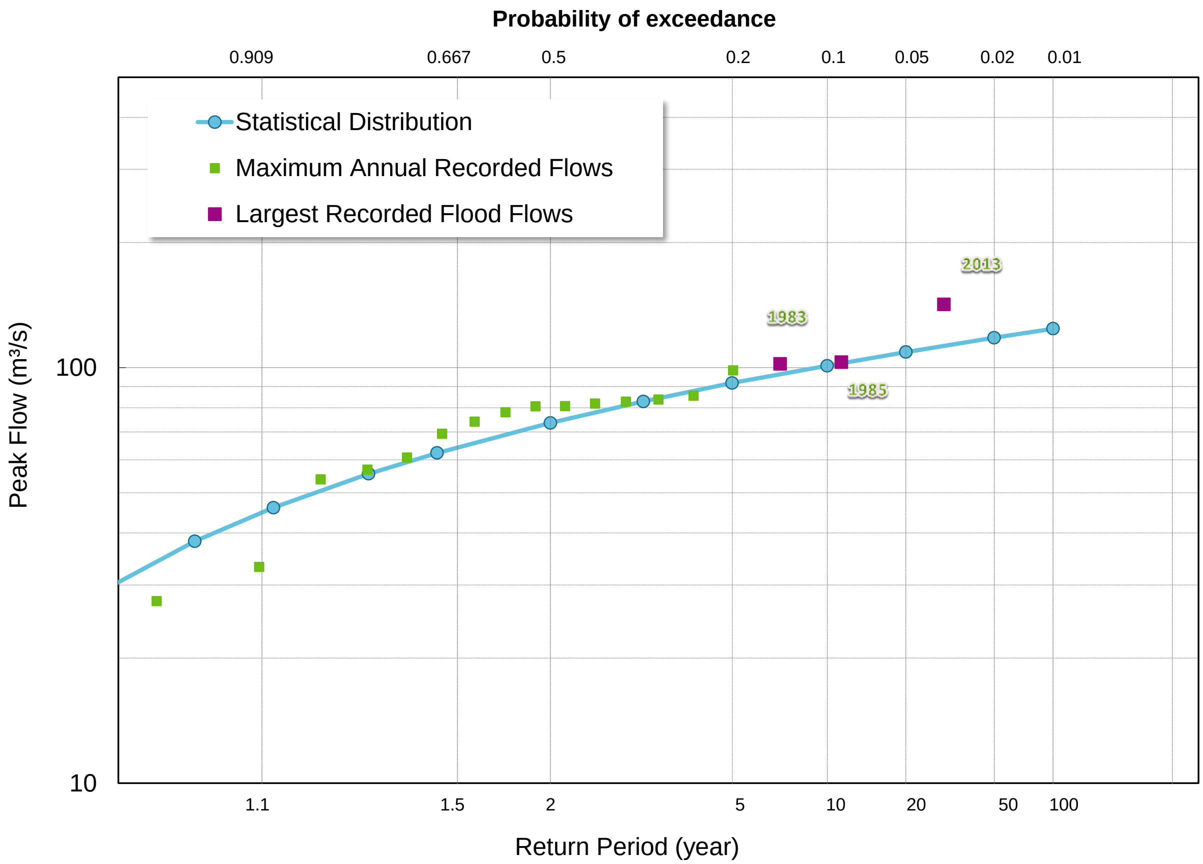

Figure 7.7 Statistical Analysis Results – Daily Peak Flood - York River near Bancroft

Historical flood flows are presented in Table 7.7 with the associated return period.

Table 7.7 Historical Flood Flows and Associated Return Periods – York River near Bancroft

Description	Maximum Recorded Peak Flood		
	Year Data	Flow (m^3/s)	Associated Return Period [(1)] (years)
York River near Bancroft	1983	102	11
York River near Bancroft	1985	103	12
York River near Bancroft	2013	142	> 100

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.7 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period for the 2013 flood on the York River near Bancroft, based on the distribution curve, would be larger than the 100 year flood. This return period however falls outside the validity range of the analysis.

7.2.6 South Branch Muskoka River at Baysville

Based on the information criteria and using the Decision Support System of HYFRAN, the Normal distribution is selected to fit the observations for the South Branch Muskoka River at Baysville.

Figure 7.8 shows the results of the statistical analysis.

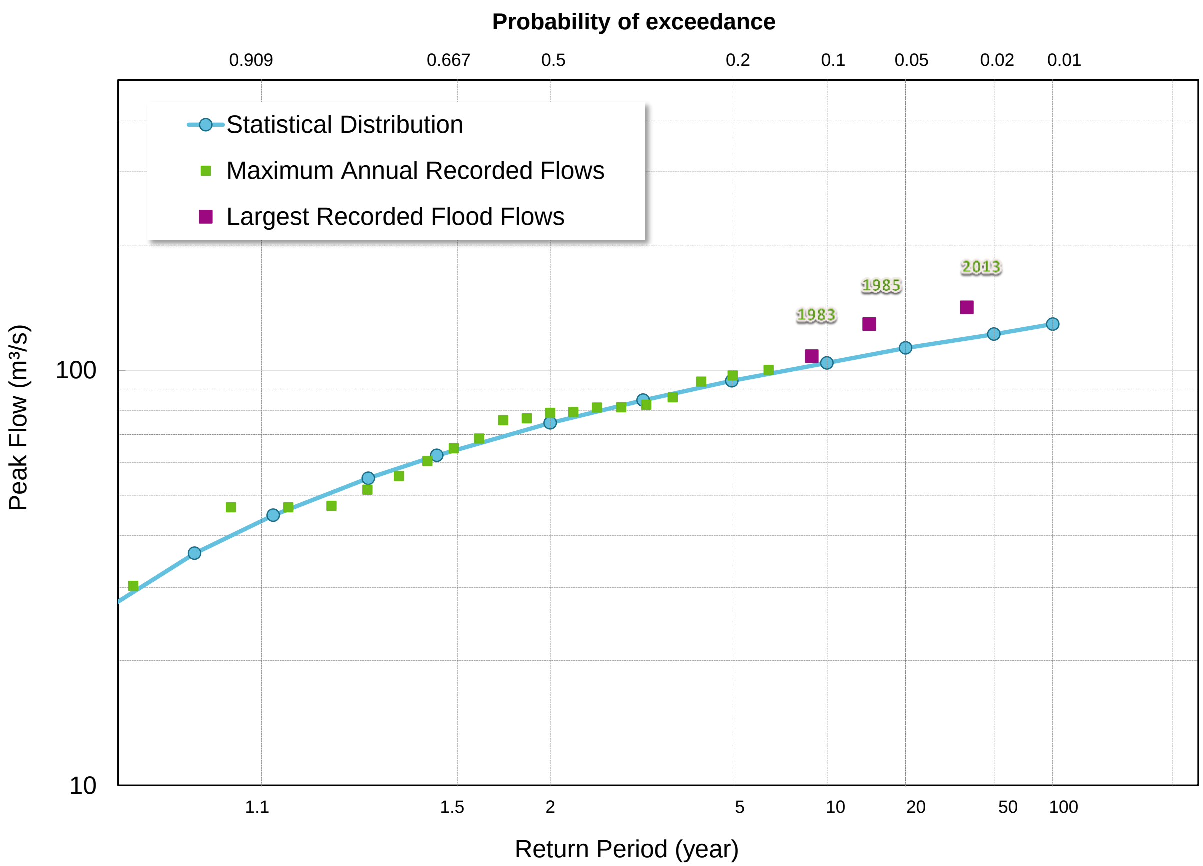

Figure 7.8 Statistical Analysis Results – Daily Peak Flood - South Branch Muskoka River at Baysville

Historical flood flows are presented in Table 7.8 with the associated return period.

Table 7.8 Historical Flood Flows and Associated Return Periods – South Branch Muskoka River at Baysville

Description	Maximum Recorded Peak Flood		
	Year	Flow	Associated Return Period [1]
	Data	(m^3/s)	(years)
South Branch Muskoka River at Baysville	1983	108	10
South Branch Muskoka River at Baysville	1985	129	26
South Branch Muskoka River at Baysville	2013	142	> 100

(1) Associated return period: Return period based on the distribution law selected to fit the recorded flows (obtained by drawing a horizontal line on Figure 7.8 beginning at the flood marker point and crossing the distribution curve at a specific return period).

The return period for the 2013 flood on the South Branch Muskoka River at Baysville, based on the distribution curve, would be larger than the 100 year flood. This return period however falls outside the validity range of the analysis.

7.2.7 Spring Flood Flows Summary

Table 7.9 present a summary of the floods statistical analysis on adjacent watersheds and on the Gull River.

Table 7.9 Summary - Return Periods of the 2013 Flood

Description	Maximum Recorded Peak Flood	
	Flow	Associated Return Period
	(m^3/s)	(years)
Gull River at Norland	93.4	> 200
Burnt River near Burnt River	211	95
Black River Near Washago	225	> 200
East River near Huntsville	208	> 500
York River near Bancroft	142	> 100
South Branch Muskoka River at Baysville	142	> 100

The 2013 spring flood on the Gull River exceeded the 200 year flood at Norland. Large floods were also observed on adjacent watersheds.

However, the theoretical limit of validity of a statistical analysis corresponds to approximately twice the sample size. Therefore, the 100-year peak flood flows estimated based on the statistical analysis fall outside the validity range for all stations and care should be brought when associating a larger return period for a flood.

8. Conclusions

8.1 Pre-Flood Analysis

The pre-flood analysis showed that:

- **April Rainfall**: April 2013 was a wet month, with 1.5 times the normal precipitation.

- **Snowpack**: The peak snowpack water equivalent of 84 to 115 mm observed in 2013 prior to the flood event is smaller than the average maximum snowpack (less than the 1: 2-year snowpack).

- **Combined Snowpack and Rainfall**: With the 113 mm of rainfall in April prior to the flooding, the snowpack added 84 to 115 mm of water equivalent to the April rainfalls, doubling the water input to the reservoir lakes.

- **Temperature and Snowmelt**: Temperature in April 2013 was within the monthly maximum and minimum climate normal, but allowed a rapid melting of the snowpack before the flooding. The snowmelt started the first week of March and lasted until the heavy rainfall of April 17th to April 19th occurred. The water input from the snowmelt contributes to the soil saturation and to the runoff volume entering the reservoirs. Soil saturation leads to a higher runoff rate and a faster water travel time to the reservoirs lakes, should a heavy rainfall occur.

- **The Spring Freshet started April 10th**: Snowmelt and rainfalls at the beginning of April, including the first intense rainfall which occurred on April 8th and 9th, contributed to the spring freshet that started on April 10th.

- **Reservoirs Levels**: Even under spring freshet conditions, water levels prior to the flood event were within usual level range for most of the lakes when compared to the historic water levels, until April 18th. Five reservoir lakes were almost at their maximum normal operating level.

- **Prior to the rainfall event (before April 17th): there was no evidence that severe flooding would occur**, but all the conditions were present to favor an efficient runoff rate and to increase the severity of a flooding, should a heavy rainfall occur.

- **Rainfall April 17th to April 19th**: the spring rainfall event of April 2013 with 75 mm of rainfall in 48 hours was, is the most severe rainfall observed in the Gull River watershed since 1962 (rainfall data available from 1962 to 2006 at Minden). This rainfall event occurred when the spring freshet was at its peak flow with some snow still on the ground (flow was about to decrease). This rainfall event has an associated return period near 100 years and is therefore considered as a severe rainfall event.

- **When the severe rainfall event occurred**: The severe rainfall event combined with the spring freshet that was at its peak generated severe flooding. The water levels started to increase on April 18th, reaching a peak water level within a week, on April 25th.

8.2 Flood Event Analysis

The flood event analysis showed that:

- The hydrometeorological conditions described in the pre-flood analysis were sufficient to generate large runoff volumes and therefore large flood flows in the Gull River system.
- The return period of the peak flood flow at Norland exceeds the 200 year flood.
- Large floods exceeding the 100 year flood were also observed in adjacent watersheds (Black River, East River, York River).

8.3 Review of the Actions Regarding Dam Operations

The review of the actions regarding dam operations revealed that:

- On April 17th, Moore Lake Dam (Elliott Falls) and Gull Lake Dams, the two reservoirs immediately downstream of Minden Hills, were fully open (all stoplogs out). Therefore the maximum discharge capacity was provided. These dams remained fully open from April 18th to May 13th when PCA started to put back stoplogs when the water levels dropped below the maximum normal operating level after the passage of the flood.
- On the evening of April 17th, when the heavy rainfall started, water levels and flows were within usual level range for most of the reservoir lakes when compared to the historic water levels, and started to increase on April 18th.
- At this point, with all the stoplogs out at Moore Lake Dam and Gull Lake Dams, the maximum discharge capacity is provided. For any flow increase entering Moore Lake and Gull Lake, water level had no other option than to increase.
- The only option that PCA had in order to avoid additional flooding in Minden Hills and downstream of Minden Hills to Coboconk was to retain water in the upstream reservoir lakes to decrease the flow entering Gull Lake. However, retaining water upstream would cause additional flooding in the upstream reservoir lakes. A decision had to be made based upon available information.
- Considering potential public safety issues to the permanent community of Minden Hills and downstream to Coboconk, the decision to put back stoplogs in the reservoir lakes upstream of Minden Hills to prevent greater downstream flooding was taken. On April 21st, addition of stoplogs occurred and continued the two following days. Parks Canada was able to respond to the situation with additional crews to monitor and manipulate dams to mitigate as much as possible the impacts of increasing water levels and river flows.
- The actions by PCA to retain water in the upstream reservoir lakes and mitigate flooding near Minden were successful. It is estimated that just at Horseshoe Lake dam, approximately 20 m^3/s were cut from the peak flood flows entering Moore Lake on April 25th, avoiding extra flooding in Minden and downstream to Coboconk.

In general, the management decisions contributed to reduce the peak flood flow on April 25th and therefore avoided additional flooding in Minden and downstream to Coboconk, without endangering public safety in upstream reservoir lakes.

The flood was not caused by poor decisions. The management staff at the Trent-Severn Waterway did an exemplary job. Other alternative water management decisions would not have led to a reduced overall flooding.

In summary, the flood event analysis showed that:

- The management of the reservoir lakes did not contribute to the flooding near Minden Hills. Furthermore, the management succeeded in avoiding additional flooding on April 25th by retaining water in the upstream reservoir lakes.
- The management in reservoir lakes was performed adequately within the recognized operational procedures in order to meet the prioritized water management objectives.

8.4 Review of Legislation, Policies and Guidelines

A review of legislation, policies, guidelines, emergency response plans and other texts was performed to identify the roles and responsibilities of PCA and other authorities over water level management in the TSW. In light of the review performed:

- PCA is responsible for the management of water levels within the TSW.
- PCA is responsible for the safe management of its structures and for ensuring the structures remain in compliance with regulations.
- PCA has the responsibility to operate its dam-reservoirs to mitigate flood impacts.
  - Upstream flooding is an acceptable practice to prevent greater downstream impacts, especially if public safety is jeopardized.
  - PCA's management of the April 2013 flood has not differed from its policies and operational procedures.
- The MNR is responsible for preparation, update and activation of the emergency management program for floods.
- The MNR and/or a municipality are responsible for declaring state of emergency within its territory.

Furthermore, emergency management requires cooperation and communication between dam operators and the civil authorities. However, communication channels between dam owner/operators and levels of government are not clearly identified by law.

8.5 Recommendations

8.5.1 Water Management Tool

The water management of the Trent-Severn Waterway to achieve the management goals and objectives requires consideration of a variety of different factors, including the Waterway's mandated requirements, scientific objectives, regulatory impacts, environmental impacts, political and public concerns as well as the day-to-day and long-term operation of the Waterway.

Considering the complexity of water management in the Trent-Severn Waterway, the management staff should eventually have a water management tool to support decision making. The tool would provide assistance in decision-making framework for choosing water releases from the reservoirs in the system to improve the operation, as well as to improve stakeholder and public understanding of the decisions that are made.

The tool should be based on physical constraints along the Trent-Severn Waterway and in the reservoir lakes to minimize damages under flood conditions, as well as to optimize indicators of a good management in normal conditions (balancing competing management goals). The tool may include a climate forecast model which would provide inputs to an optimization model, for all or for specific management goals. For example, under an emergency situation, the tool may provide assistance to optimize public safety. This tool would help in better management for extreme weather events by the TSW.

8.5.2 Dam Safety Reviews and Emergency Preparedness and Response Plans

It is also recommended that dam safety reviews continue to be carried out for all sites to analyse structural stability of all dams, to provide inundation mapping in case of a dam failure and to have emergency preparedness and response plans available to better assure public safety under large flood conditions. As stated in the Canadian Dam Association (CDA) Dam Safety Guidelines (2007, Reference 7), an effective emergency management relies on establishment of a clear emergency response structure that is understood by all responders, supported by the following four components:

- An internal, dam-specific emergency response plan (ERP), including actions the dam owner will take in response to unusual or emergency conditions.
- An emergency preparedness plan (EPP), developed by the dam owner for external use, defining the hazards posed by the dam, the roles and responsibilities of all parties, and notifications to be made.
- Municipal, community, or regional emergency plans, developed by responding agencies for their own use to warn and evacuate residents within the floodplains.
- A maintenance, testing, and training program to ensure that the processes are effectively integrated and kept up to date preparedness plan (EPP) would provide communication.

During an emergency both the dam owner's staff and the community responders must understand the relationships between the different emergency operations centres (EOCs). Emergency plans should document the response structure, such as the widely used "incident command" model, as shown in Table 8.1 (Reference 7).

Table 8.1 Incident Command Model (Reference 7)

EOC	Typical Role
SCP	The SCP manages the emergency in the vicinity of the dam and reservoir. Dam staff attempt mitigation measures if required and also performs initial notifications as described in the fan-out procedures. The SCP coordinates broader response activities until regional EOC or corporate EOC is set up to assist.
Dam Owner EOC	In some cases an EOC is established by the dam owner upon notification of a major dam emergency. The centre normally provides comprehensive support for site activities by coordinating site security, logistical requirements, on-going communication with stakeholders and media, and technical and administrative support
Provincial Government EOC	In a serious emergency, the provincial government may activate a government EOC to manage the emergency at the provincial level. The government EOC is staffed with the appropriate government officials and agency representatives as needed for emerging events, and normally activates a public media information room
Municipal EOC	Municipalities activate their municipal emergency plans and perform the required emergency response procedures outlined in their plans. These procedures are based on the information supplied by the dam owner. In most cases a municipal EOC is set up
Acronyms: EOC, emergency operations centre; SCP, site command post.	

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Appendix A
Trent River Watershed

Table A1 – Sub-Basin Nodes – Description and Drainage Areas

Figure A1 – Trent River Watershed – General Location Plan

Figure A2 – Trent River Watershed Flow Chart

Table A1 Sub-Basin Nodes – Description and Drainage Areas

Node ID			Watershed	Drainage Area (km²)					Lake Area (ha)	
				From Project Brief		From Hydrometric station	From DEM		From Project Brief	From DEM
ID	Name	Type		Inter-mediate	Cumulative		Inter-mediate	Cumulative		
Gull River Watershed										
1	Kennisis Lake Dam	Dam	Gull	174.0	174.0		147.1	147.1	1641.0	1649.6
2	Red Pine Lake Dam	Dam	Gull	39.5	213.5		37.9	185.0	385.0	423.5
3	Nunikani Lake Dam	Dam	Gull	7.4	220.9		6.2	191.2	109.0	108.6
4	Hawk Lake and Little Brother Lake Dams	Dam	Gull	84.0	304.9		56.7	247.9	1087.0	806.4
5	Halls Lake Dam	Dam	Gull	21.5	326.4		21.1	269.0	529.0	542.3
6	Kushog Lake (including St. Nora Lake) and Sherborne Lake Dams	Dam	Gull	111.0	111.0		109.1	109.1	915.0	1149.9
7	Percy Lake Dam	Dam	Gull	74.0	74.0		72.1	72.1	563.0	487.2
8	Oblong Lake Dam (including Haliburton Lake)	Dam	Gull	77.0	151.0		77.7	149.9	1094.0	1007.2
9	Eagle Lake Dam[1] (including Moose Lake)	Dam	Gull	44.0	195.0		49.3	199.1	515.0	521.1
10	Redstone Lake East and West Dams	Dam	Gull	169.0	169.0		183.2	183.2	1422.0	1435.8
11	Gull River at Maple Lake	H.ST (H4-1)	Gull		364.0	527.0	126.7	509.0		576.4
12	Twelve Mile Lake Dam (including Boshkung, Little Boshkung and Beech Lakes)	Dam	Gull	29.0	830.4		72.1	959.3	1161.0	1306.1
13	Horseshoe Lake Dam (including Mountain Lake)	Dam	Gull	46.6	877.0		50.1	1009.4	556.0	620.6
14	Bob Lake Dam	Dam	Gull	32.3	32.3		38.0	38.0	226.0	230.3
15	Little Bob Lake Dam	Dam	Gull	13.5	45.8		6.5	44.5	73.0	86.1
16	Gull Lake Dams 1 & 2	Dam	Gull	167.0	1089.8		178.8	1232.6	998.0	1067.8
17	Norland Dam and Moore Lake Dam (Elliott Falls)	Dam, H.ST (H4)	Gull	42.2	1132.0	1280.0	63.3	1295.9	194.0	207.9
18	Coboconk Dam (including Silver and Shadow Lakes)	Dam	Gull				60.2	1356.2		450.2
							1356.2	**1356.2**		
Burnt River Watershed										
19	Drag Lake Dams North & South	Dam	Burnt	121.0	121.0		129.0	129.0	1102.0	1105.7
20	Canning Lake Dams 1 & 2 (including Kashagawigamog Lake)	Dam	Burnt	168.0	289.0		170.3	299.3	1274.0	1548.6
21	Long Lake Dam (including Miskwabi Lake)	Dam	Burnt	20.2	20.2		21.3	21.3	335.0	346.1
22	Loon Lake Dam	Dam	Burnt	45.7	65.9		43.3	64.7	254.0	248.1
23	Koshlong Lake Dam	Dam	Burnt	30.1	30.1		29.1	29.1	405.0	403.9
24	Burnt River at Gelert	H.ST (H5-1)	Burnt			543	129.7	522.7		
25	Farquhar Lake Dam	Dam	Burnt	29.5	29.5		20.7	20.7	345.0	340.3
26	Pusey Lake Dam (including Grace Lake)	Dam	Burnt	47.2	76.7		44.1	64.8	295.0	277.8
27	Esson Lake Dam	Dam	Burnt	20.2	20.2		24.0	24.0	236.0	241.4

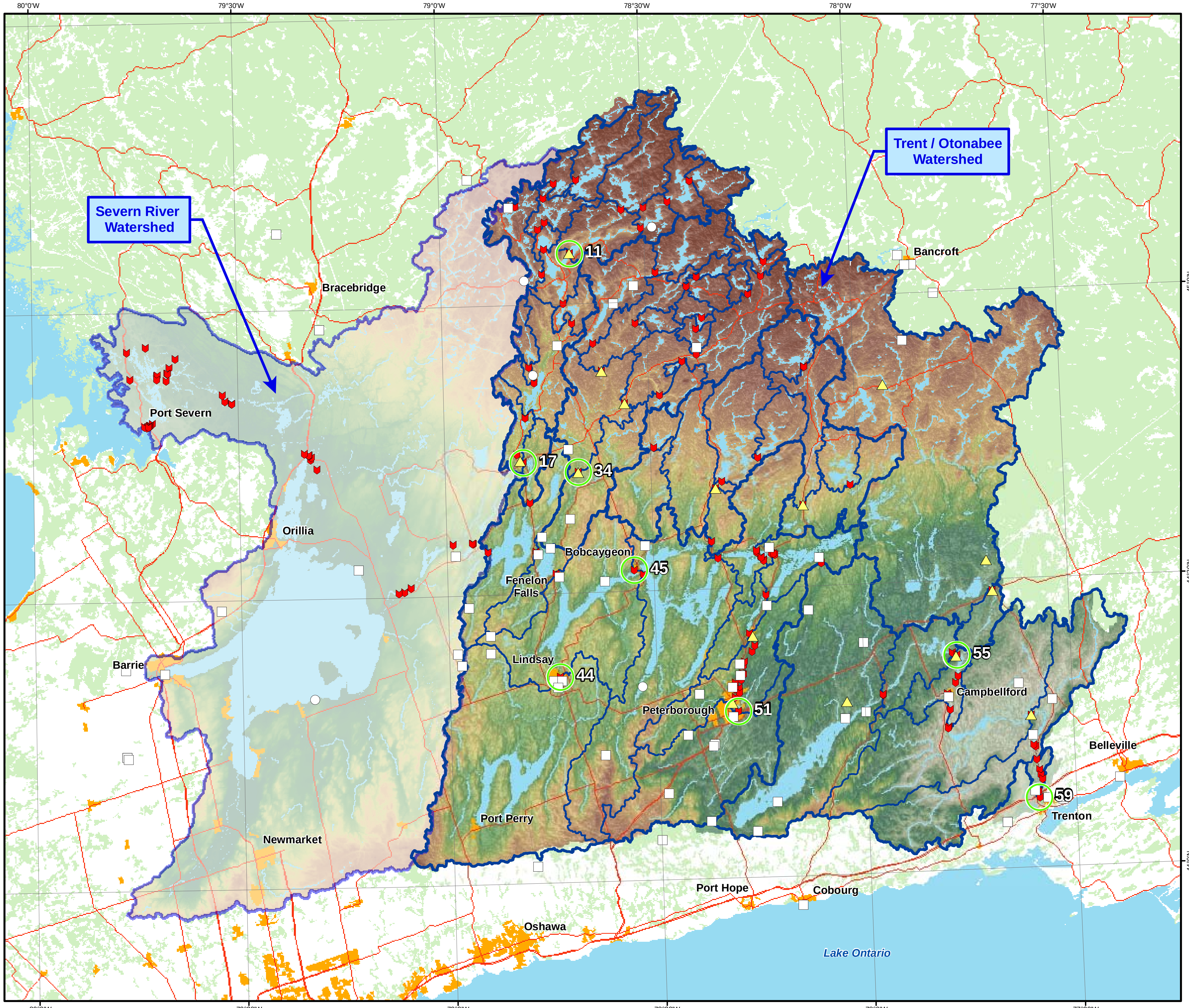
Node ID: ID	Node ID: Name	Node ID: Type	Watershed	Drainage Area (km²): From Project Brief: Inter-mediate	Drainage Area (km²): From Project Brief: Cumulative	Drainage Area (km²): From Hydrometric station	Drainage Area (km²): From DEM: Inter-mediate	Drainage Area (km²): From DEM: Cumulative	Lake Area (ha): From Project Brief	Lake Area (ha): From DEM
28	Little Glamor Lake Dam	Dam	Burnt	26.8	26.8		26.0	26.0	63.0	69.0
29	Glamor Lake Dam	Dam	Burnt	4.7	31.5		6.6	32.6	187.0	198.6
30	Gooderham Lake Dam	Dam	Burnt	41.2	72.7		27.2	59.8	85.0	88.6
31	Contau Lake Dam	Dam	Burnt	5.4	5.4		5.3	5.3	119.0	135.1
32	White Lake Dam (including Salmon Lake)	Dam	Burnt	54.0	54.0		50.6	50.6	160.0	166.5
33	Irondale River at Furnace Falls	H.ST (H5-2)	Burnt			534	326.1	530.7		
34	Burnt River near Burnt River and Kinmount Dam	Dam, H.ST (H5)	Burnt			1270.0	211.7	1265.0		
							1265.0	**1265.0**		
Jacks Creek Watershed										
35	Jack Lake Dam	Dam	Jack	83.0	83.0		81.9	81.9	1296.0	1329.4
				83.0	**83.0**		**81.9**	**81.9**		
Mississagua River Watershed										
36	Anstruther Lake Dam	Dam	Mississagua	93.0	93.0		89.9	89.9	621.0	629.4
37	Mississagua Lake Dam	Dam	Mississagua	218.0	311.0		209.5	299.3	2061.0	2233.5
38	Mississagua River Below Mississagua Lake	H.ST (H8)	Mississagua			326.0	6.2	305.6		
							305.6	**305.6**		
Eels Creek Watershed										
39	Eels Lake 1 & 2 Dams	Dam	Eels	104.0	104.0		106.0	106.0	815.0	932.7
40	Eels Creek Below Apsley	H.ST (H7)	Kawartha			241.0	153.4	259.3		
				104.0	**104.0**		**259.3**	**259.3**		
Nogies Creek Watershed										
41	Crystal Lake Dam	Dam	Nogies	50.0	50.0		45.6	45.6	449.0	476.0
				50.0	**50.0**		**45.6**	**45.6**		
Kawartha Lakes Watershed										
42	Dam at Lock 35 (Rosedale)	Dam	Kawartha		1596.0		282.5	1638.6	4745.0	4793.1
	Dam at Lock 34 (Fenelon Falls) - from Burnt Watershed		Burnt				218.1			
	Dam at Lock 34 (Fenelon Falls) - from Kawartha Watershed		Kawartha				126.0			
43	Dam at Lock 34 (Fenelon Falls) - total	Dam	Kawartha		3294.0		344.1	3247.7	1450.0	1437.7
44	Dam at Lock 33 (Lindsay)	Dam	Kawartha	964.0	964.0		1014.0	1014.0	6354.0	6745.4
45	Dam at Lock 32 (Bobcaygeon) and Little Bob Channel Dam	Dam	Kawartha		4813.0		566.4	4828.2	4562.0	4787.5

Node ID			Watershed	Drainage Area (km²)					Lake Area (ha)	
				From Project Brief		From Hydrometric station	From DEM		From Project Brief	From DEM
ID	Name	Type		Inter-mediate	Cumulative		Inter-mediate	Cumulative		
	Dam at Lock 31 (Buckhorn) - from Nogies		Nogies				143.8			
	Dam at Lock 31 (Buckhorn) - from Nogies		Miskwaa Ziibi (Squaw)				199.0			
	Dam at Lock 31 (Buckhorn) - from Kawartha		Kawartha				784.7			
46	Dam at Lock 31 (Buckhorn) - total	Dam	Kawartha		6032.0		1127.5	6001.3	12186.0	12316.2
	Scott Mills Dam - from Mississagua		Mississagua				65.5			
	Dams at Lock 30 (Lovesick) - from Kawartha		Kawartha				220.8			
47	Dams at Lock 30 (Lovesick) - Dams 1, 2, 3, 4, 5, 6 & 7 - total	Dam	Kawartha		6596.0		286.2	6593.1	1250.0	1273.9
48	Dams at Lock 28 (Burleigh Falls) and Perrys Creek 1, 2 & 3 Dams	Dam	Kawartha		6805.0		8.7	6601.8	266.0	256.1
	Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Eels		Eels				91.1			
	Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Jack		Jack				97.8			
	Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Kawartha		Kawartha				154.0			
49	Dam at Lock 27 (Young's Point) - total	Dam	Kawartha		7442.0		342.86	7285.8	3733.0	3834.5
50	Dam at Lock 26 (Lakefield)	Dam, H.ST (H3)	Kawartha		7526.0	7360.0	93.4	7379.2	379.0	403.7
	Dam at Lock 20 (Ashburnham), Dam at Lock 21 (Peterborough Lift Locks), Dam at Lock 22 (Nassau Mills), Dam at Lock 23 (Otonabee), Dam at Lock 24 (Douro), Dam at Lock 25 (Sawyer Creek)									
51	Dam at Lock 19 (Scotts Mills)	Dam, H.ST (H3-1)	Kawartha				288.1	7667.3		176.5
52	Otonabee River at Rice Lake		Kawartha				507.7	8175.1		
							4861.5	**8175.1**		
Crowe River Watershed										
53	Crowe River at Marmora	Dam, H.ST (H6)	Crowe			1990.0	1893.8	1893.8		1956.7
						1990.0	**1893.8**	**1893.8**		
Rice Lake Watershed										
54	Dam at Lock 18 (Hastings) and Hastings Side Dams		Rice		9130.0		906.3	9081.4	10123.0	9597.5
					9130.0	**906.3**		**9081.4**		
Trent River Watershed										
	Dam at Locks 16/17 & Dam at Lock 15 (Healey Falls)									
55	Dam at Locks 16/17 (Healey Falls)	Dam, H.ST (H2)	Trent		9350.0	9090.0	156.1	9237.5	1335.0	1267.8

Node ID			Watershed	Drainage Area (km²)					Lake Area (ha)	
				From Project Brief		From Hydrometric station	From DEM		From Project Brief	From DEM
ID	Name	Type		Inter-mediate	Cumulative		Inter-mediate	Cumulative		
	Dam 8 at Lock 9 (Meyers) - from Crowe		Crowe				65.8		285.0	310.0
	Dam 8 at Lock 9 (Meyers), Dam 9 at Lock 10 (Hagues Reach), Dam 10 at Lock 11/12 (Ranney Falls), Trout Creek Aqueduct, Dam 11 at Lock 13 (Campbellford) and Dam 12 at Lock 14 (Crowe Bay) - from Trent						91.4		77.7	90.8
56	Dam 8 at Lock 9 (Meyers) - total	Dam	Trent		12300.0		157.2	11288.5	362.7	400.8
57	Dam 7 at Lock 7 (Glen Ross)	Dam, H.ST (H1)	Trent			12000.0	727.0	12015.5	1477.0	1195.4
	Dam 6 at Lock 6 (Frankford) and Sill Island Dam C									
58	Dam 5 at Lock 5 (Trent)	Dam	Trent				485.0	12500.5	381.6	460.4
	Dam 2 at Lock 2 (Sidney), Dam 3 at Lock 3 (Glen Miller), Dam 4 at Lock 4 (Batawa) and Sonoco Papermill Dam									
59	Dam 1 at Lock 1 (Trenton)	Dam	Trent		12600.0	12400.0	22.8	12523.3	115.3	129.1
							1548.1	**12523.3**		

Study Node

Note: 1 - Cumulative area excludes Redstone Lake (for simplification purposes)



Travaux publics et Services gouvernementaux Canada | Public Works and Government Services Canada

Parcs Canada | Parks Canada

TRENT RIVER WATERSHED HYDRO-TECHNICAL STUDY

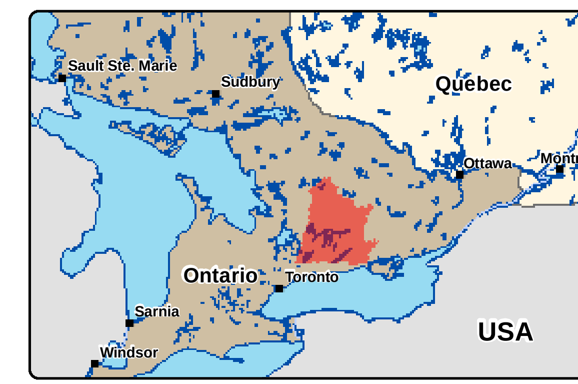
Legend

- Study Node
- Dam
- Climatological Station
- Hydrometric Station
- Snow Station
- Sub-basin
- Watershed

Value

High : 562

Low : 49



0 10 20 30 40 km

1 : 750 000

UTM 17
NAD 83 Datum

GENERAL LOCATION PLAN

September 2010

AECOM

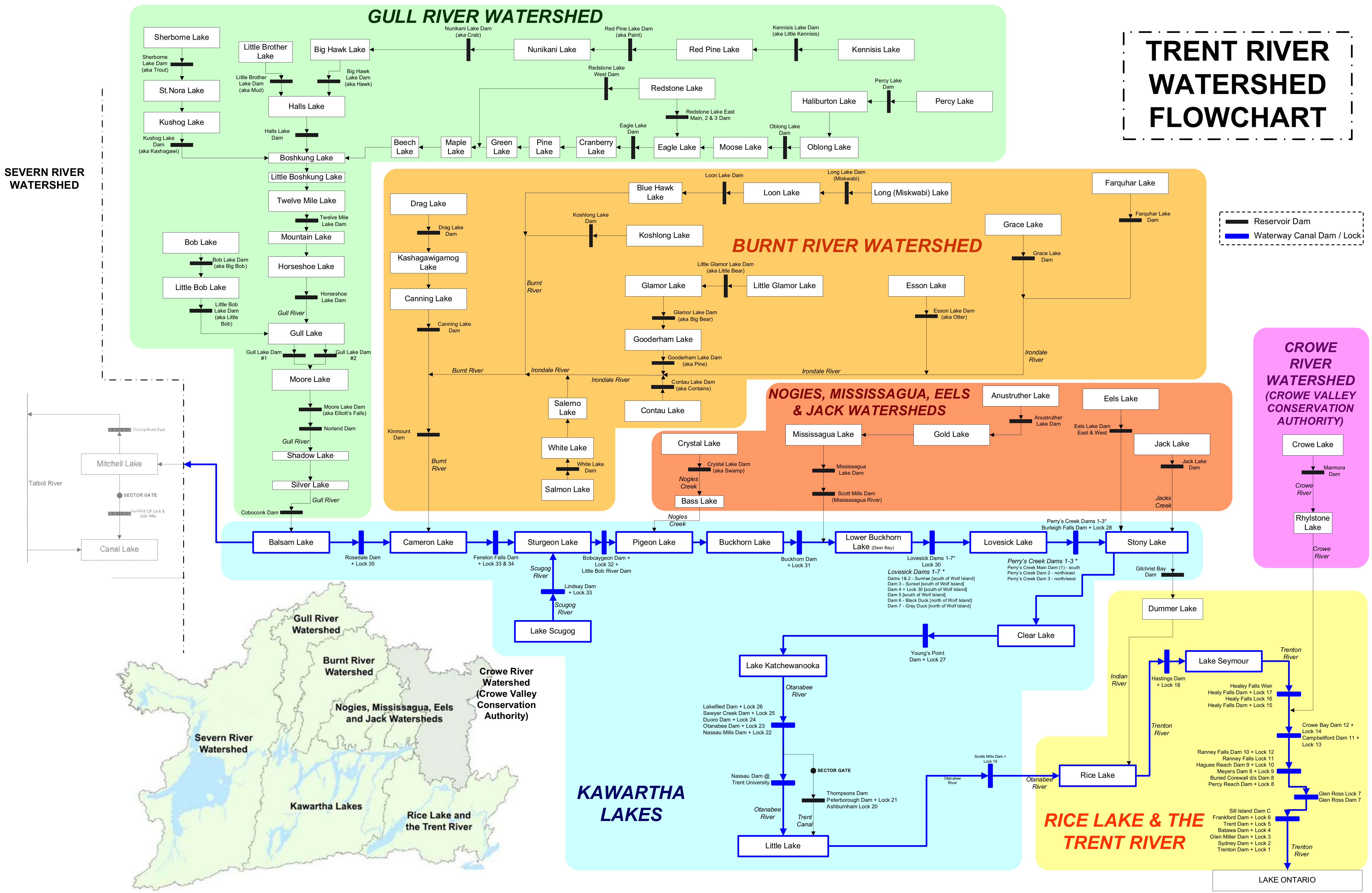


FIGURE A2 - Trent River Watershed Flow Chart

Appendix B
Book of Maps – Gull River

Travaux publics et Services gouvernementaux Canada

Public Works and Government Services Canada

Parcs Canada

Parks Canada

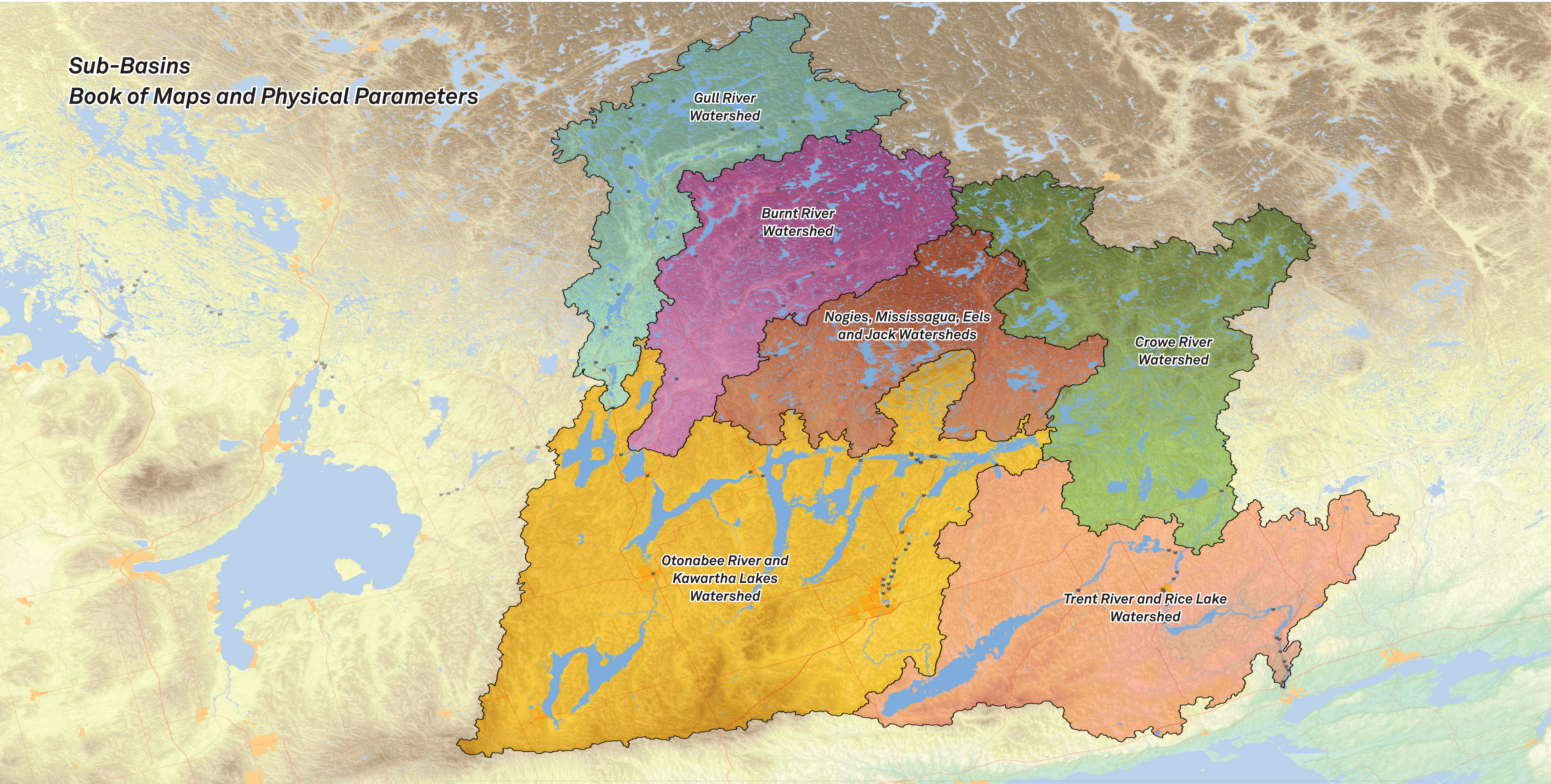
Trent-Severn Waterway
National Historic Site of Canada,
Parks Canada Agency

No project: 60154038-2.2
May 2011

Trent River Watershed Hydro-Technical Study

AECOM

Sub-Basins Book of Maps and Physical Parameters

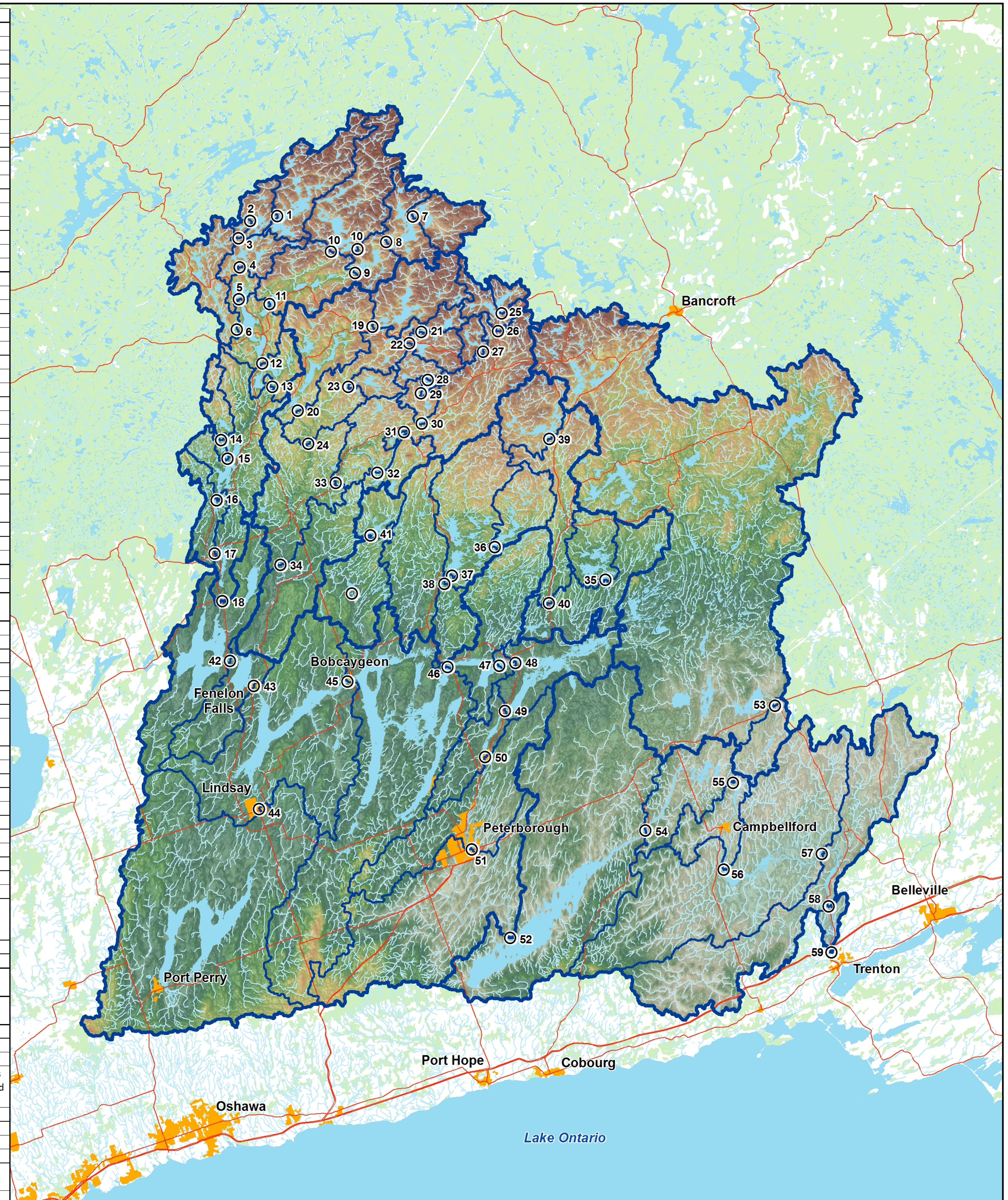


Travaux publics et Services gouvernementaux Canada
Public Works and Government Services Canada

Parcs Canada
Parks Canada

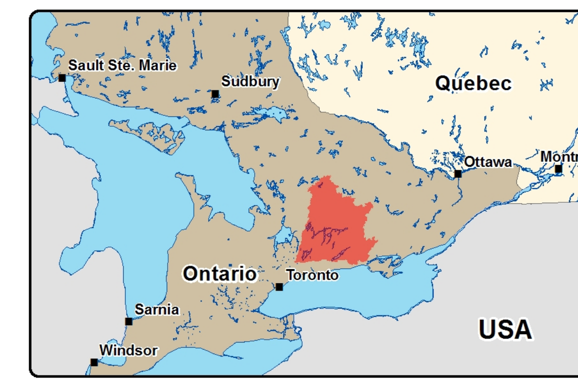
TRENT RIVER WATERSHED HYDRO-TECHNICAL STUDY

	Map	Name
Gull River Watershed	1	Kennisis Lake Dam
	2	Red Pine Lake Dam
	3	Nunikani Lake Dam
	4	Hawk Lake and Little Brother Lake Dams
	5	Halls Lake Dam
	6	Kushog Lake (including St. Nora lake) and Sherborne Lake Dams
	7	Percy Lake Dam
	8	Oblong Lake Dam (including Haliburton Lake)
	9	Eagle Lake Dam[1] (including Moose Lake)
	10	Redstone Lake East and West Dams
	11	Gull River at Maple Lake
	12	Twelve Mile Lake Dam (including Boshkung, Little Boshkung and Beech Lakes)
	13	Horseshoe Lake Dam (including Mountain Lake)
	14	Bob Lake Dam
	15	Little Bob Lake Dam
	16	Gull Lake Dams 1 & 2
	17	Norland Dam and Moore Lake Dam (Elliott Falls)
	18	Coboconk Dam (including Silver and Shadow Lakes)
Burnt River Watershed	19	Drag Lake Dams North & South
	20	Canning Lake Dams 1 & 2 (including Kashagawigamog Lake)
	21	Long Lake Dam (including Miskwabi Lake)
	22	Loon Lake Dam
	23	Koshlong Lake Dam
	24	Burnt River at Gelert
	25	Farquhar Lake Dam
	26	Pusey Lake Dam (including Grace Lake)
	27	Esson Lake Dam
	28	Little Glamor Lake Dam
	29	Glamor Lake Dam
	30	Gooderham Lake Dam
	31	Contau Lake Dam
	32	White Lake Dam (including Salmon Lake)
	33	Irondale River at Furnace Falls
	34	Burnt River near Burnt River and Kinmount Dam (MNR)
Jacks Creek Watershed	35	Jack Lake Dam
Mississagua River Watershed	36	Anstruther Lake Dam
	37	Mississagua Lake Dam
	38	Mississagua River below Mississagua Lake
Eels Creek Watershed	39	Eels Lake Dams 1 & 2
	40	Eels Creek below Apsley
Nogies Creek Watershed	41	Crystal Lake Dam
Kawartha Lakes & Otonabee Watershed	42	Dam at Lock 35 (Rosedale)
	43	Dam at Lock 34 (Fenelon Falls) - from Burnt Watershed
		Dam at Lock 34 (Fenelon Falls) - from Kawartha Watershed
		Dam at Lock 34 (Fenelon Falls) - total
	44	Dam at Lock 33 (Lindsay)
	45	Dam at Lock 32 (Bobcaygeon) and Little Bob Channel Dam
	46	Dam at Lock 31 (Buckhorn) - from Nogies
		Dam at Lock 31 (Buckhorn) - from Nogies
		Dam at Lock 31 (Buckhorn) - from Kawartha
		Dam at Lock 31 (Buckhorn) - total
	47	Scott Mills Dam - from Missisagua
		Dams at Lock 30 (Lovesick) - from Kawartha
		Dams at Lock 30 (Lovesick) - Dams 1, 2, 3, 4, 5, 6 & 7
	48	Dams at Lock 28 (Burleigh Falls) and Perrys Creek 1, 2 & 3 Dams
	49	Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Eels
		Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Jack
		Dam at Lock 27 (Young's Point) and Gilchrist Bay Dam - from Kawartha
		Dam at Lock 27 (Young's Point)
	50	Dam at Lock 26 (Lakefield)
	51	Dam at Lock 19 (Scotts Mills), Dam at Lock 20 (Ashburnham), Dam at Lock 21 (Peterborough Lift Locks), Dam at Lock 22 (Nassau Mills), Dam at Lock 23 (Otonabee), Dam at Lock 24 (Douro), Dam at Lock 25 (Sawyer Creek)
		Dam at Lock 19 (Scotts Mills)
	52	Otanabee River at Rice Lake
Crowe River Watershed	53	Crowe River at Marmora
Rice Lake Watershed	54	Dam at Lock 18 (Hastings) and Hastings Side Dams
Trent River Watershed	55	Dam at Locks 16/17 & Dam at Lock 15 (Healey Falls)
		Dam at Locks 16/17 (Healey Falls)
	56	Dam 8 at Lock 9 (Meyers) - from Crowe
		Dam 8 at Lock 9 (Meyers), Dam 9 at Lock 10 (Hagues Reach), Dam 10 at Locks 11/12 (Ranney Falls), Trout Creek Aqueduct, Dam 11 at Lock 13 (Campbellford) and Dam 12 at Lock 14 (Crowe Bay) - from Trent
		Dam 8 at Lock 9 (Meyers)
	57	Dam 7 at Lock 7 (Glen Ross)
	58	Dam 5 at Lock 5 (Trent), Dam 6 at Lock 6 (Frankford) and Sill Island Dam C
		Dam 5 at Lock 5 (Trent)
	59	Dam 1 at Lock 1 (Trenton), Dam 2 at Lock 2 (Sidney), Dam 3 at Lock 3 (Glen Miller), Dam 4 at Lock 4 (Batawa) and Sonoco Papermill Dam
		Dam 1 at Lock 1 (Trenton)



Sub-basin Node
Sub-basin
Watershed

Value
High : 551
Low : 77



0 10 20 30 40 km

1 : 750 000

UTM 17
NAD 83 Datum

GENERAL LOCATION PLAN

May 2011

AECOM

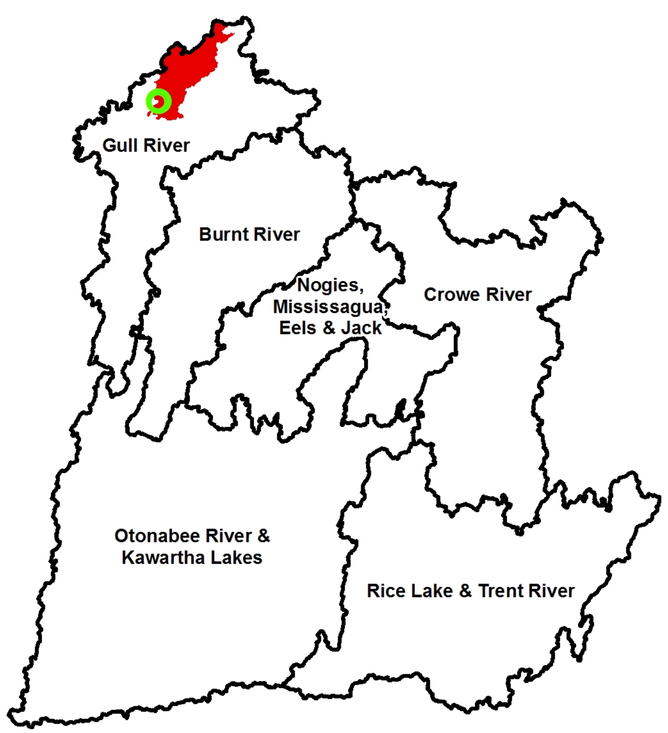
Map 1

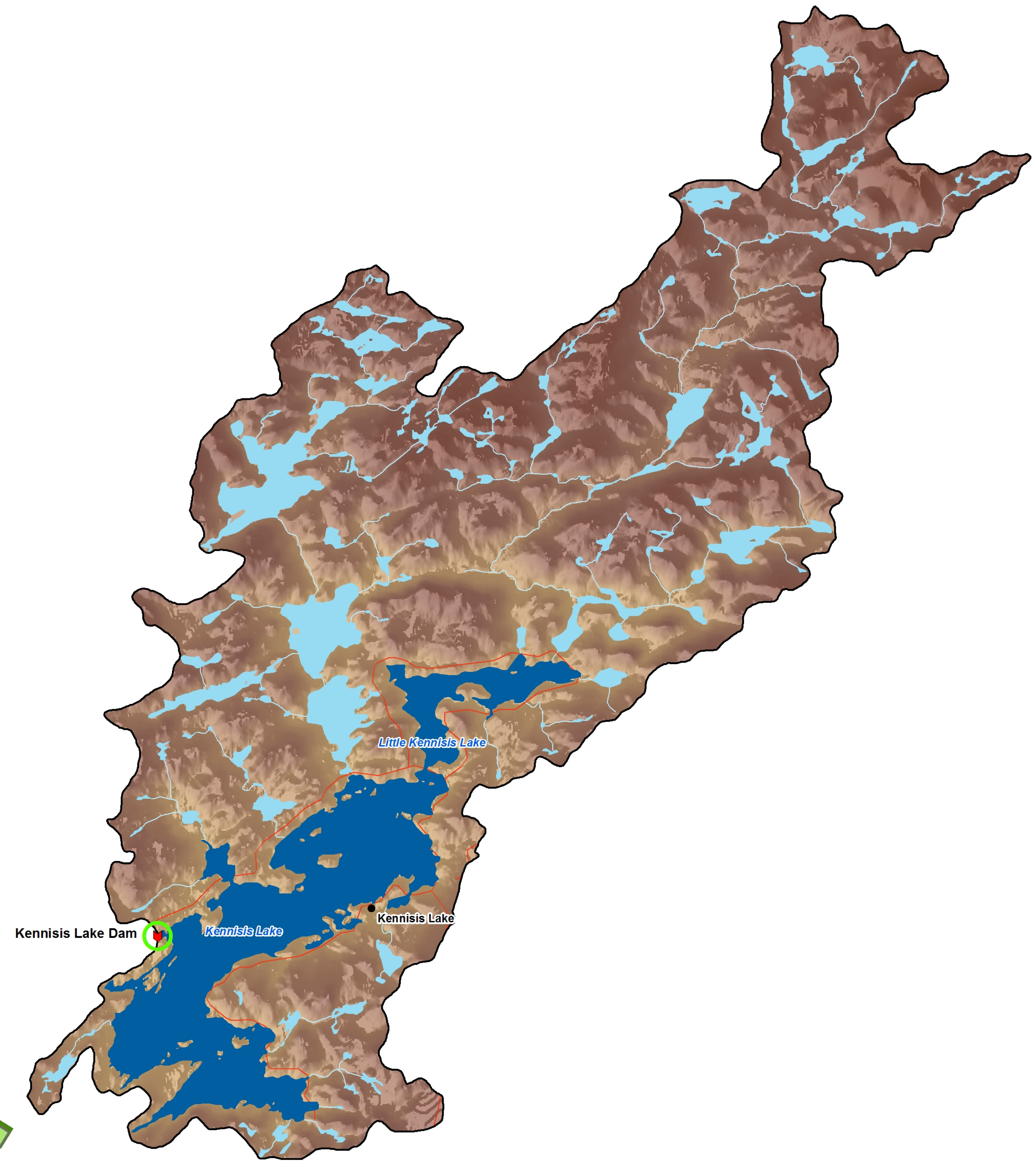
Kennisis Lake Dam

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream





1: 100 000

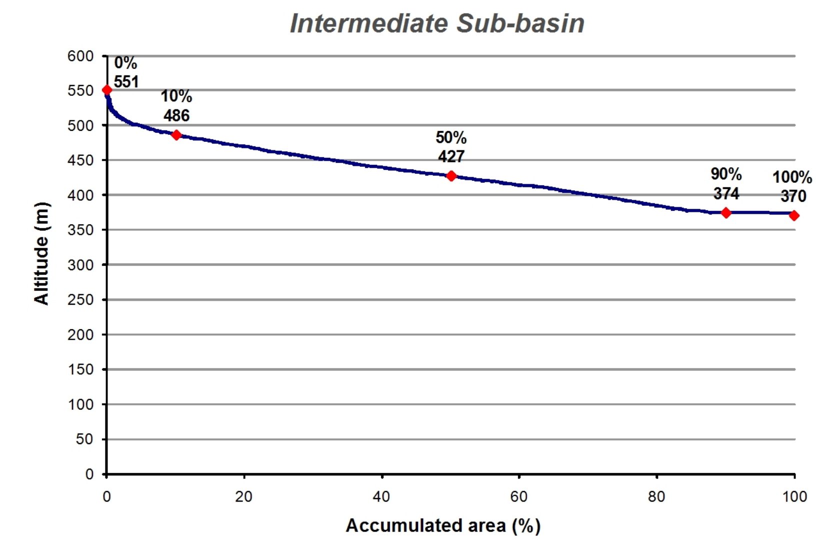
0 1 2 3 4 5 km

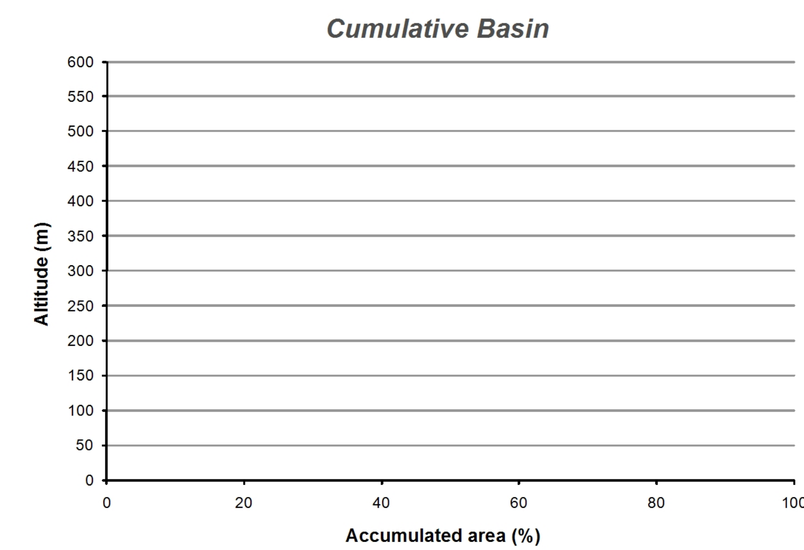
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	147.14	-	km²
Maximum elevation	551	-	m
Minimum elevation	370	-	m
Maximum vertical difference	181	-	m

Lakes and reservoirs	Area	
Kennisis Lake	1421.9	ha
Little Kennisis Lake	227.6	ha

Hypsometric Curves



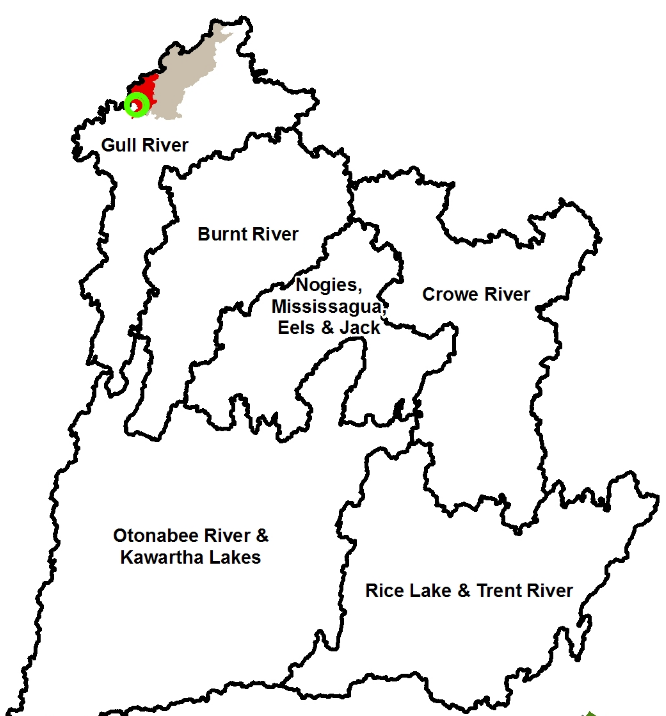


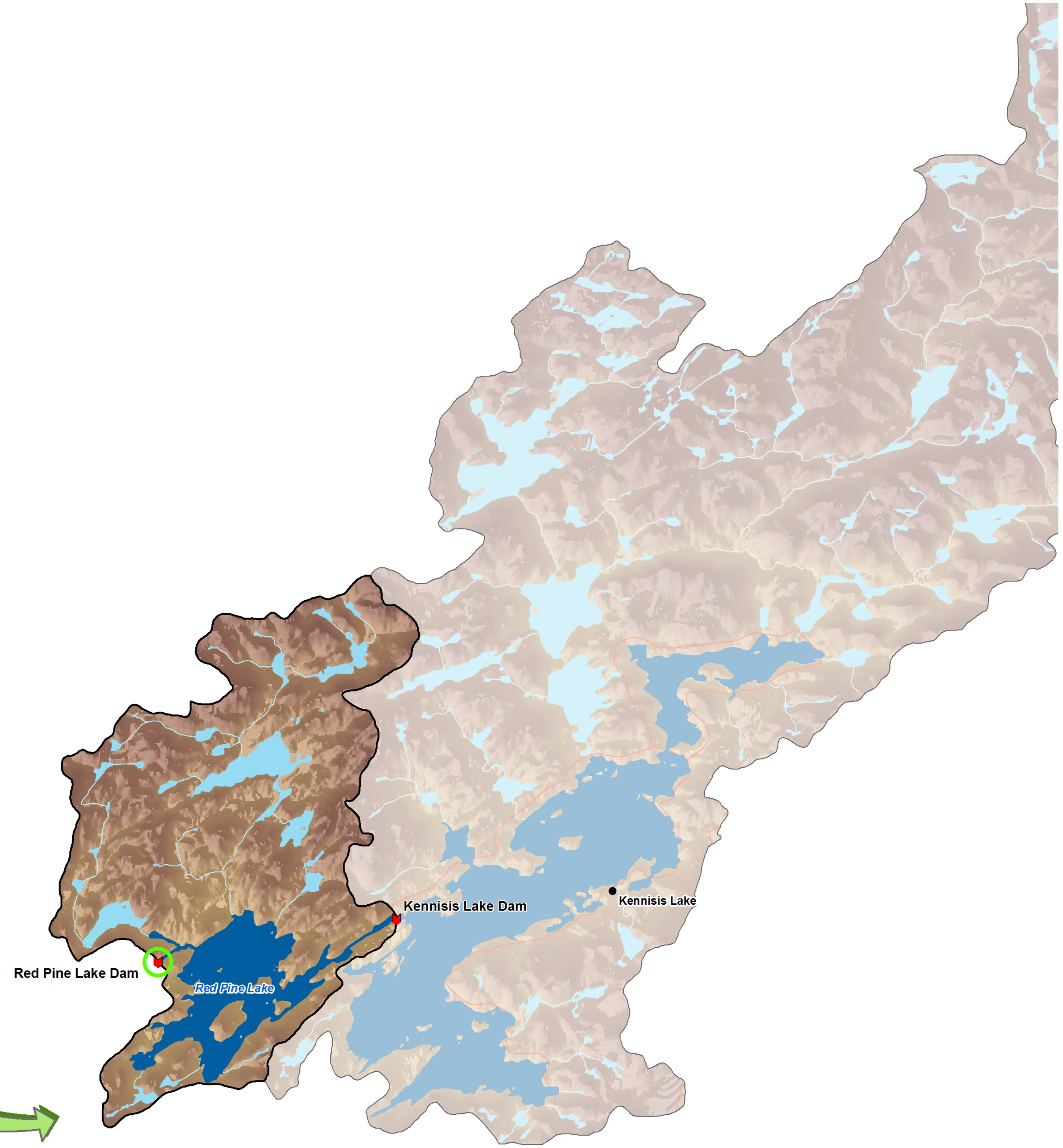
Red Pine Lake Dam

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream





1: 100 000

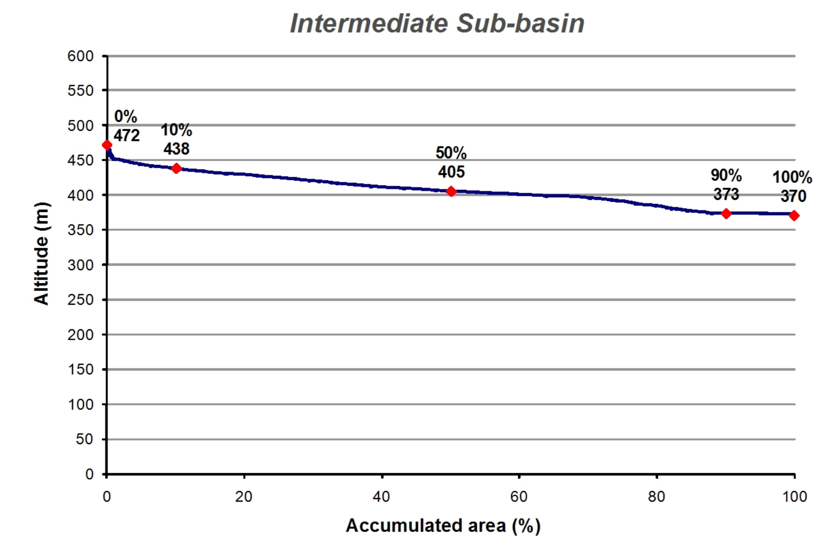
0 1 2 3 4 5 km

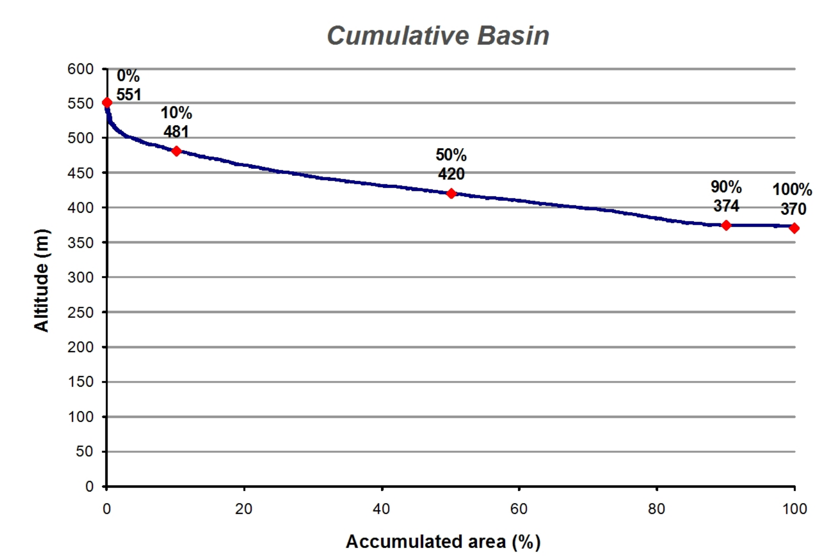
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin
Area	37.89	185.03 km²
Maximum elevation	472	551 m
Minimum elevation	370	370 m
Maximum vertical difference	102	181 m

Lakes and reservoirs	Area
Red Pine Lake	423.5 ha

Hypsometric Curves

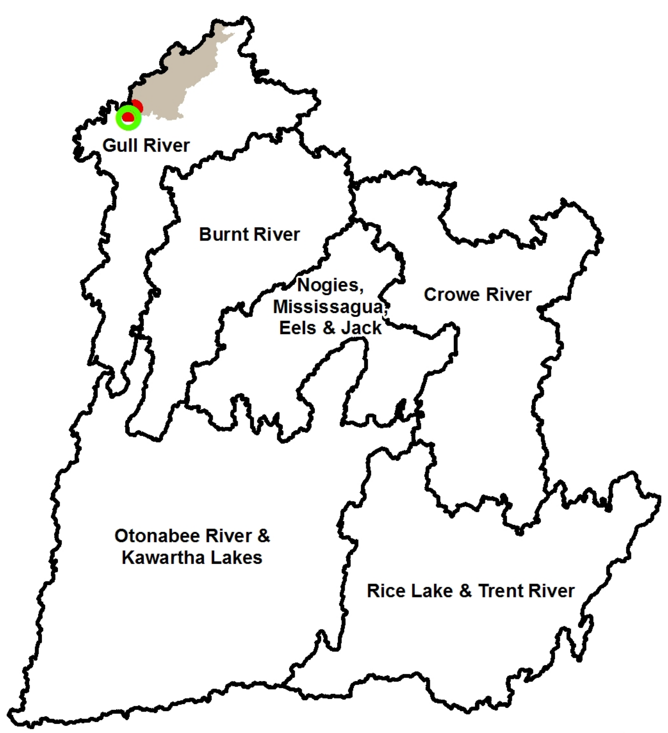


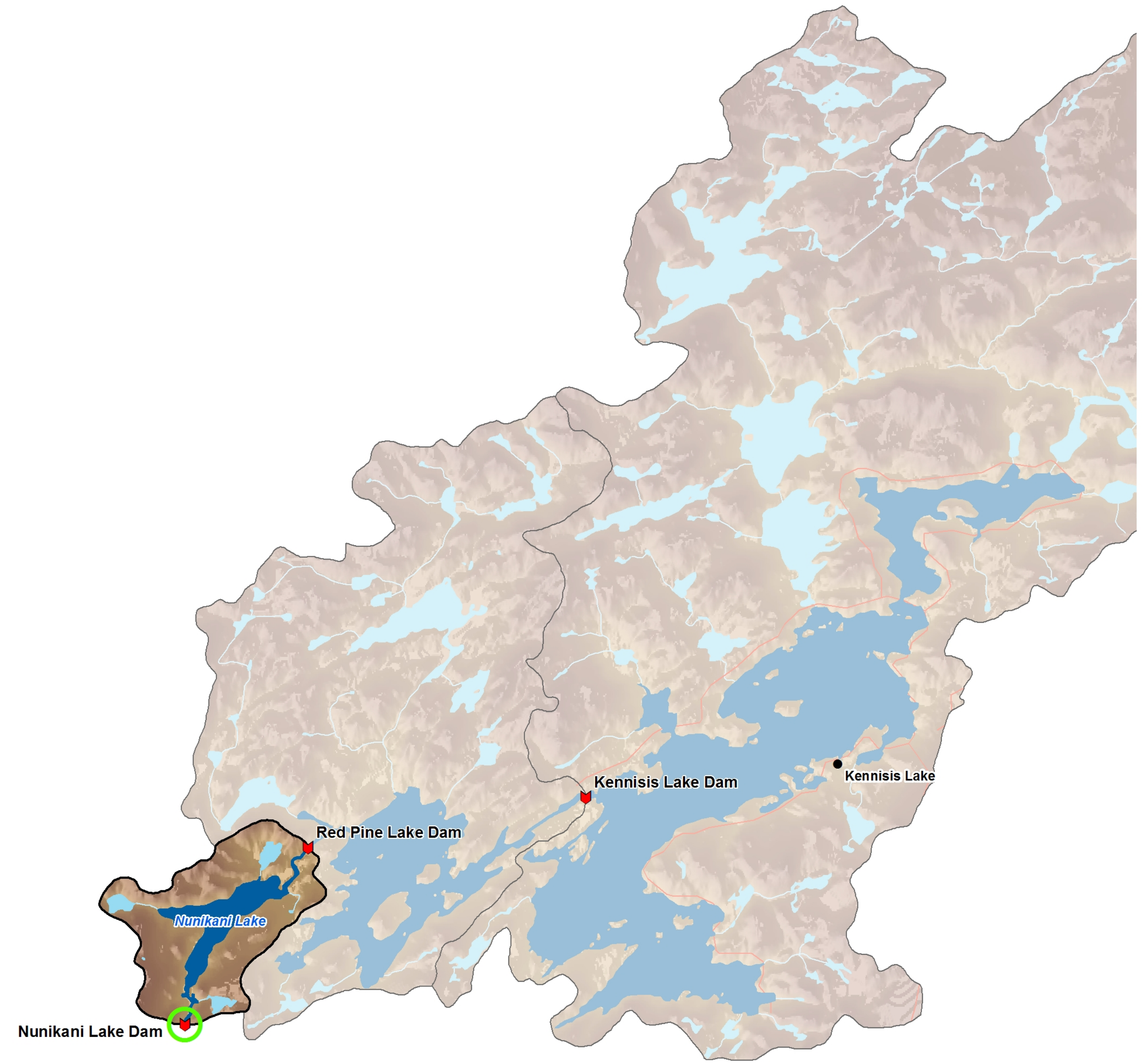


Nunikani Lake Dam

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream





1: 100 000

0 1 2 3 4 5 km

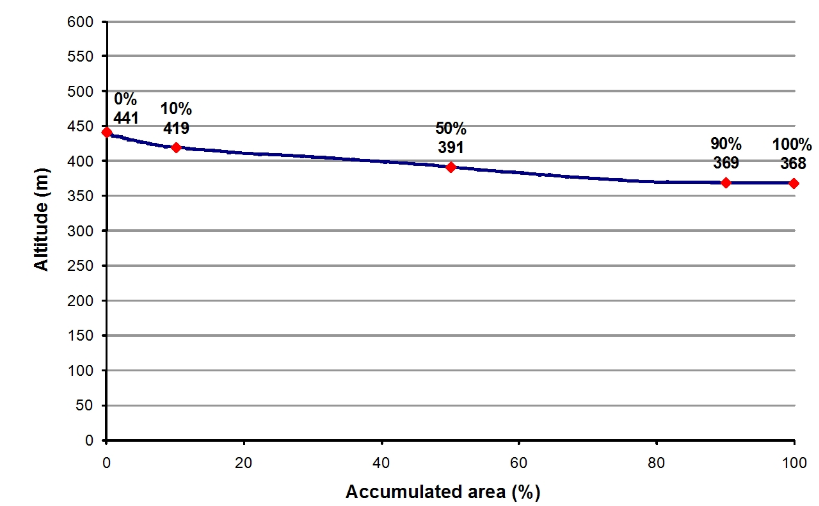
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	6.18	191.21	km²
Maximum elevation	441	551	m
Minimum elevation	368	368	m
Maximum vertical difference	73	183	m

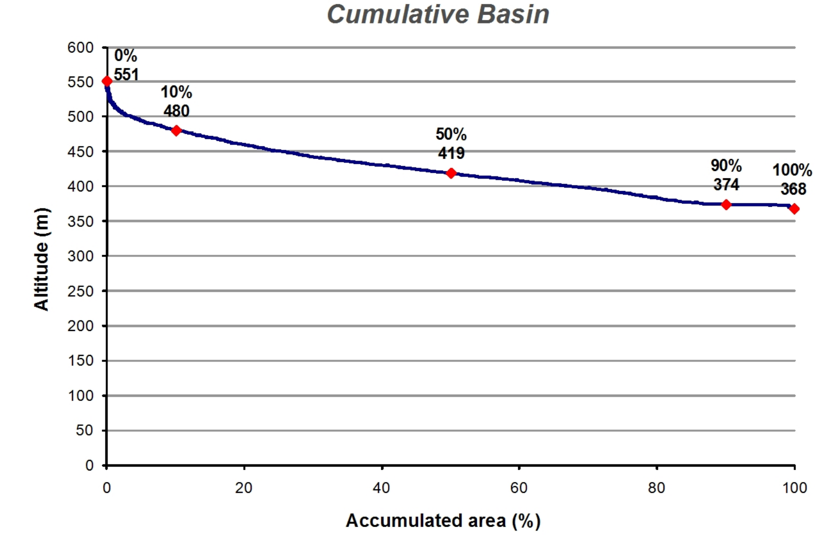
Lakes and reservoirs	Area	
Nunikani Lake	108.6	ha

Hypsometric Curves

Intermediate Sub-basin



Cumulative Basin

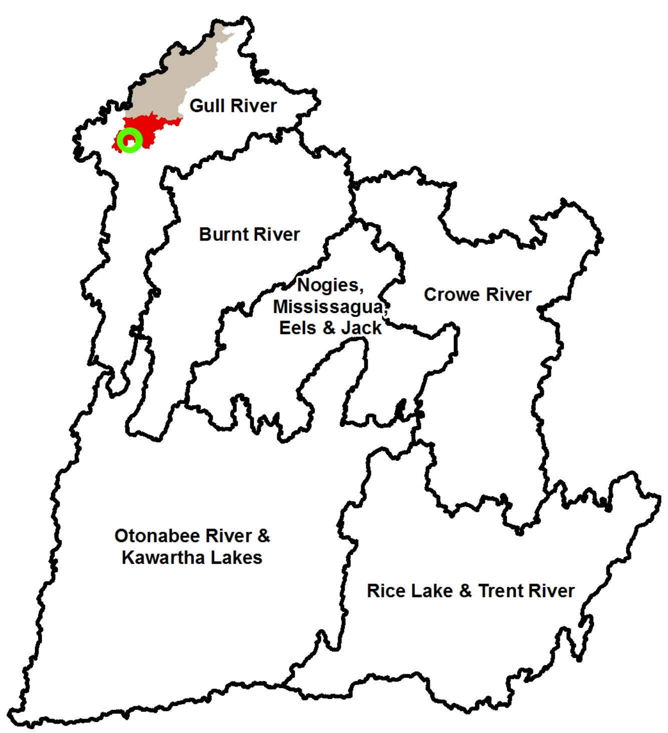


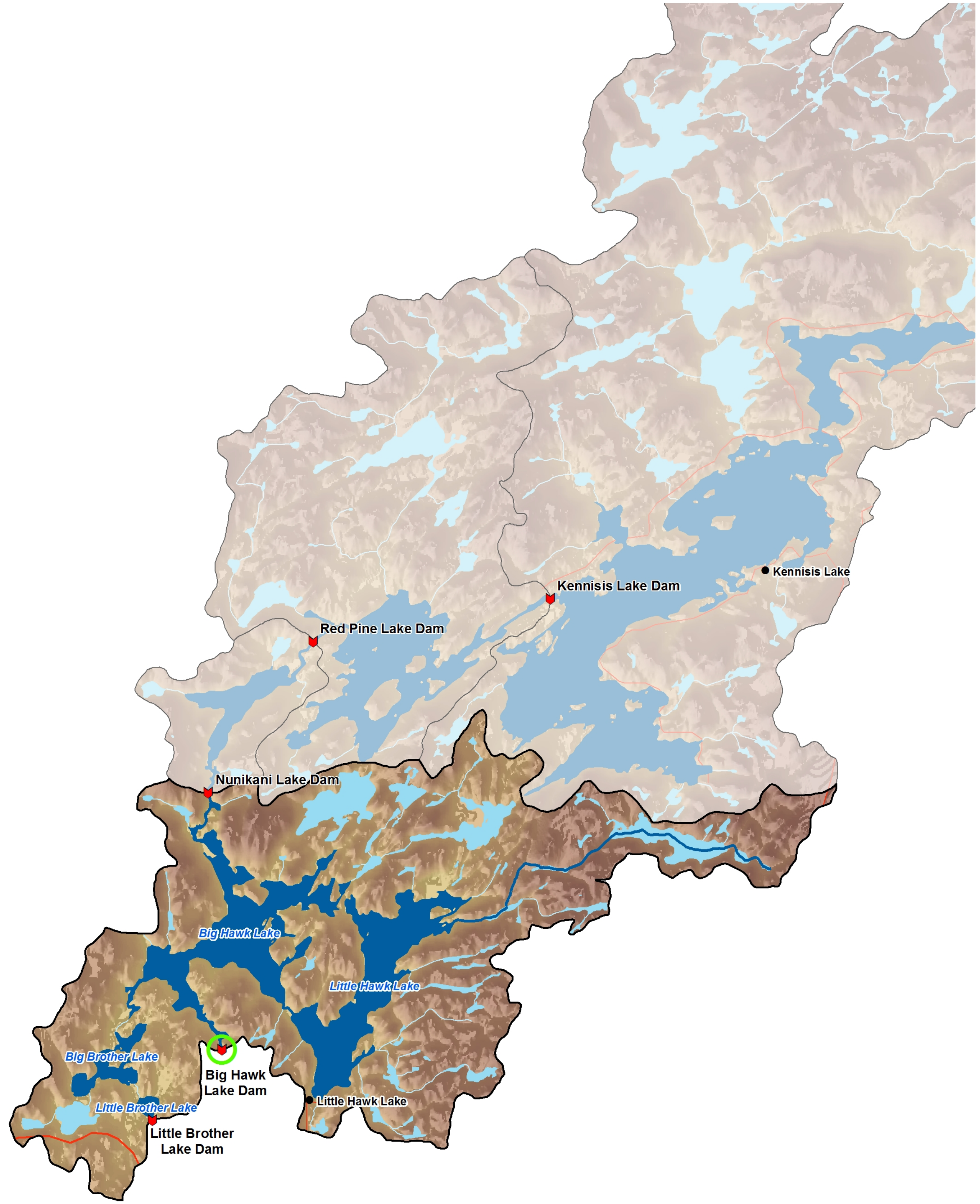
Map 4 — Hawk Lake and Little Brother Lake Dams

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream





1: 100 000

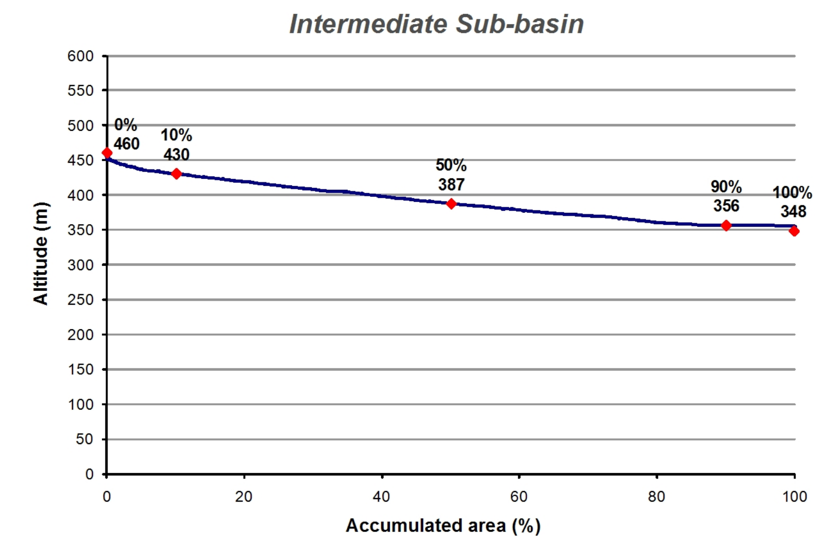
0 1 2 3 4 5 km

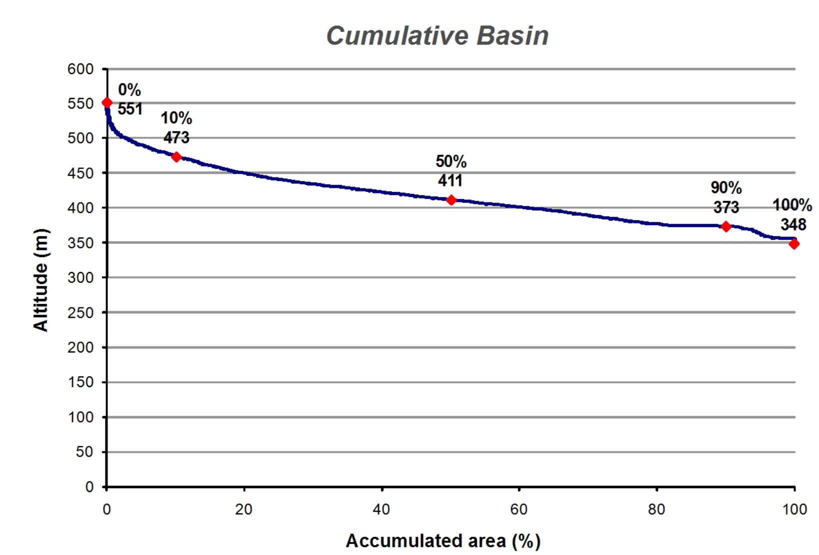
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	56.71	247.92	km²
Maximum elevation	460	551	m
Minimum elevation	348	348	m
Maximum vertical difference	112	203	m

Lakes and reservoirs	Area	
Big Hawk Lake	387.3	ha
Little Hawk Lake	345.5	ha
Big Brother Lake	60.5	ha
Little Brother Lake	13.2	ha

Hypsometric Curves



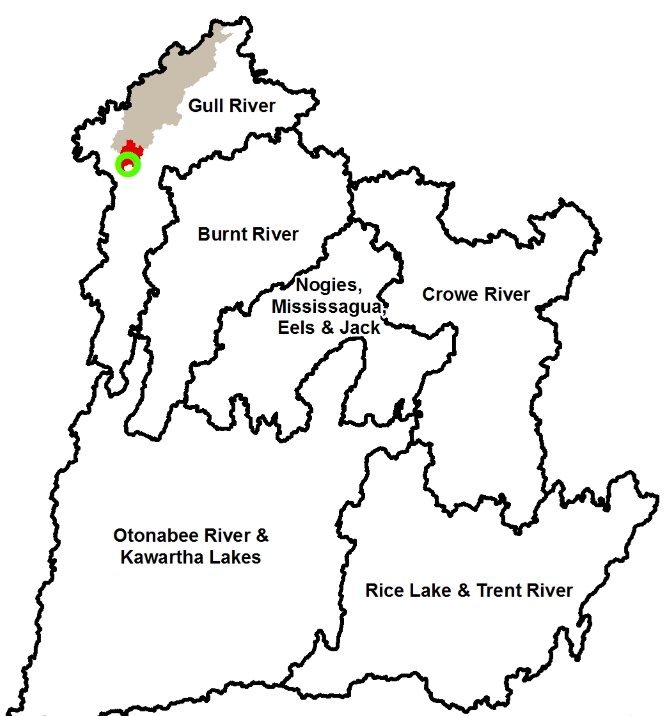


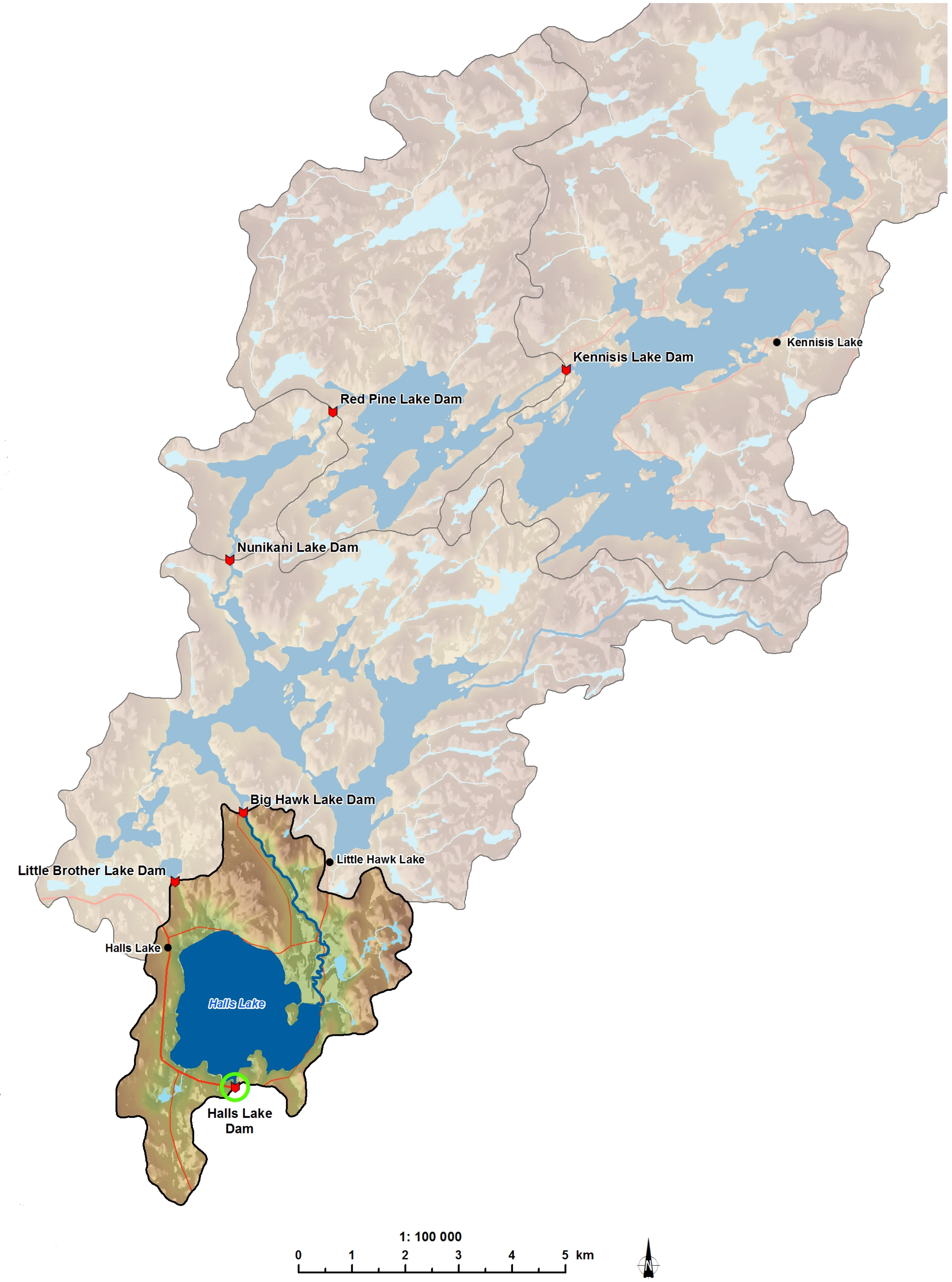
Halls Lake Dam

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



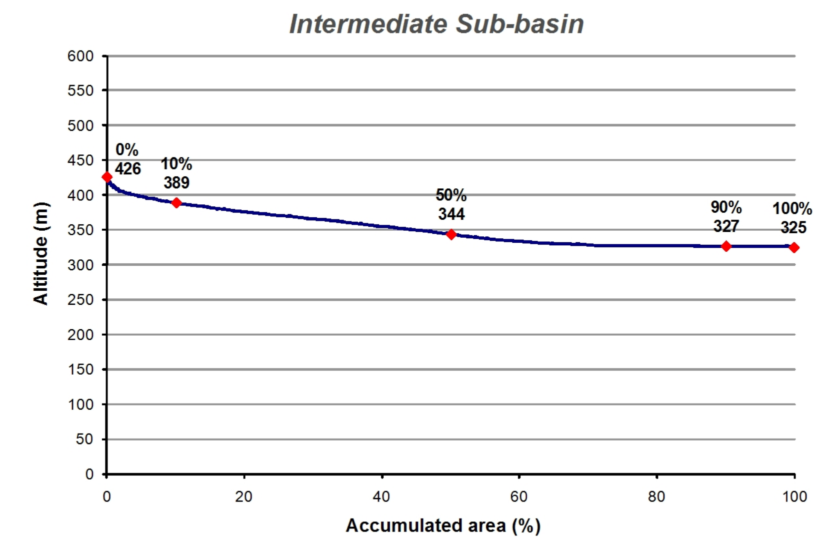


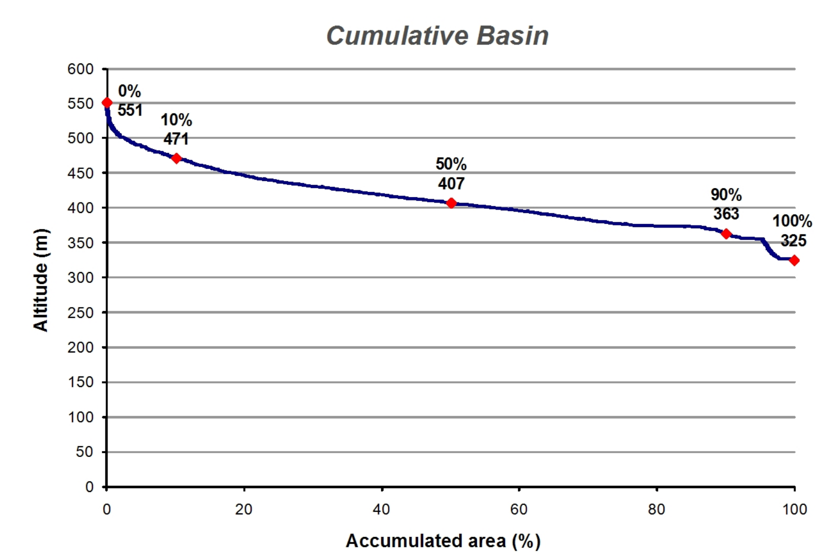
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	21.07	268.99	km²
Maximum elevation	426	551	m
Minimum elevation	325	325	m
Maximum vertical difference	101	226	m

Lakes and reservoirs	Area	
Halls Lake	542.3	ha

Hypsometric Curves

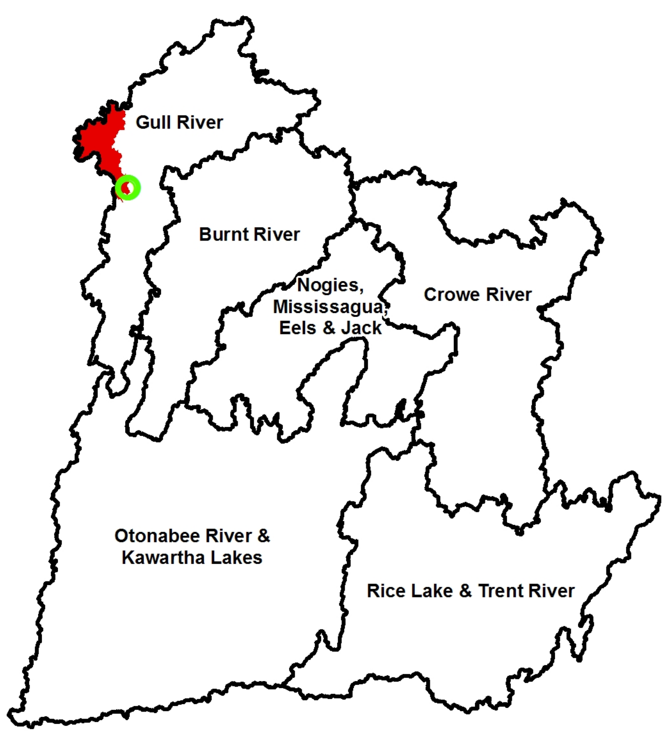


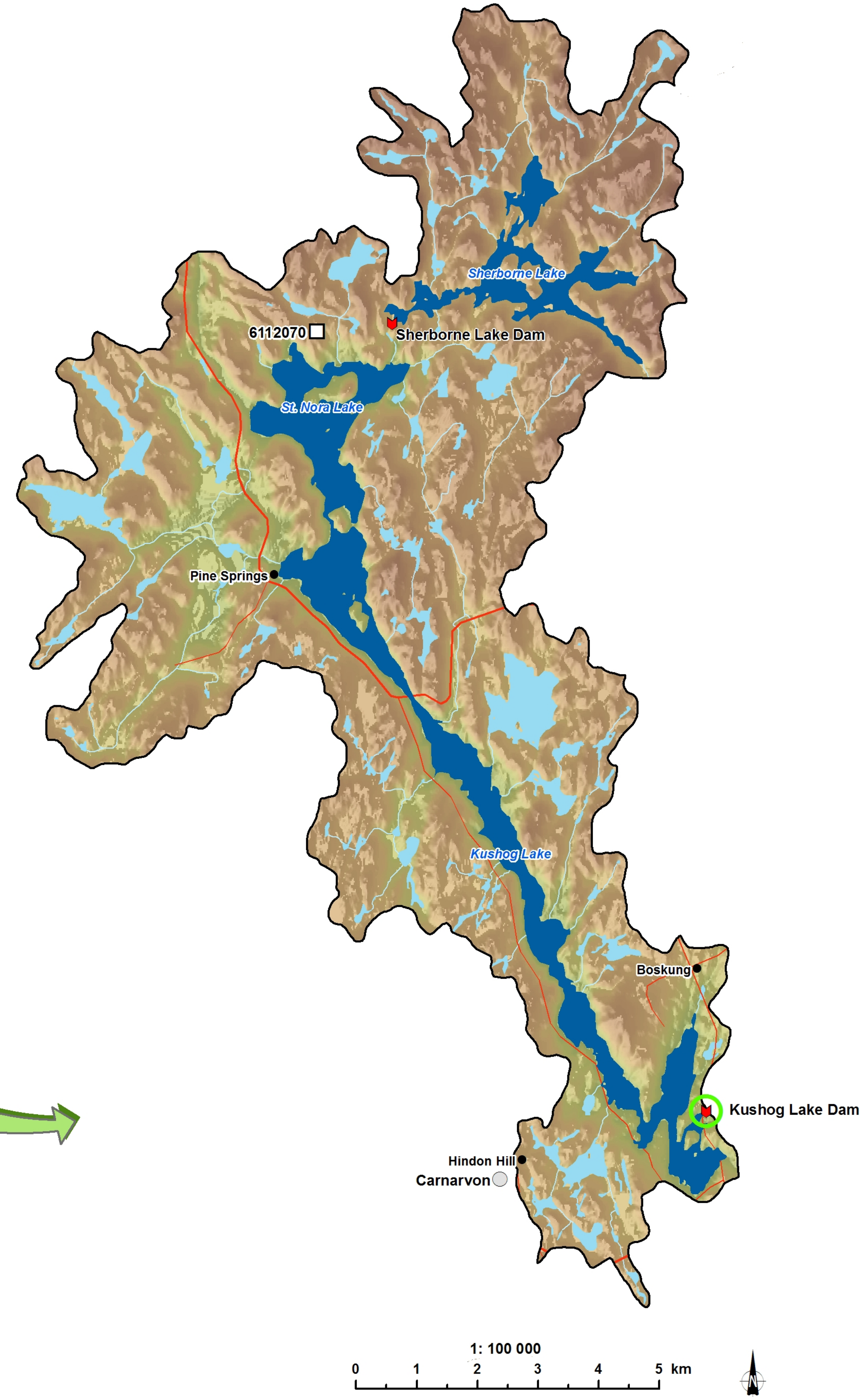


Map 6 Kushog Lake (including St. Nora Lake) and Sherborne Lake Dams

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



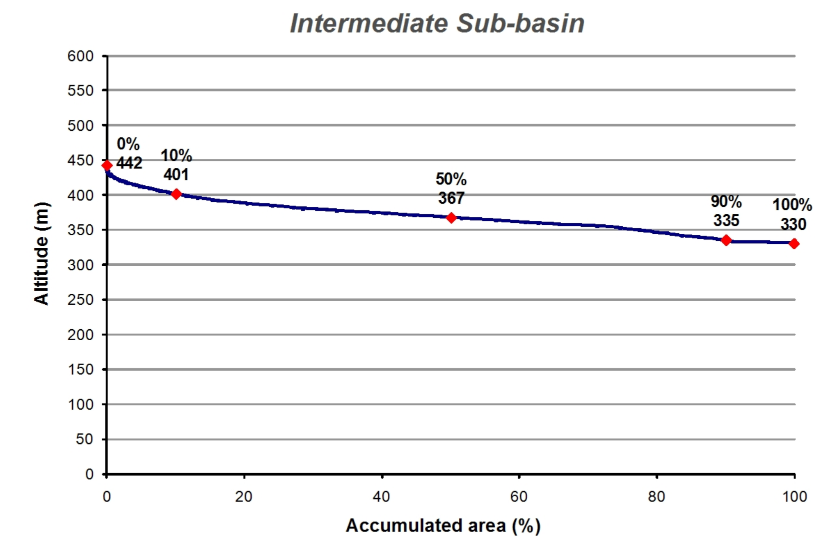


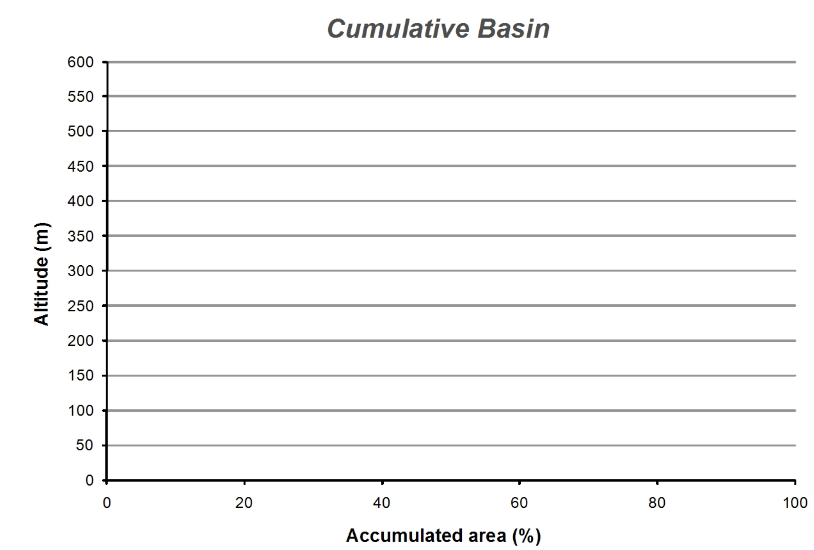
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	109.14	-	km²
Maximum elevation	442	-	m
Minimum elevation	330	-	m
Maximum vertical difference	112	-	m

Lakes and reservoirs	Area	
Kushog Lake	638.1	ha
Sherborne Lake	242.5	ha
St. Nora Lake	269.3	ha

Hypsometric Curves



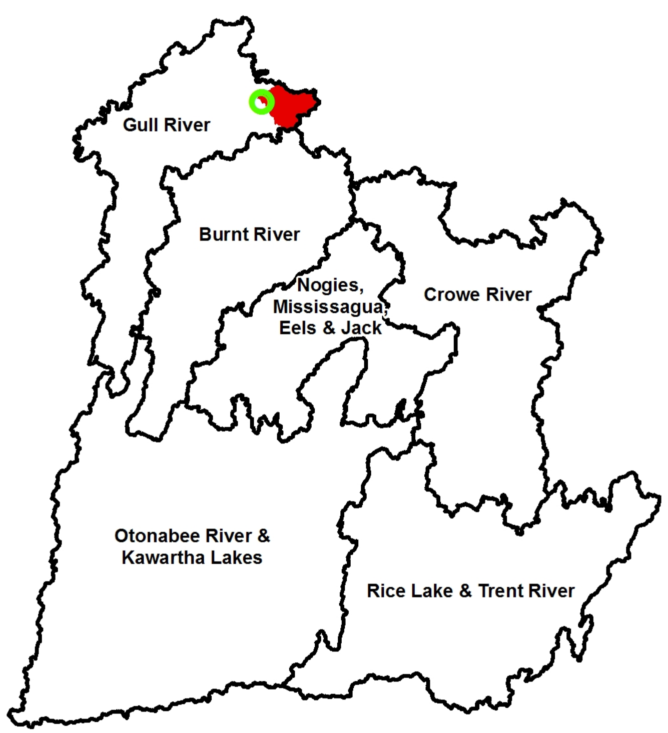


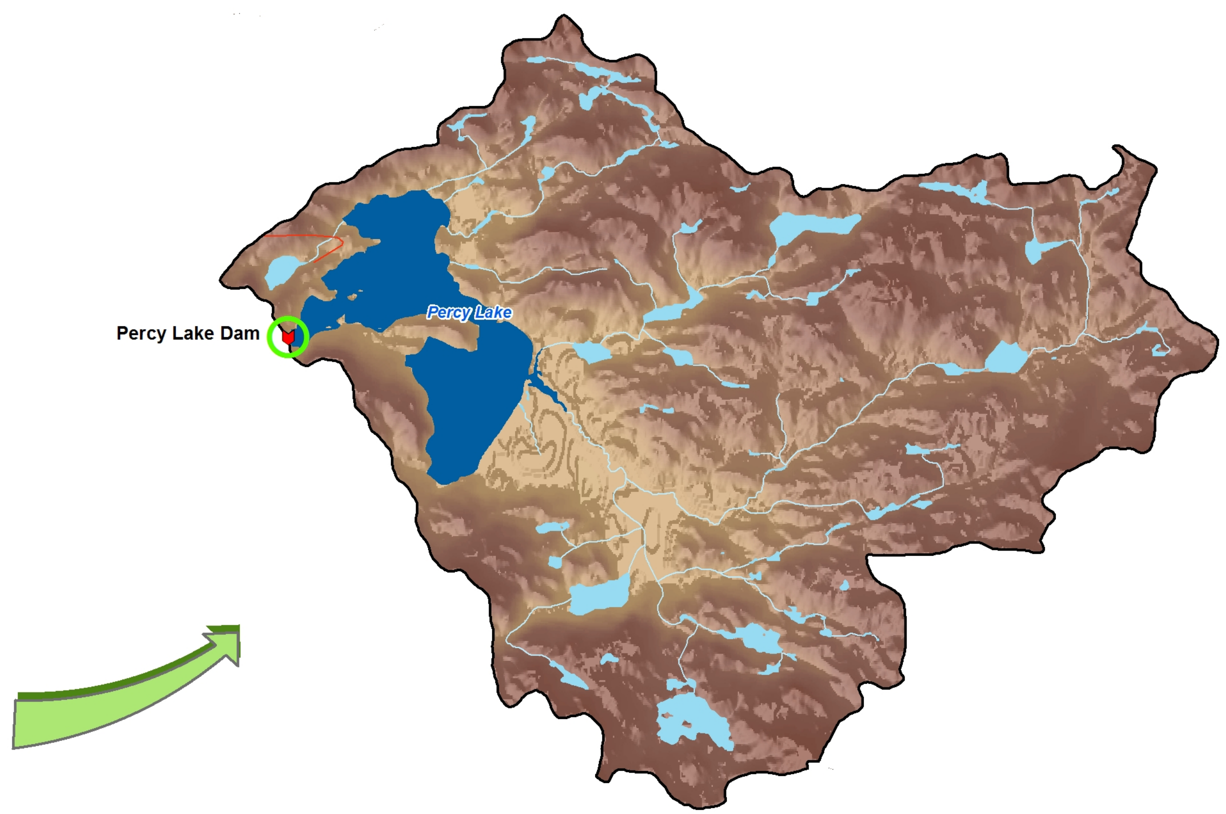
Percy Lake Dam

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



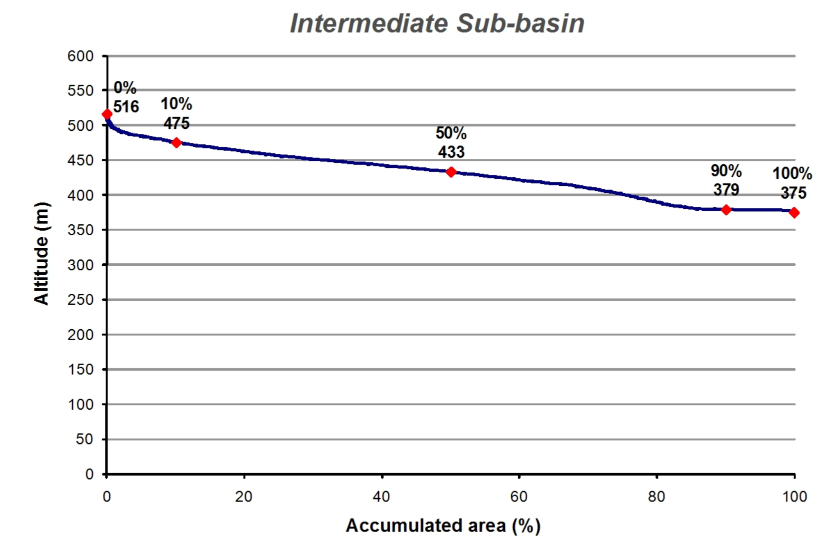


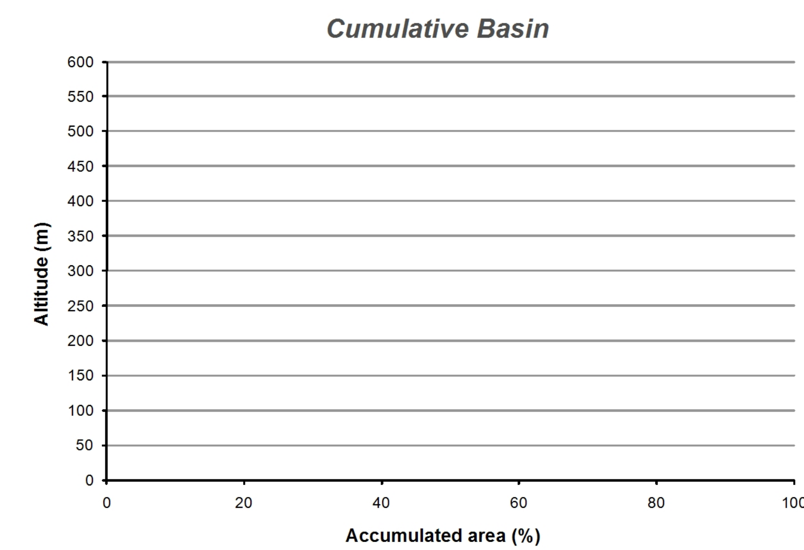
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	72.14	-	km²
Maximum elevation	516	-	m
Minimum elevation	375	-	m
Maximum vertical difference	141	-	m

Lakes and reservoirs	Area
Percy Lake	487.2 ha

Hypsometric Curves

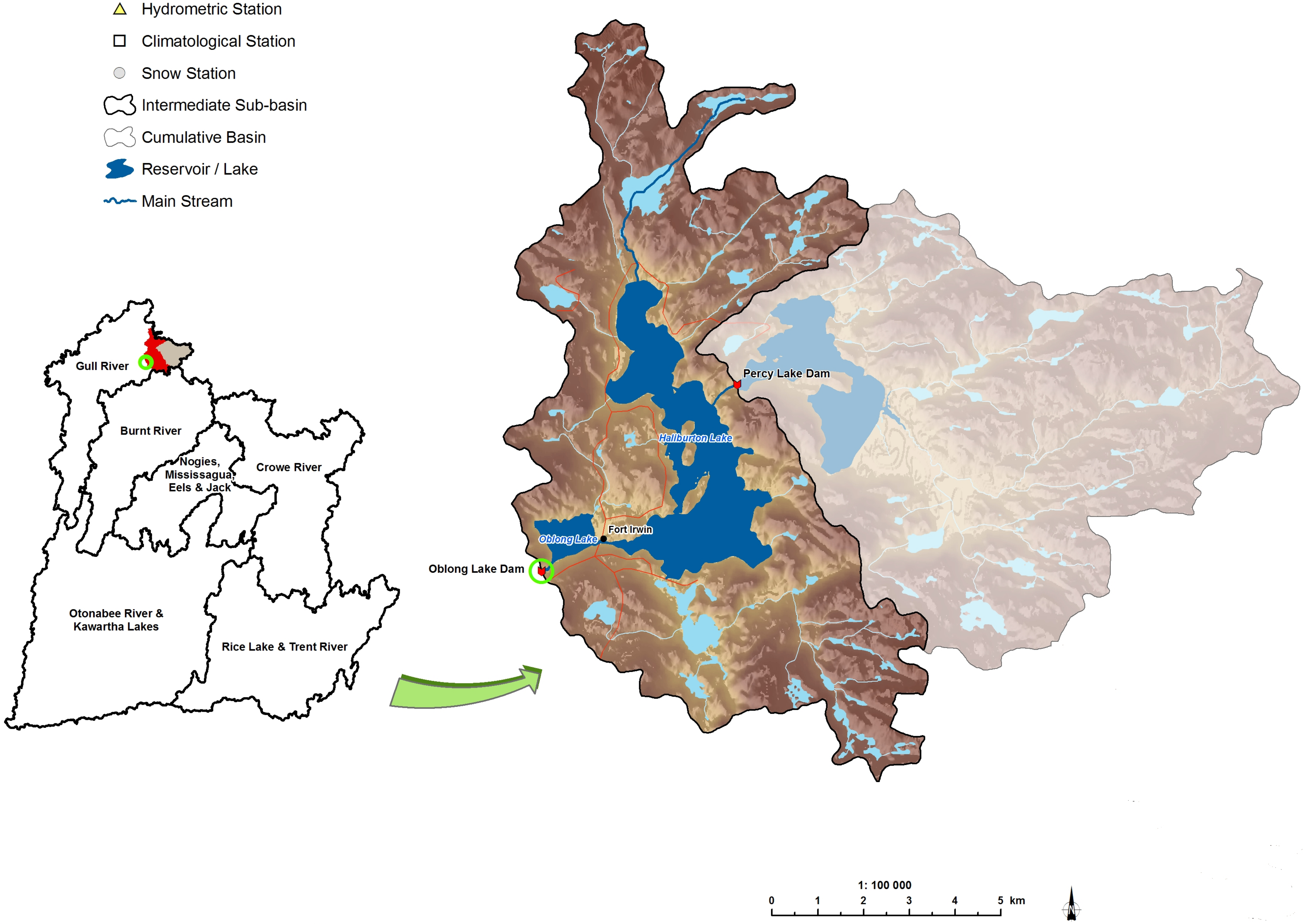




Oblong Lake Dam (including Haliburton Lake)

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream

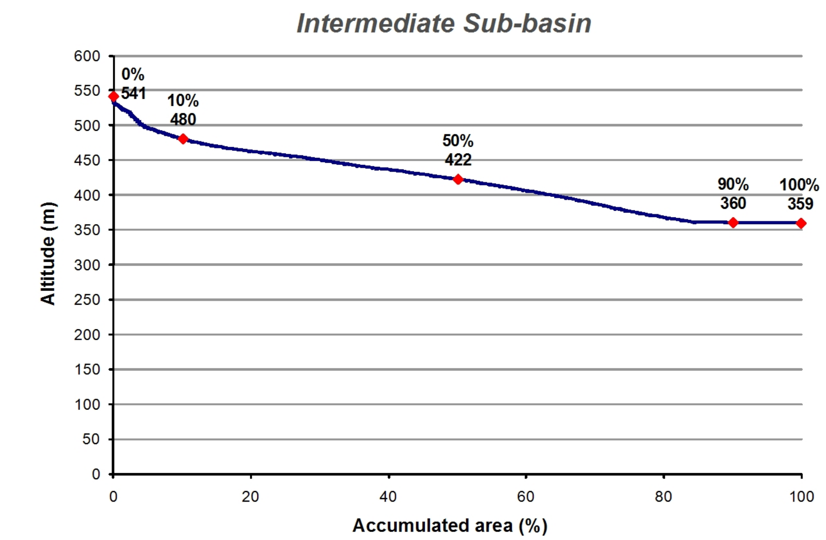


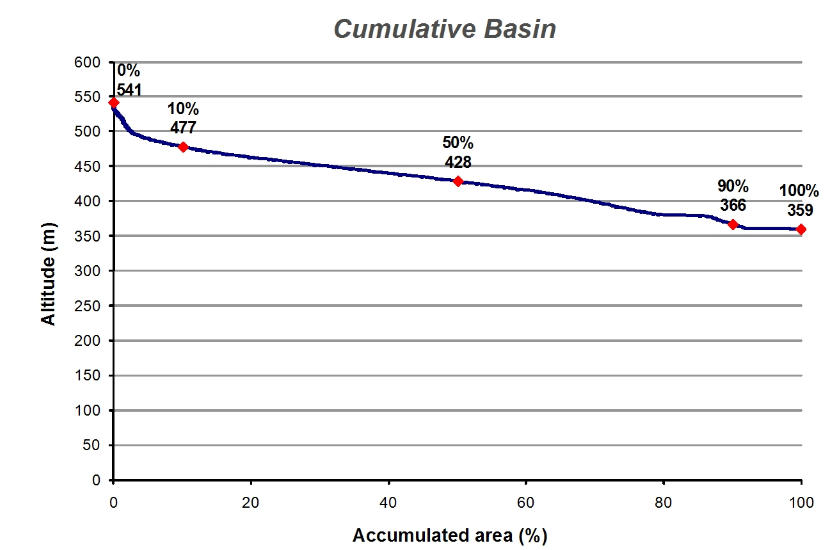
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	77.73	149.88	km²
Maximum elevation	541	541	m
Minimum elevation	359	359	m
Maximum vertical difference	182	182	m

Lakes and reservoirs	Area	
Oblong Lake	89.3	ha
Haliburton Lake	917.9	ha

Hypsometric Curves

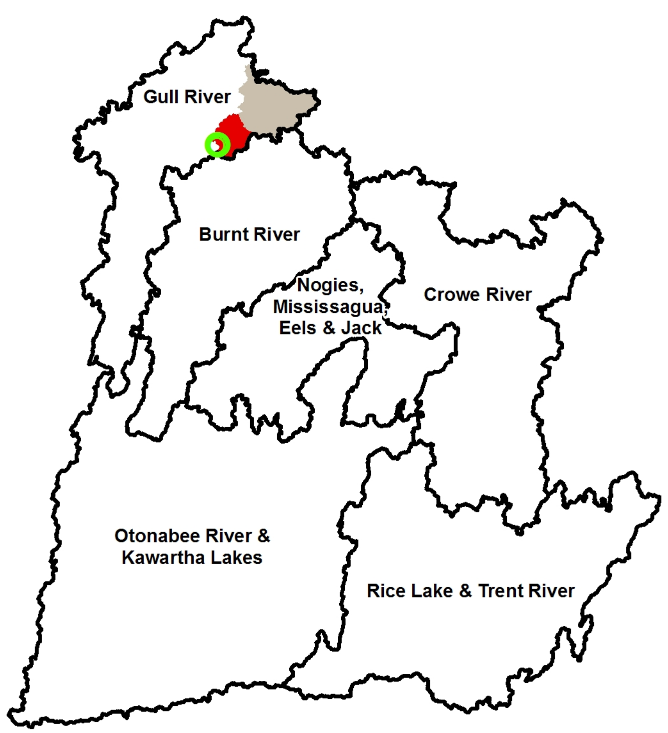


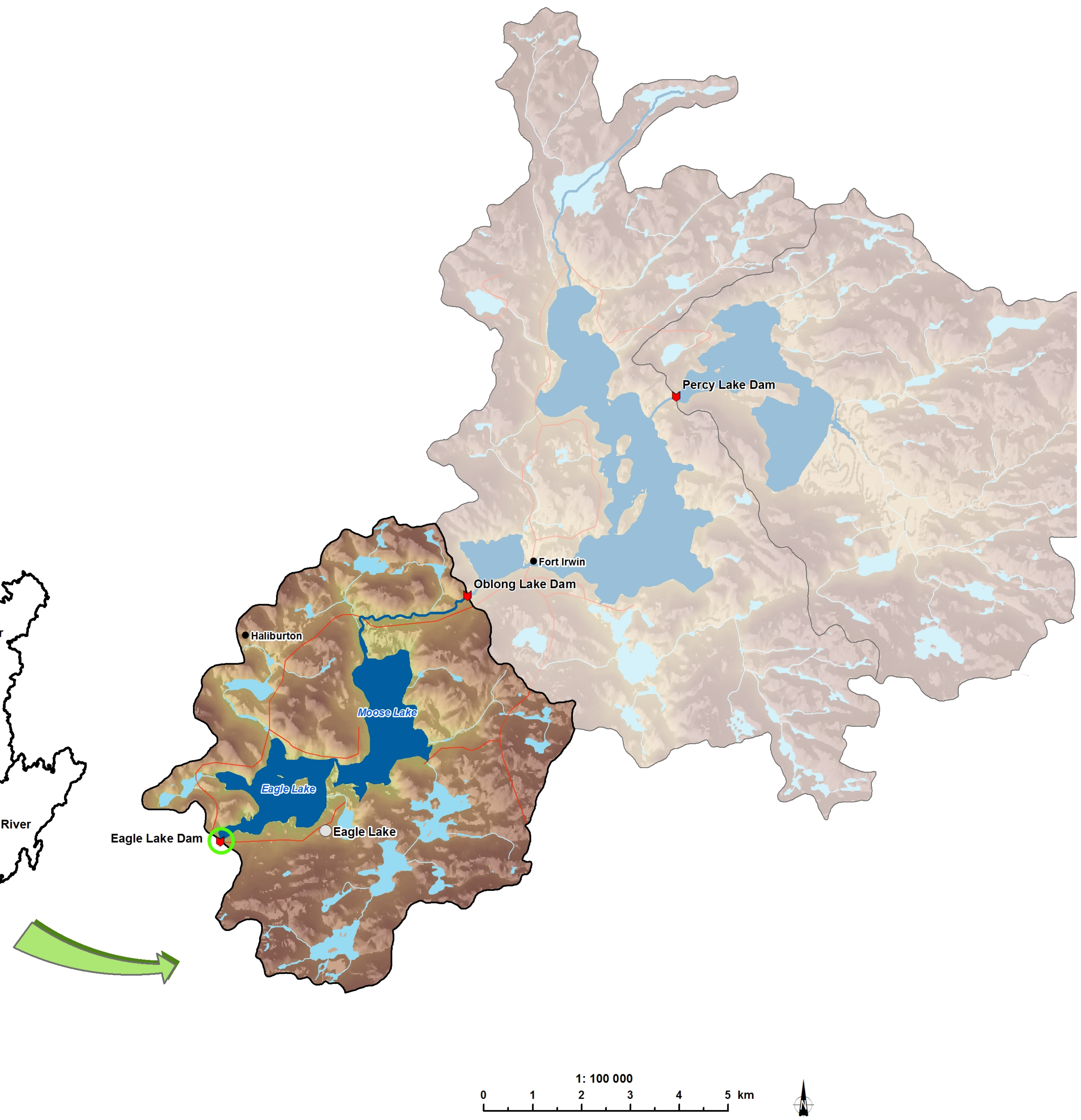


Eagle Lake Dam (including Moose Lake)

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



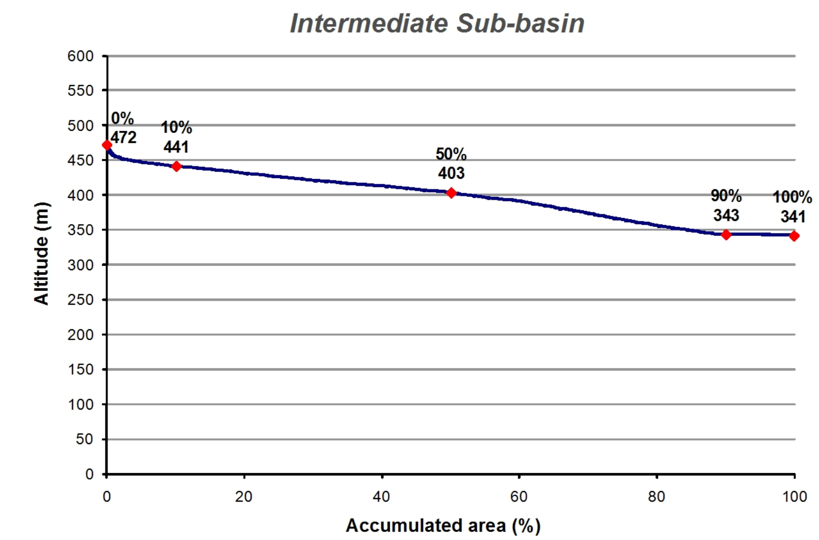


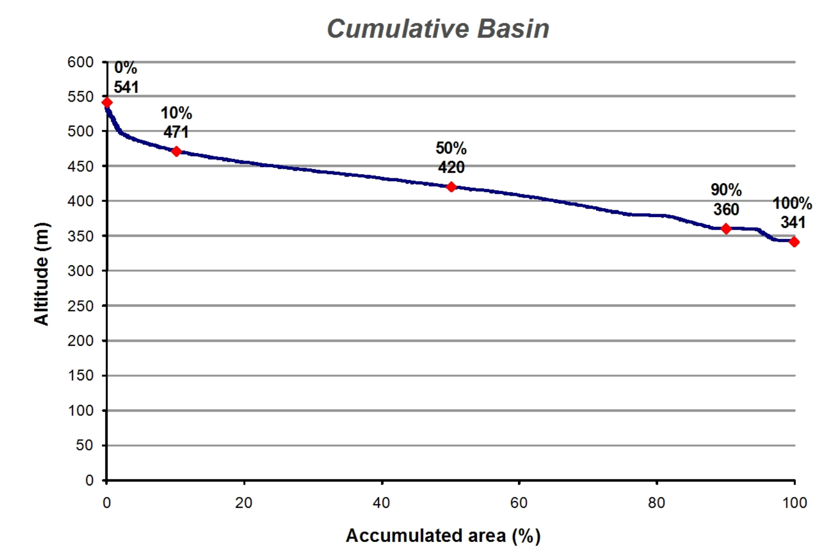
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin
Area	49.26	199.14 km²
Maximum elevation	472	541 m
Minimum elevation	341	341 m
Maximum vertical difference	131	200 m

Lakes and reservoirs	Area
Eagle Lake	234.2 ha
Moose Lake	286.9 ha

Hypsometric Curves

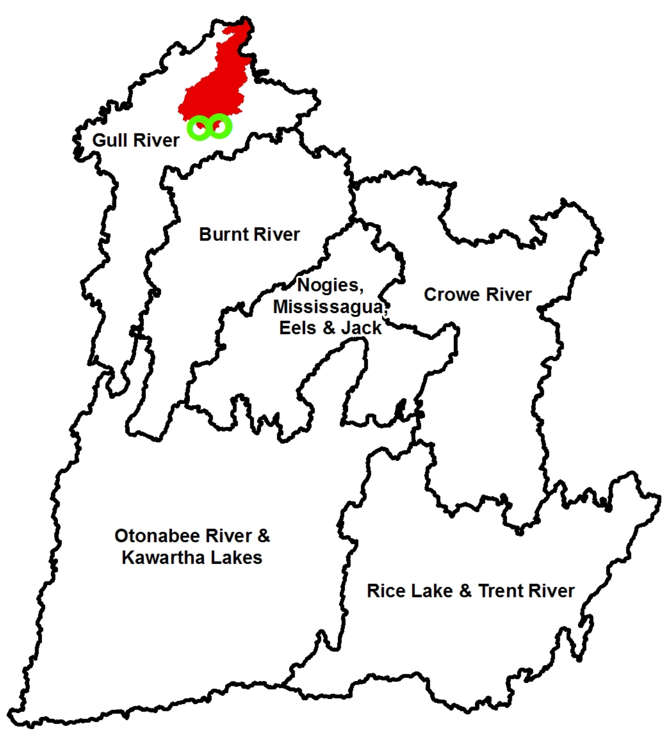




Redstone Lake East and West Dams

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



1: 200 000

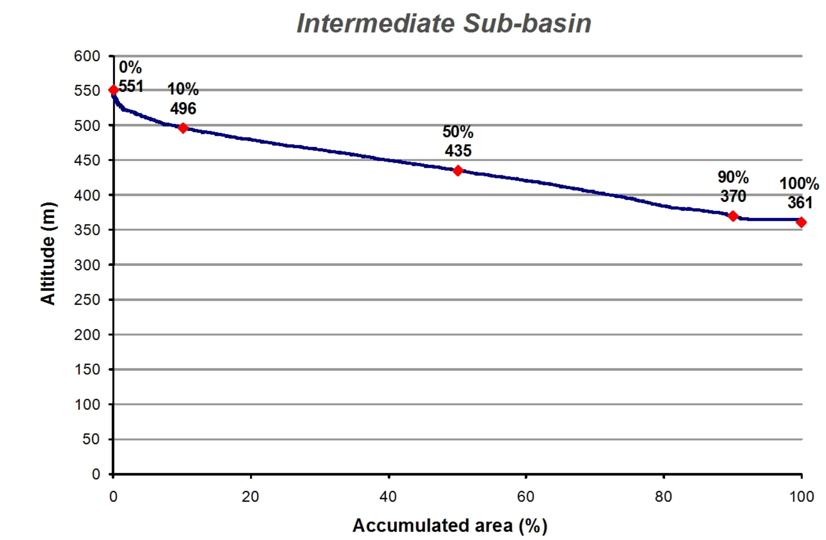
0 2 4 6 8 10 km

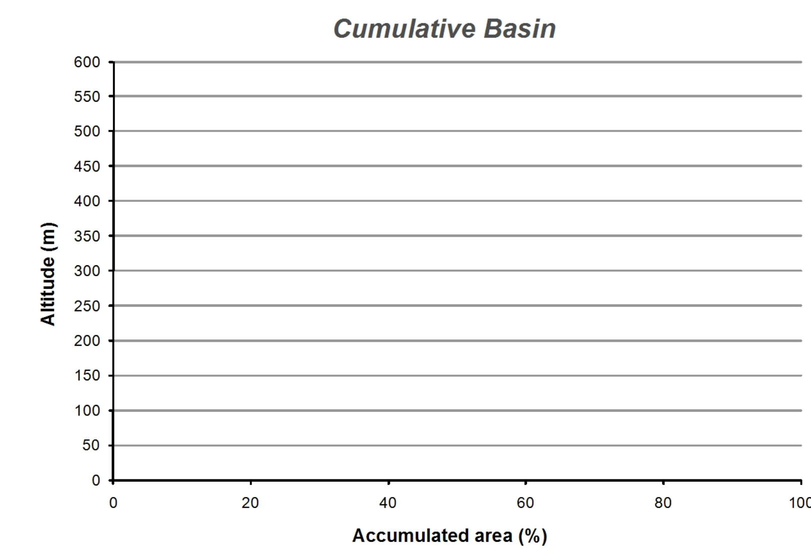
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	183.18	-	km²
Maximum elevation	551	-	m
Minimum elevation	361	-	m
Maximum vertical difference	190	-	m

Lakes and reservoirs	Area	
Redstone Lake	1164.2	ha
Little Redstone Lake	249.5	ha
Pelaw Lake	22.1	ha

Hypsometric Curves

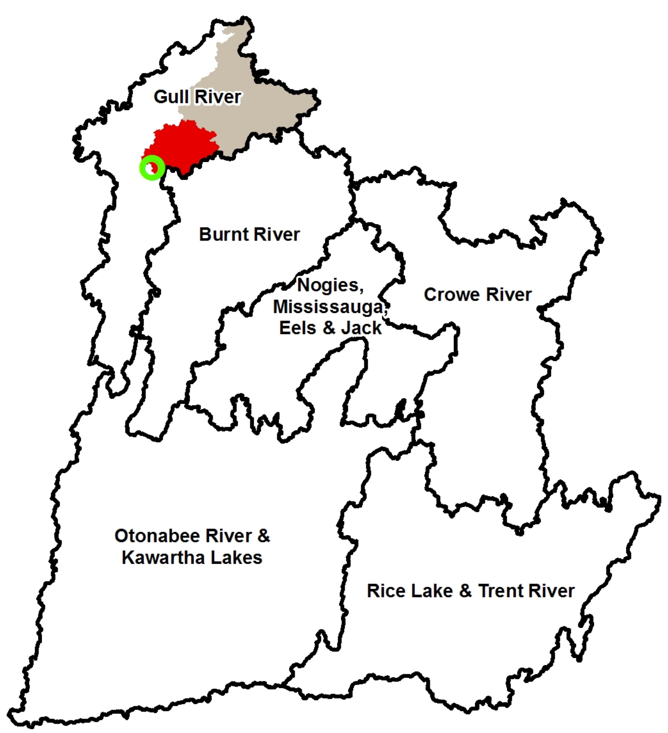


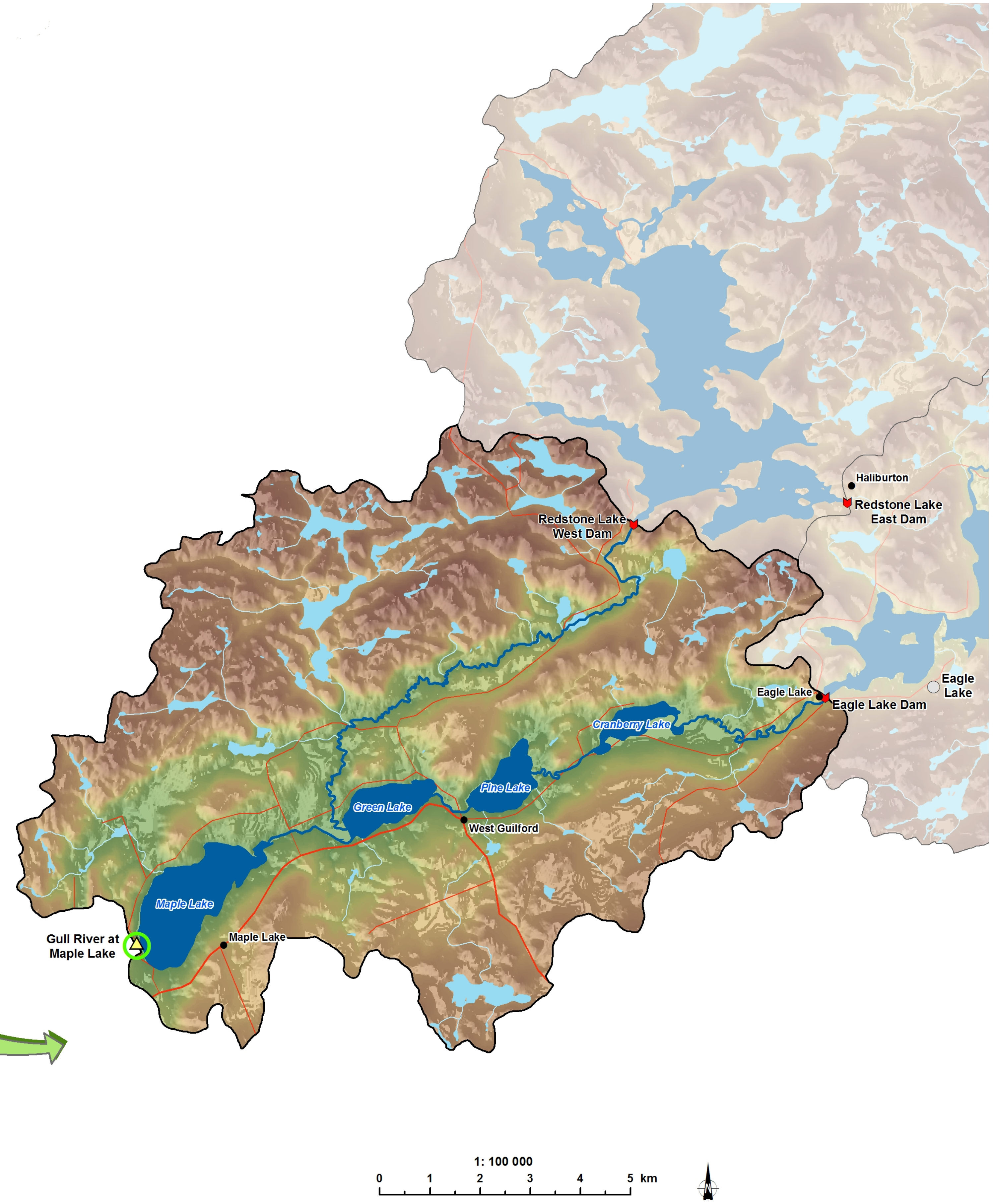


Gull River at Maple Lake

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



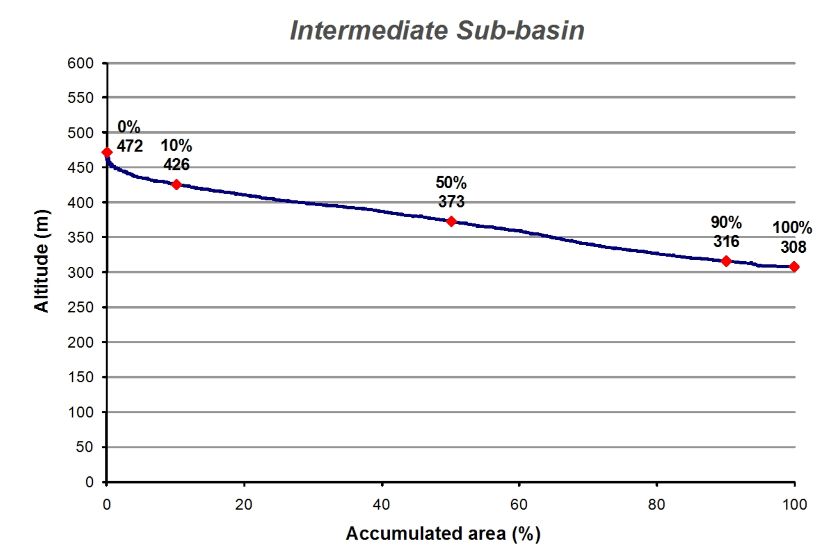


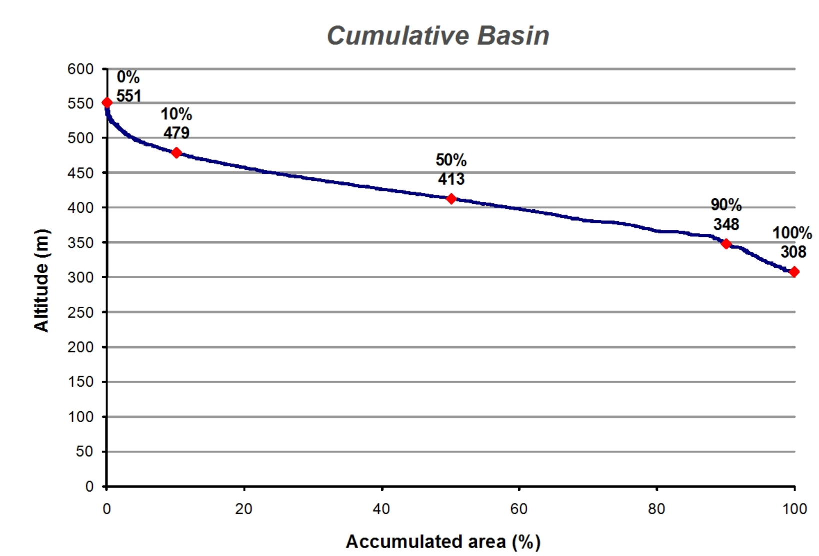
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	126.72	509.04	km²
Maximum elevation	472	551	m
Minimum elevation	308	308	m
Maximum vertical difference	164	243	m

Lakes and reservoirs	Area	
Maple Lake	330.1	ha
Green Lake	133.6	ha
Pine Lake	112.7	ha
Cranberry Lake	75.3	ha

Hypsometric Curves

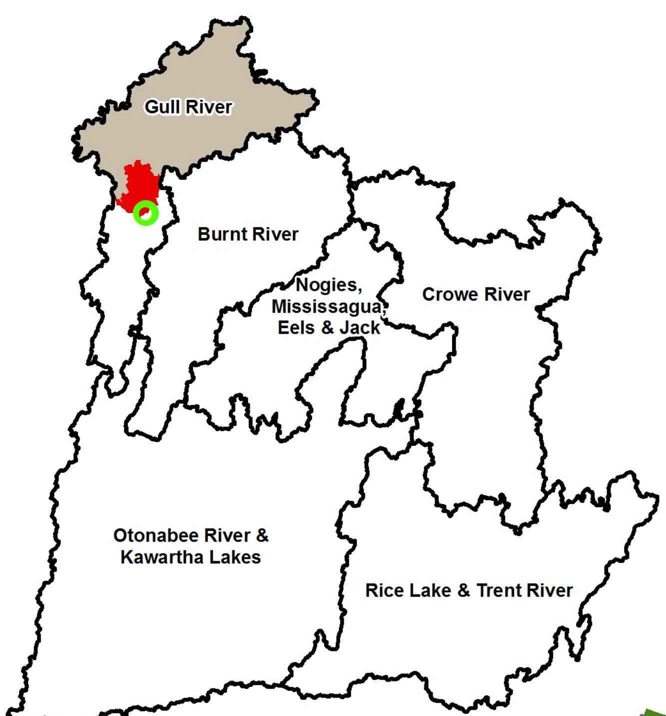


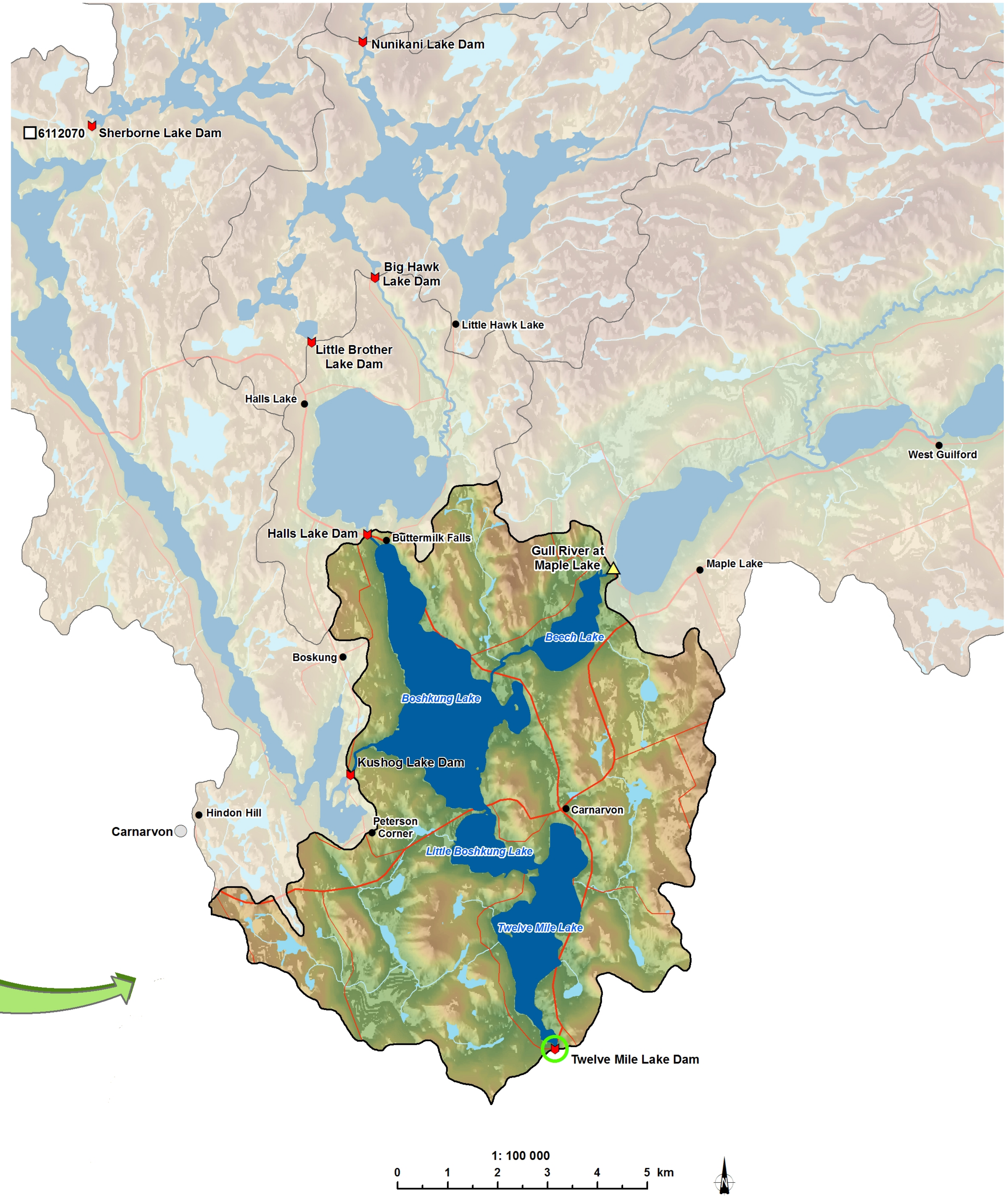


Map 12 Twelve Mile Lake Dam (including Boshkung, Little Boshkung and Beech Lakes)

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



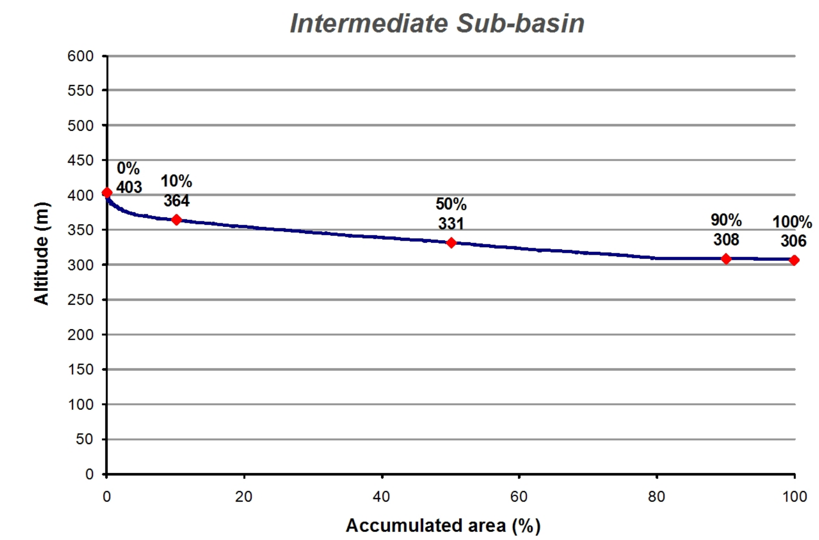


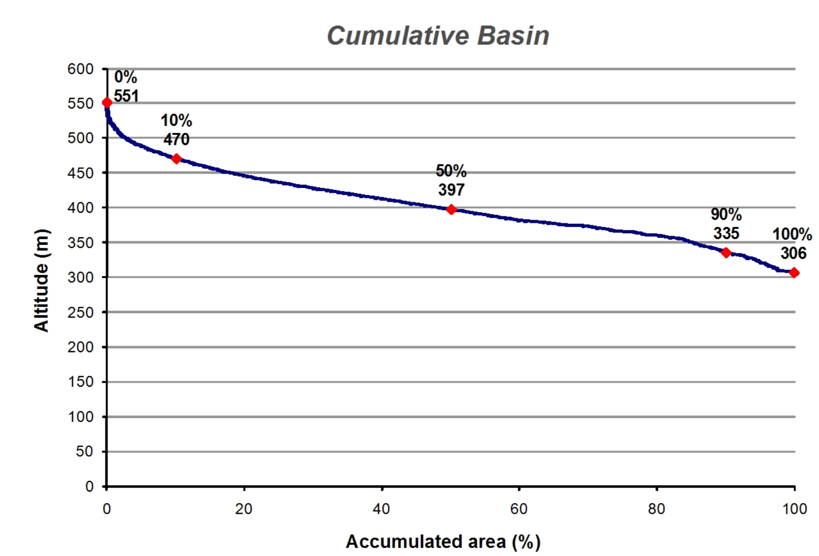
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	72.10	959.28	km²
Maximum elevation	403	551	m
Minimum elevation	306	306	m
Maximum vertical difference	97	245	m

Lakes and reservoirs	Area	
Twelve Mile Lake	347.6	ha
Little Boshkung Lake	128.5	ha
Boshkung Lake	691.8	ha
Beech Lake	138.1	ha

Hypsometric Curves



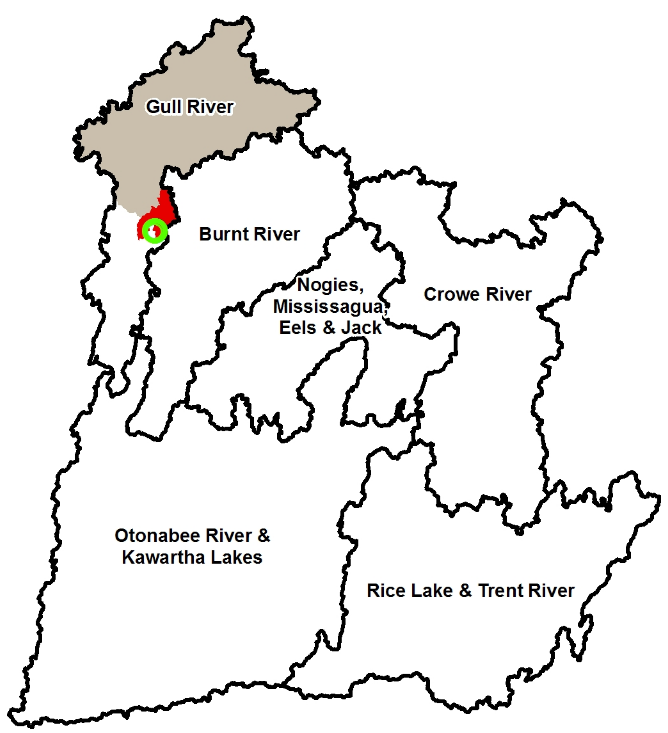


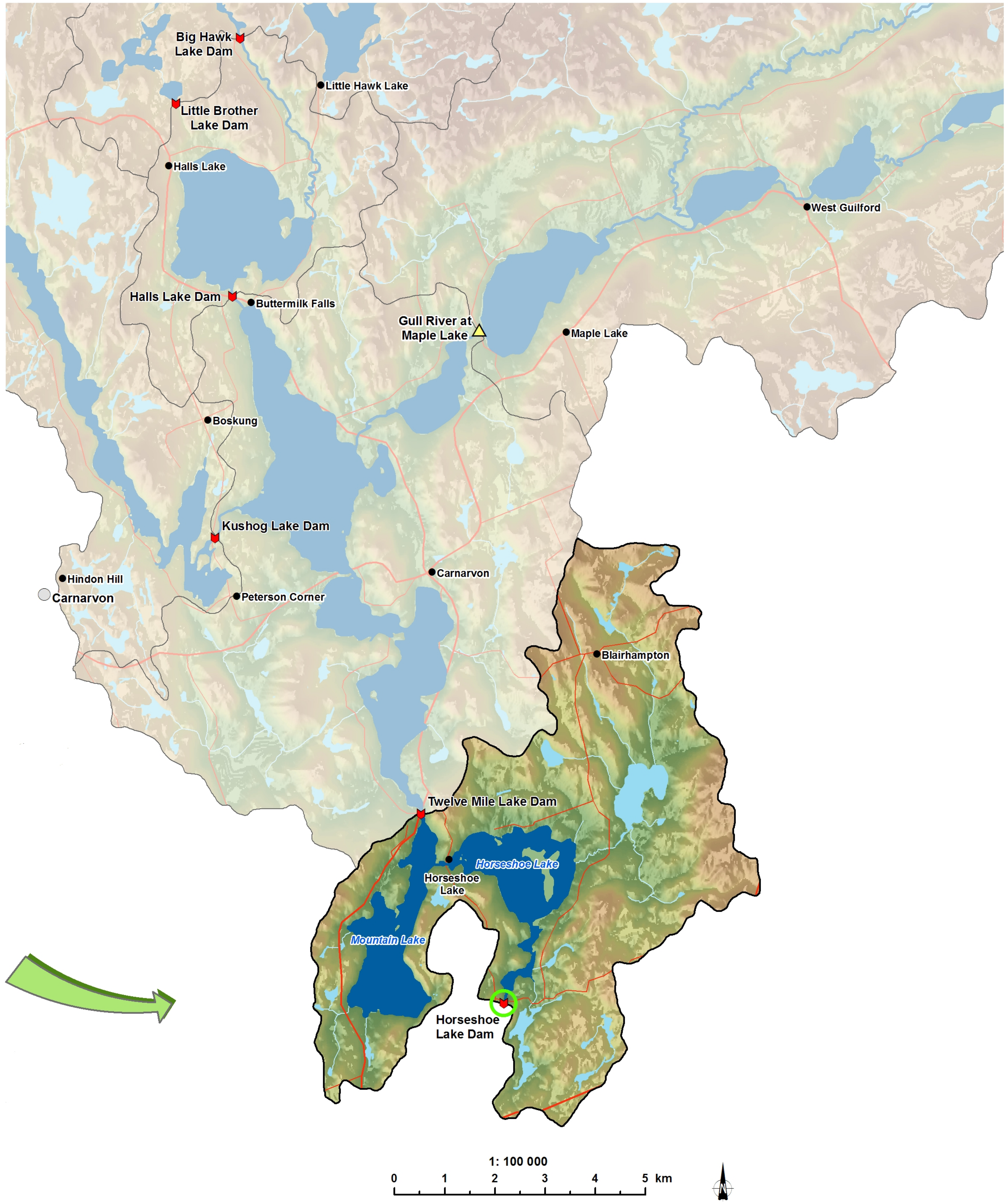
Map 13 Horseshoe Lake Dam (including Mountain Lake)

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



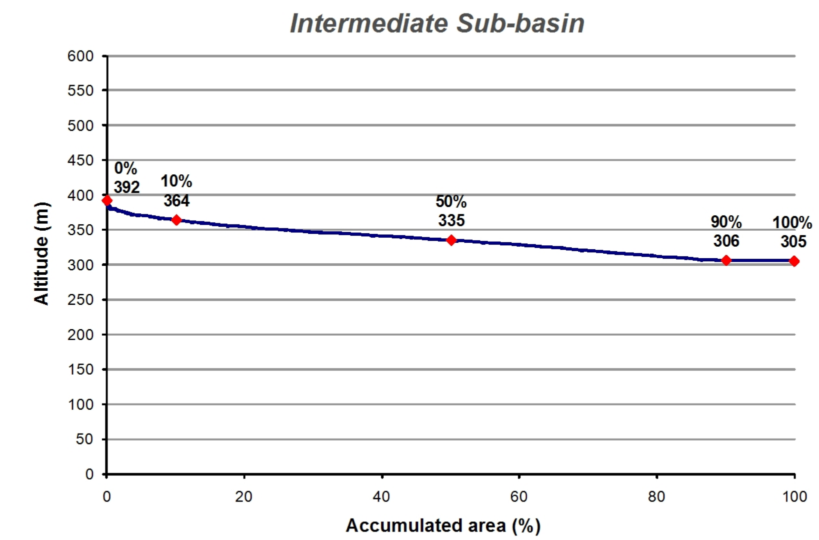


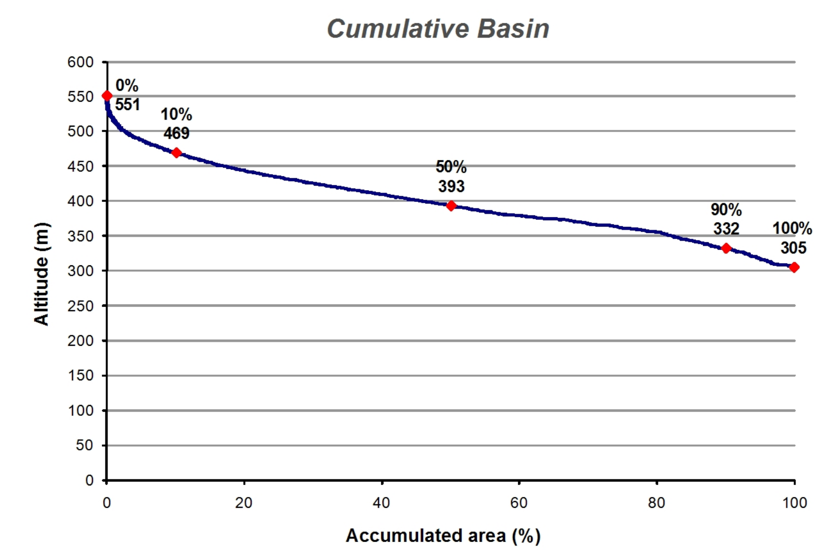
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	50.08	1009.35	km²
Maximum elevation	392	551	m
Minimum elevation	305	305	m
Maximum vertical difference	87	246	m

Lakes and reservoirs	Area	
Horseshoe Lake	299.8	ha
Mountain Lake	320.8	ha

Hypsometric Curves



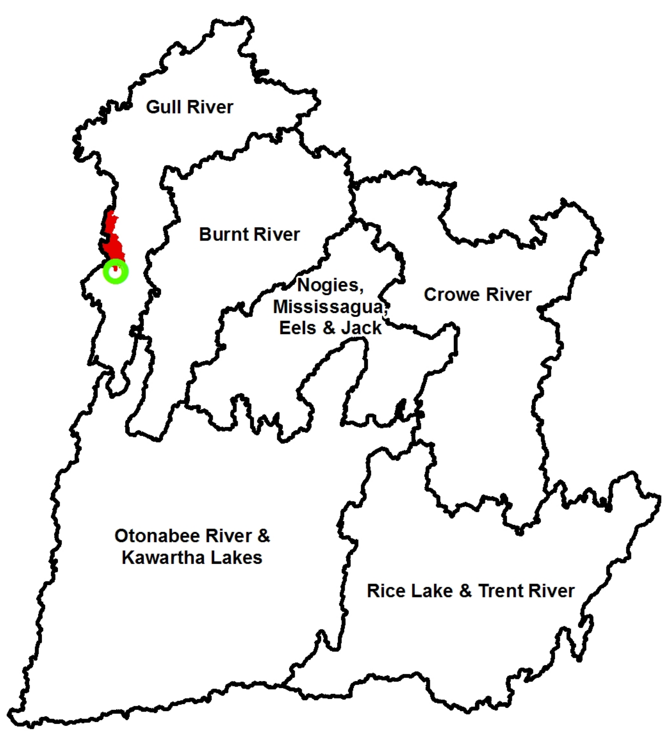


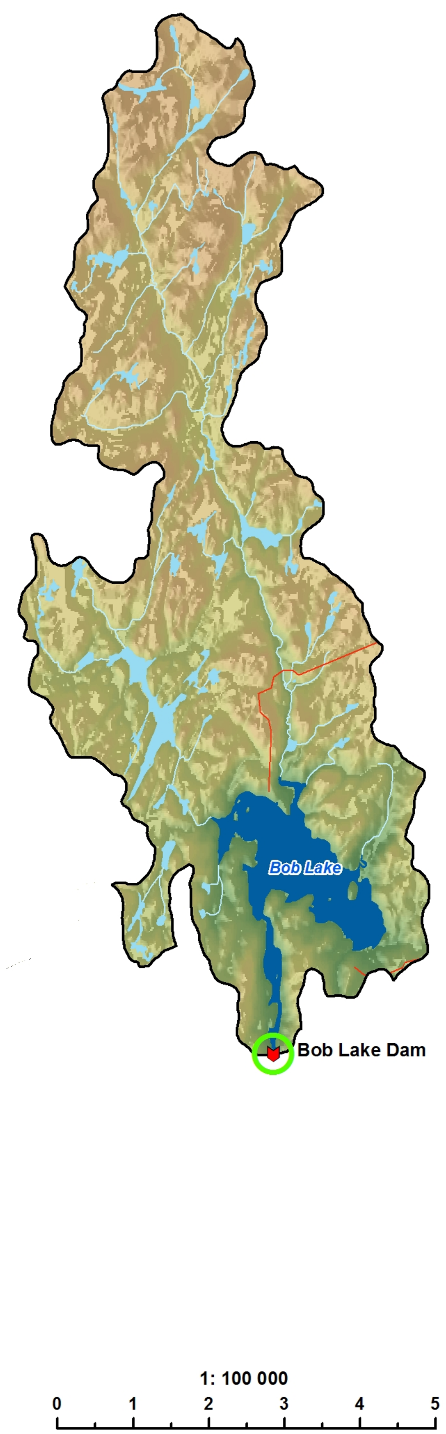
Bob Lake Dam

Trent River Watershed Hydro-Technical Study

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



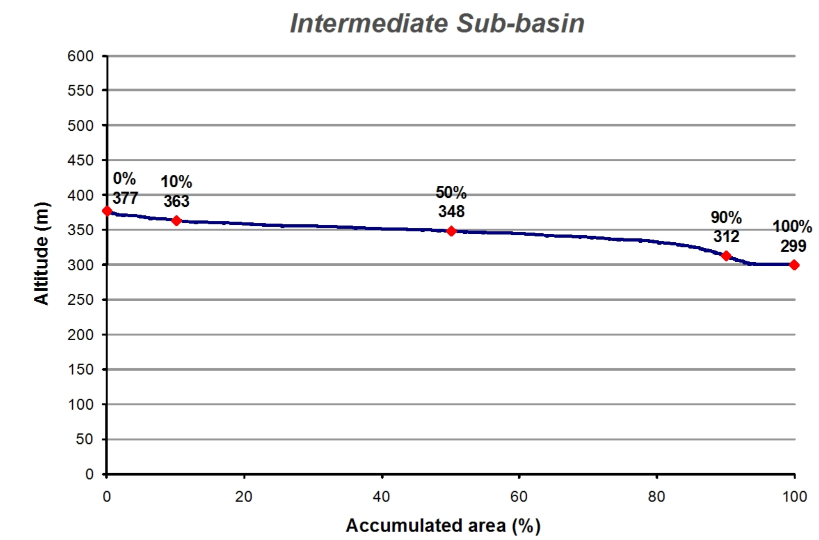


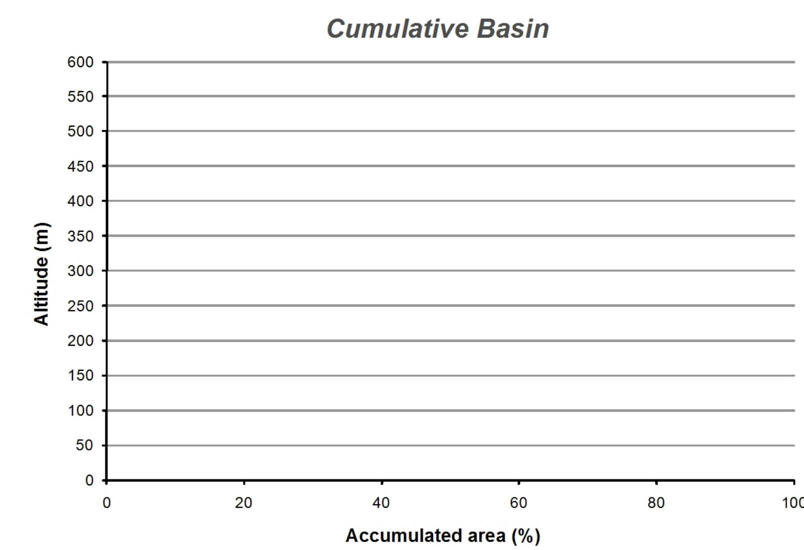
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	38.03	-	km²
Maximum elevation	377	-	m
Minimum elevation	299	-	m
Maximum vertical difference	78	-	m

Lakes and reservoirs	Area	
Bob Lake	230.3	ha

Hypsometric Curves

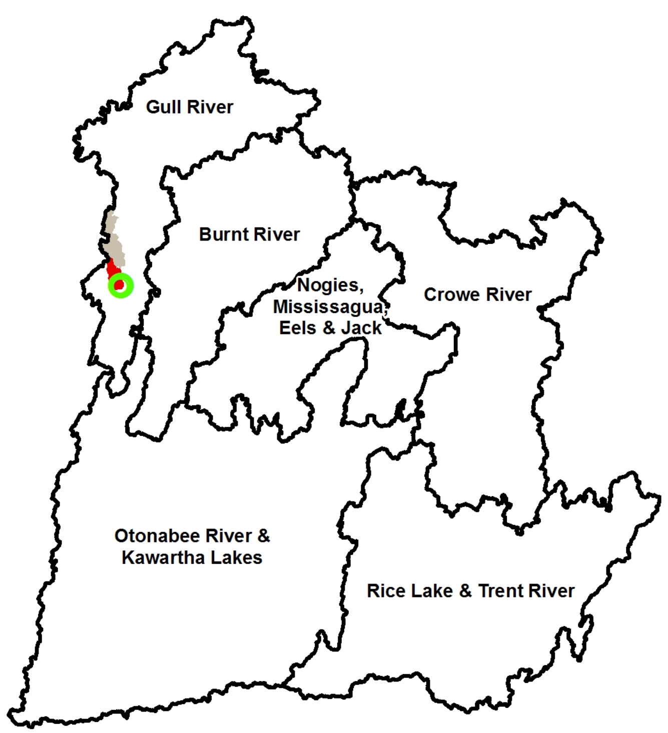


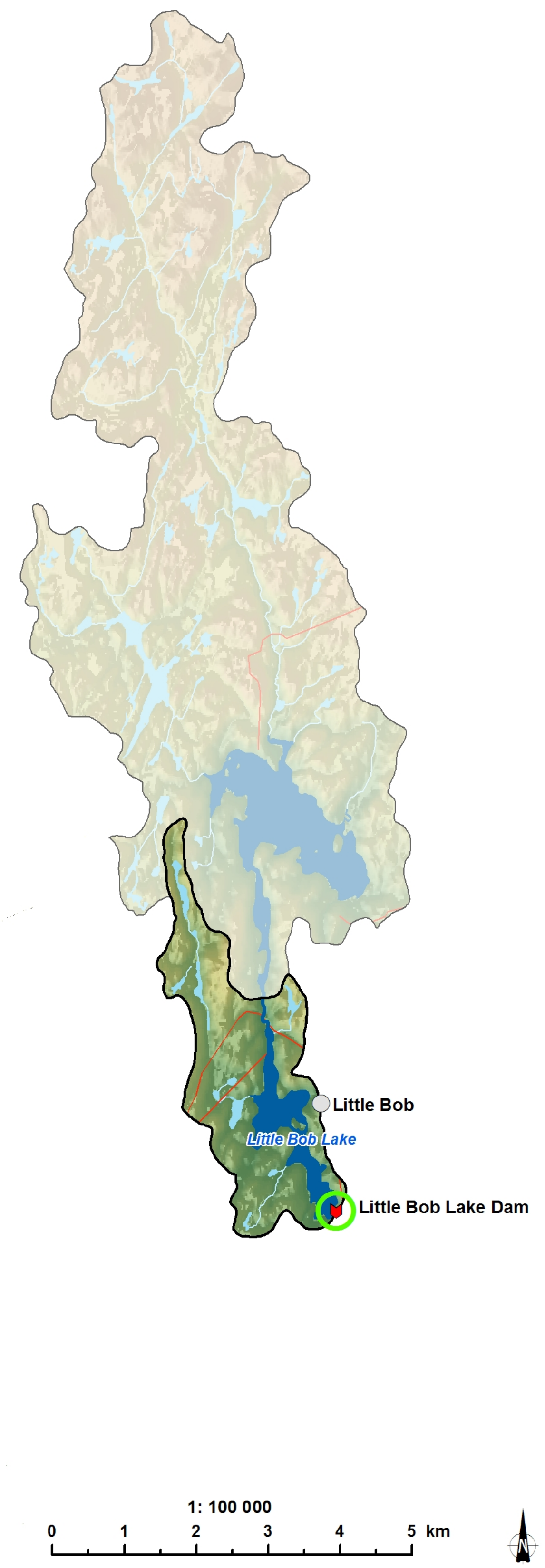


Little Bob Lake Dam

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



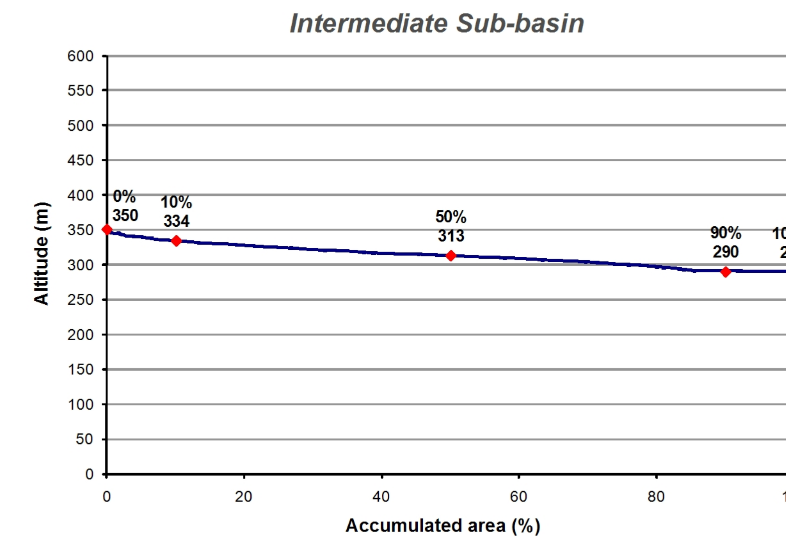


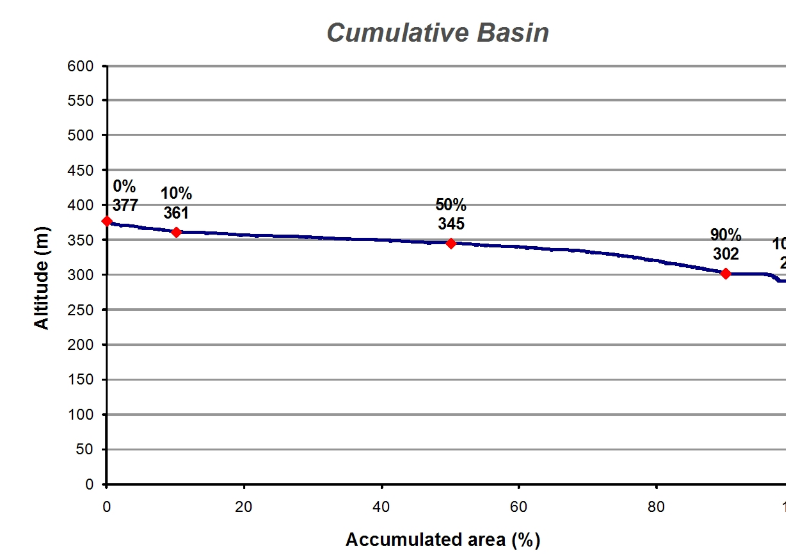
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	6.46	44.49	km²
Maximum elevation	350	377	m
Minimum elevation	289	289	m
Maximum vertical difference	61	88	m

Lakes and reservoirs	Area	
Little Bob Lake	86.1	ha

Hypsometric Curves

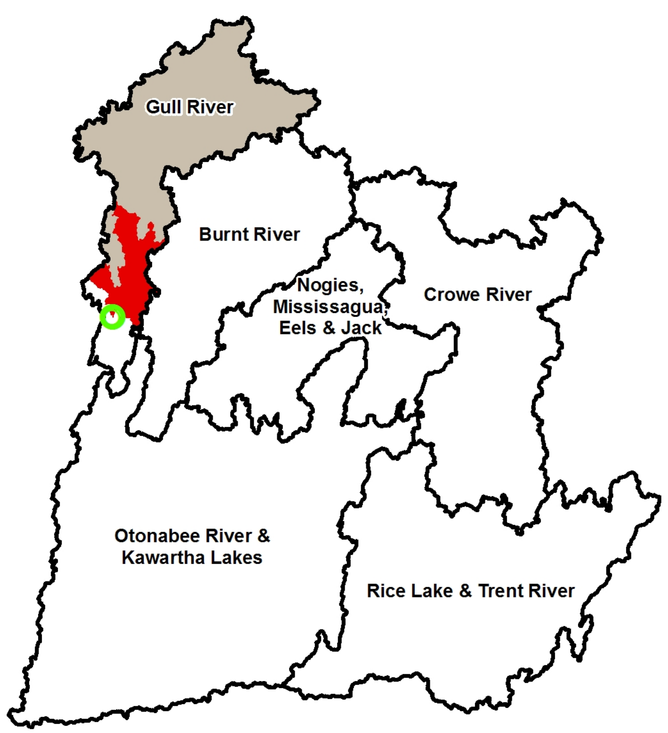


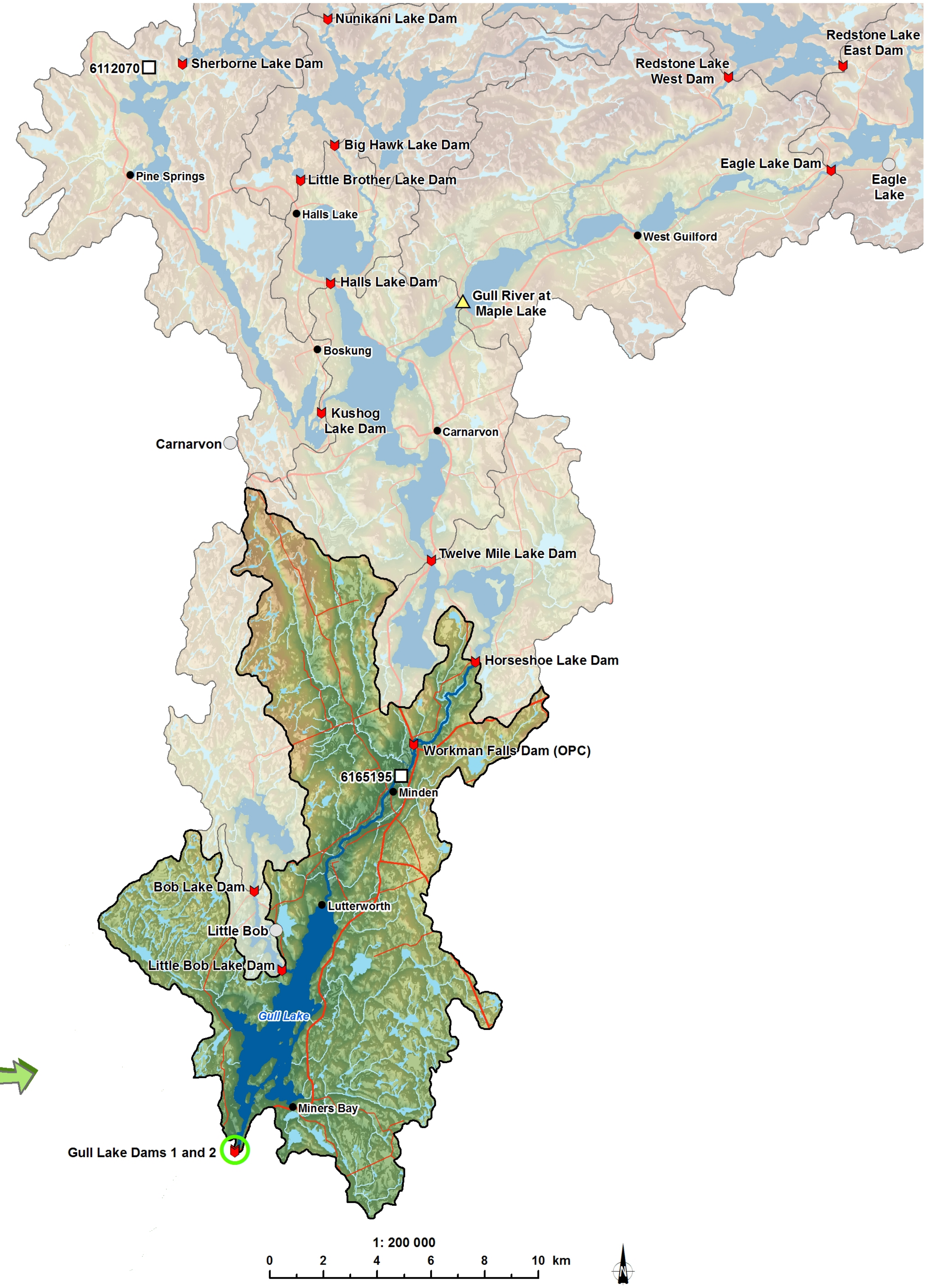


Gull Lake Dams 1 & 2

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream





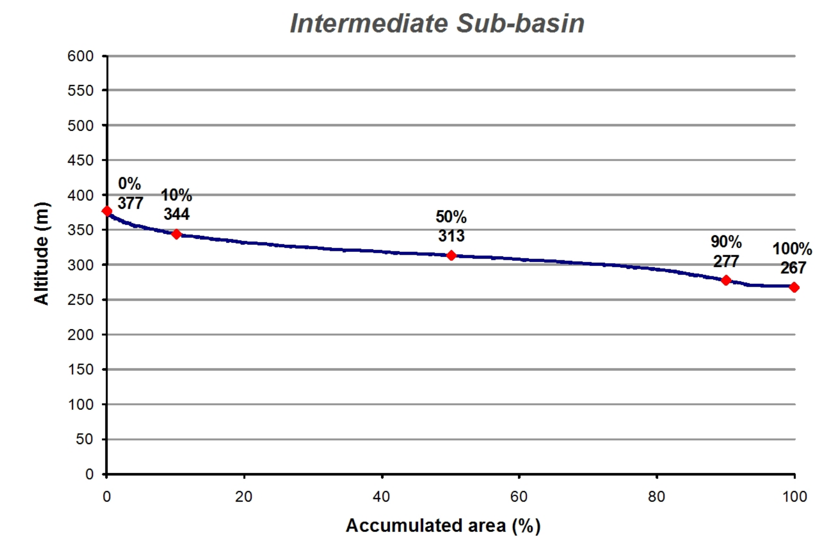
Trent River Watershed Hydro-Technical Study

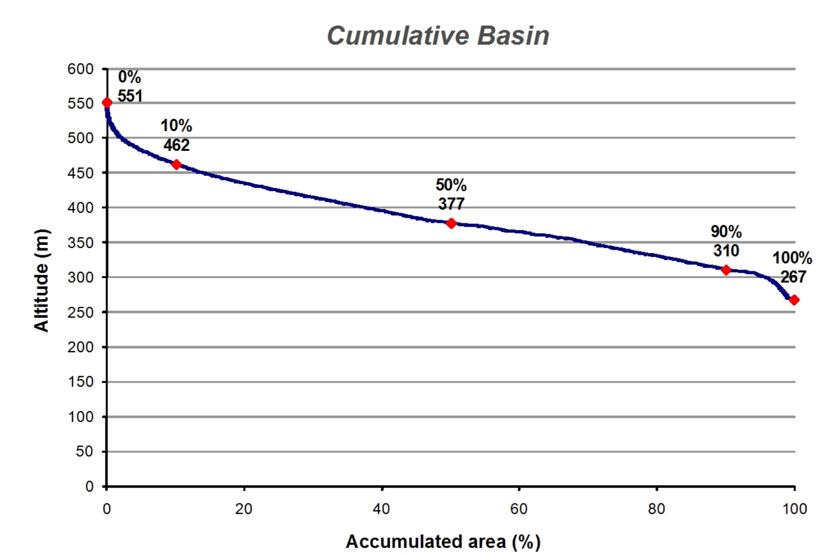
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	178.79	1232.62	km²
Maximum elevation	377	551	m
Minimum elevation	267	267	m
Maximum vertical difference	110	284	m

Lakes and reservoirs	Area	
Gull Lake	1067.8	ha

Hypsometric Curves

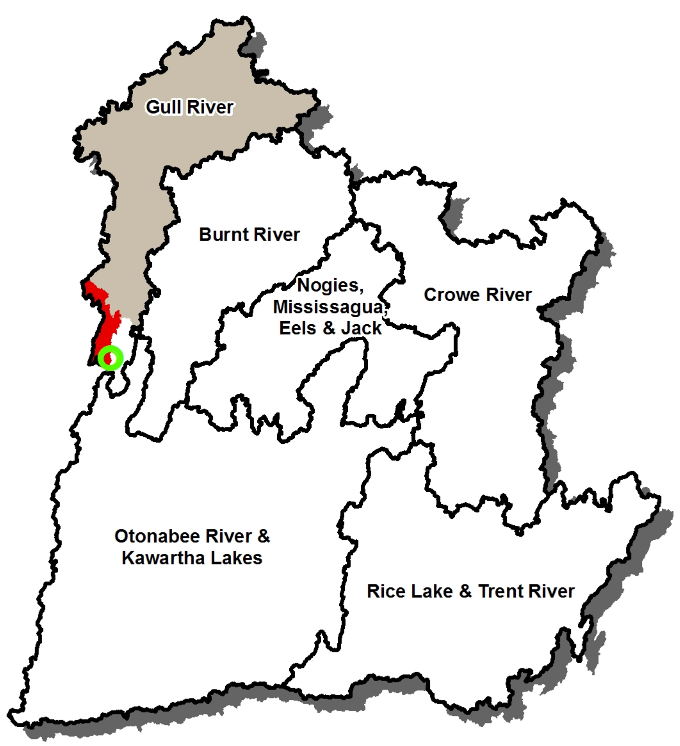


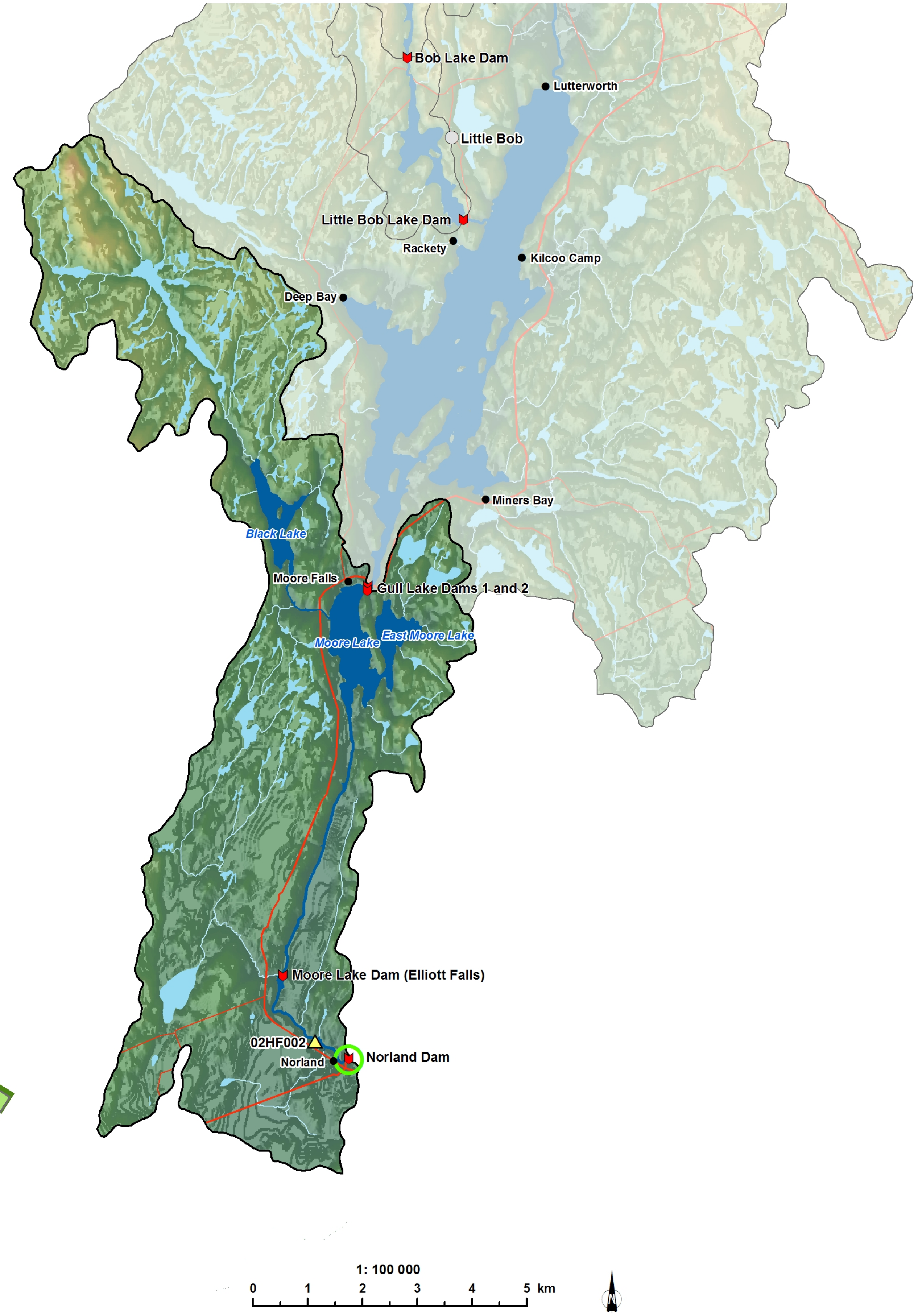


Norland Dam and Moore Lake Dam (Elliott Falls)

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



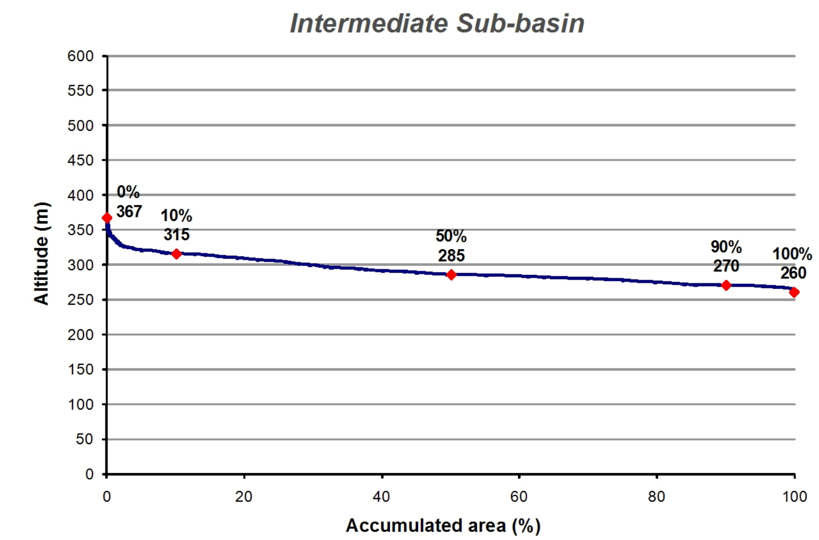


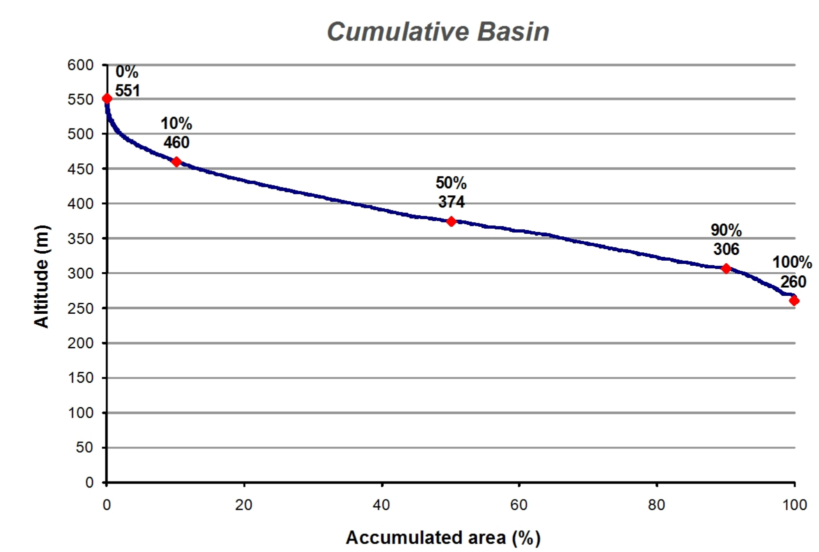
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	63.28	1295.91	km²
Maximum elevation	367	551	m
Minimum elevation	260	260	m
Maximum vertical difference	107	291	m

Lakes and reservoirs	Area	
Moore Lake	127.5	ha
East Moore Lake	57.1	ha
Black Lake	72.2	ha

Hypsometric Curves

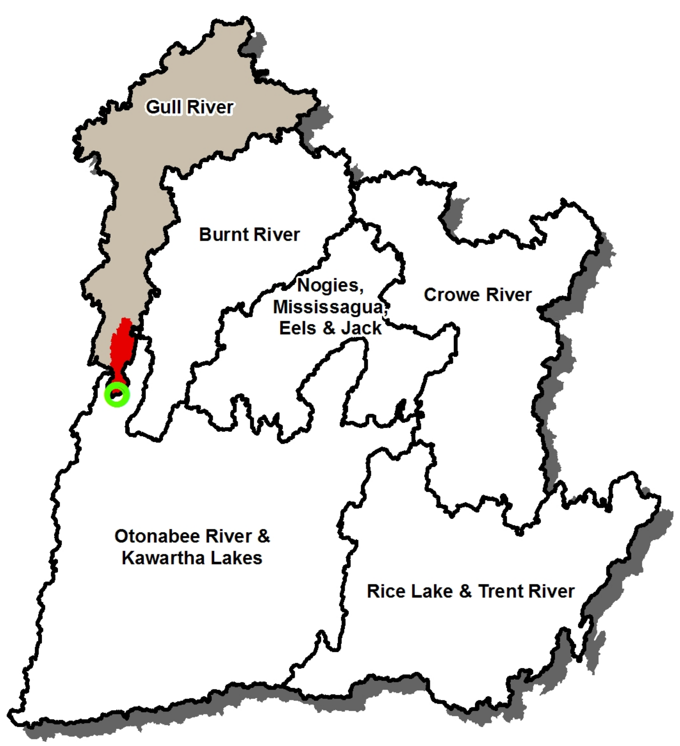




Map 18 Coboconk Dam (including Silver and Shadow Lakes)

Legend

- Sub-basin Node
- Dam
- Hydrometric Station
- Climatological Station
- Snow Station
- Intermediate Sub-basin
- Cumulative Basin
- Reservoir / Lake
- Main Stream



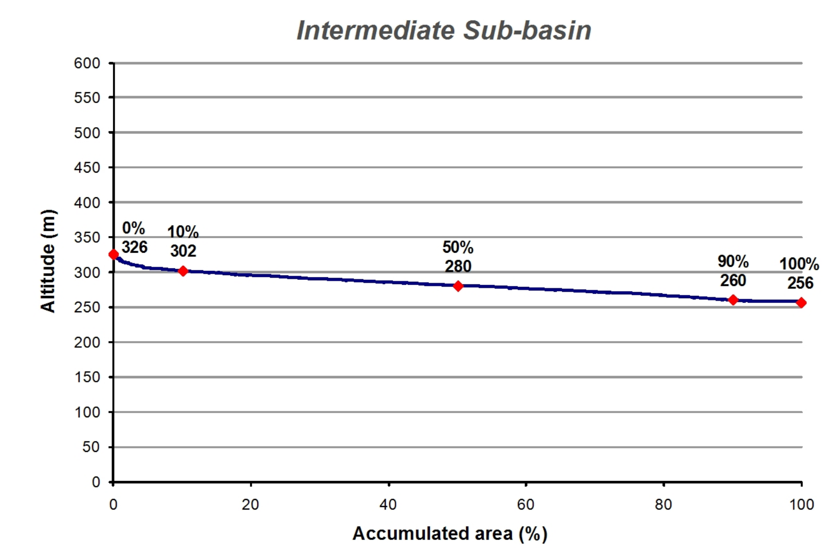
Physical Parameters

	Intermediate Sub-basin	Cumulative Basin	
Area	60.26	1356.16	km²
Maximum elevation	326	551	m
Minimum elevation	256	256	m
Maximum vertical difference	70	295	m

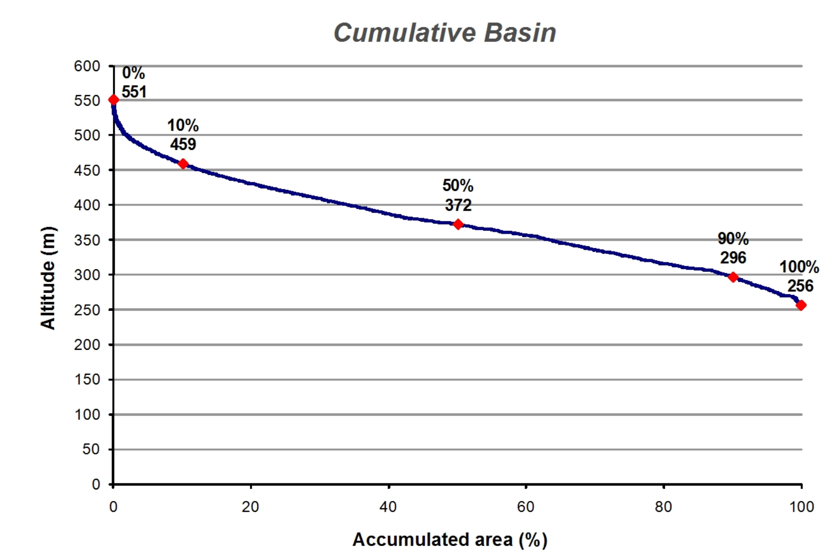
Lakes and reservoirs	Area	
Silver Lake	87.8	ha
Shadow Lake	362.4	ha

Hypsometric Curves

Intermediate Sub-basin



Cumulative Basin



Appendix C

Stoplogs Settings and Reservoir Levels

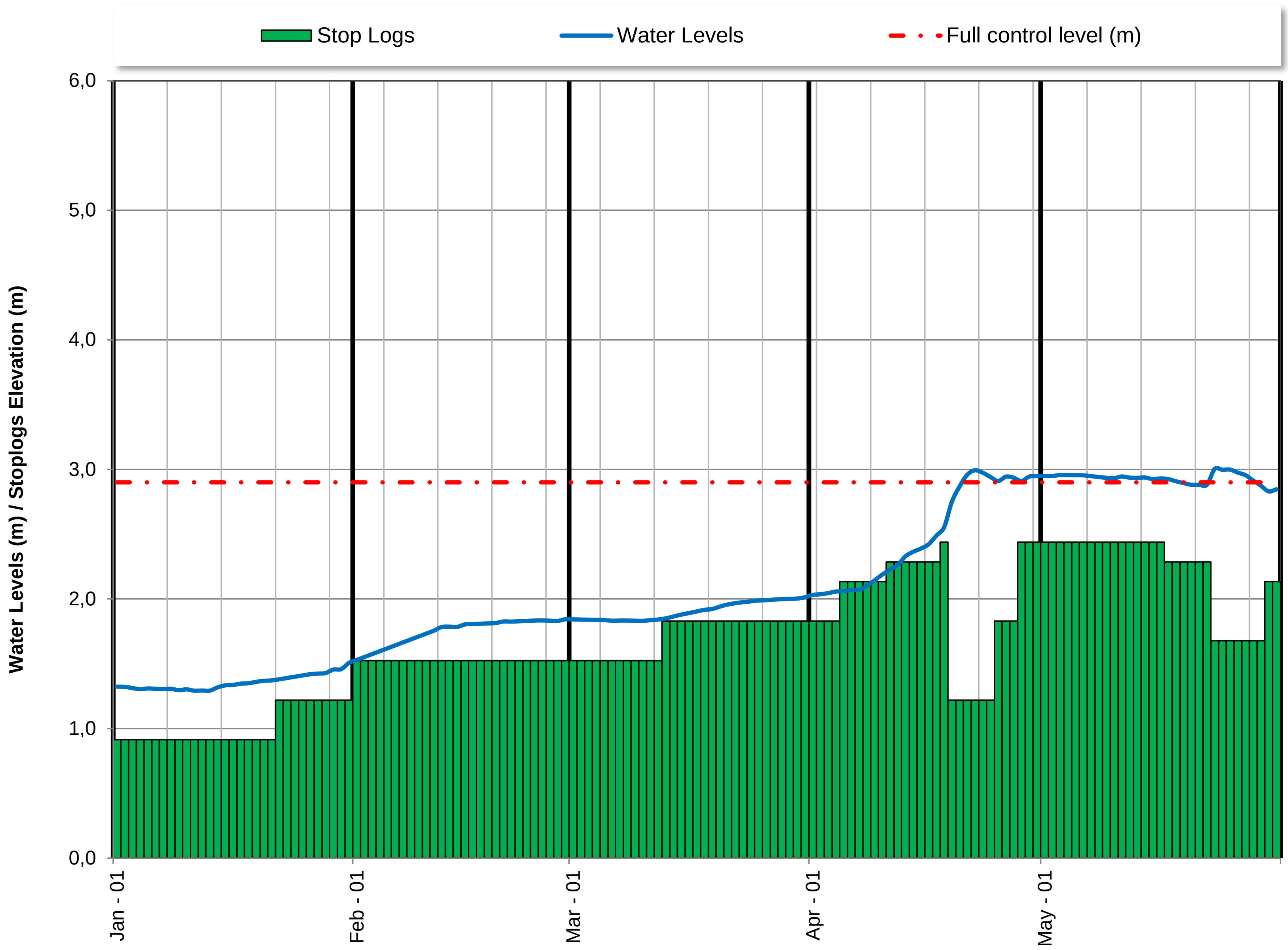


Figure C1 - Kennisis Lake Dam (Map 1)

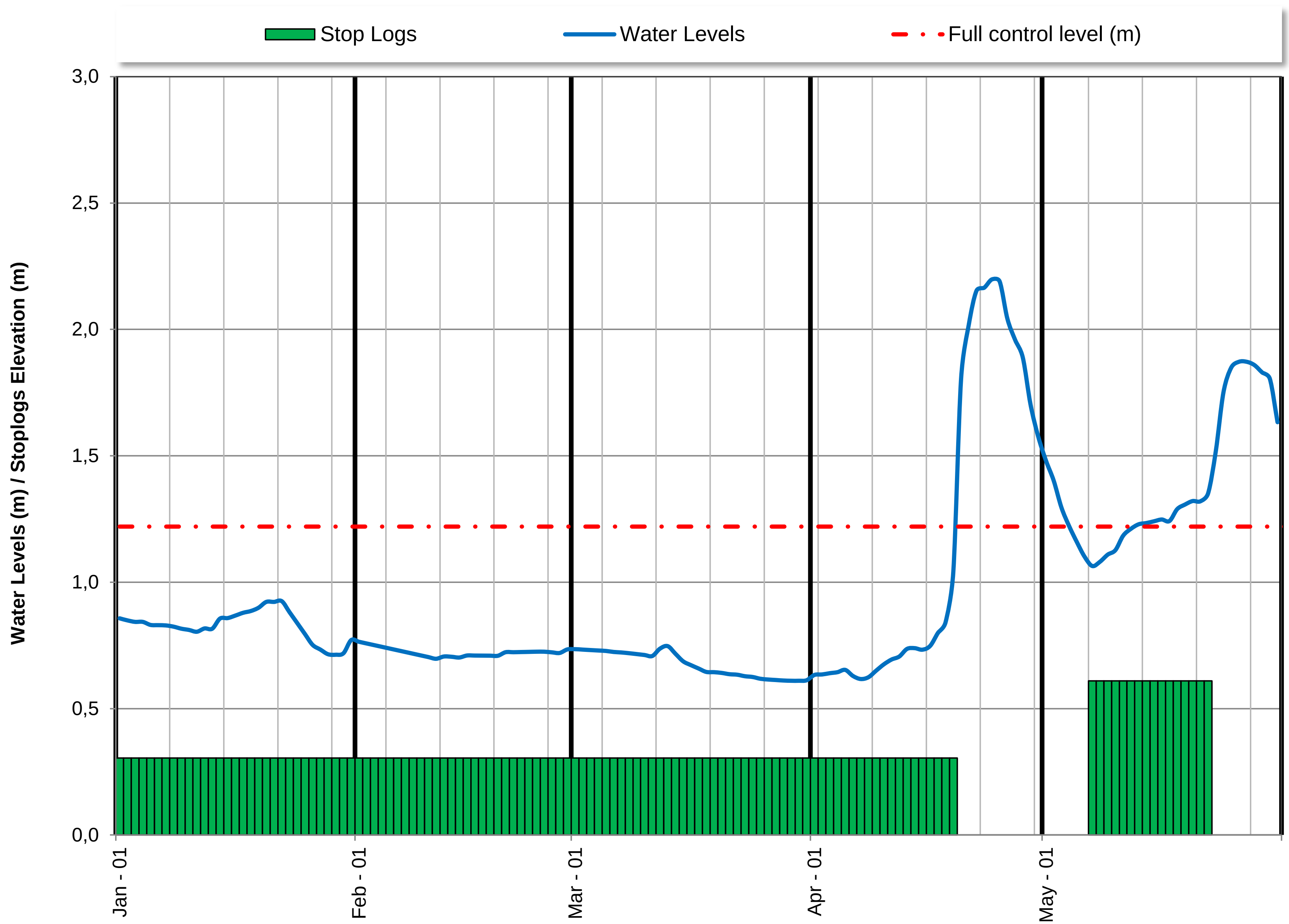


Figure C2 - Red Pine Lake Dam (Map 2)

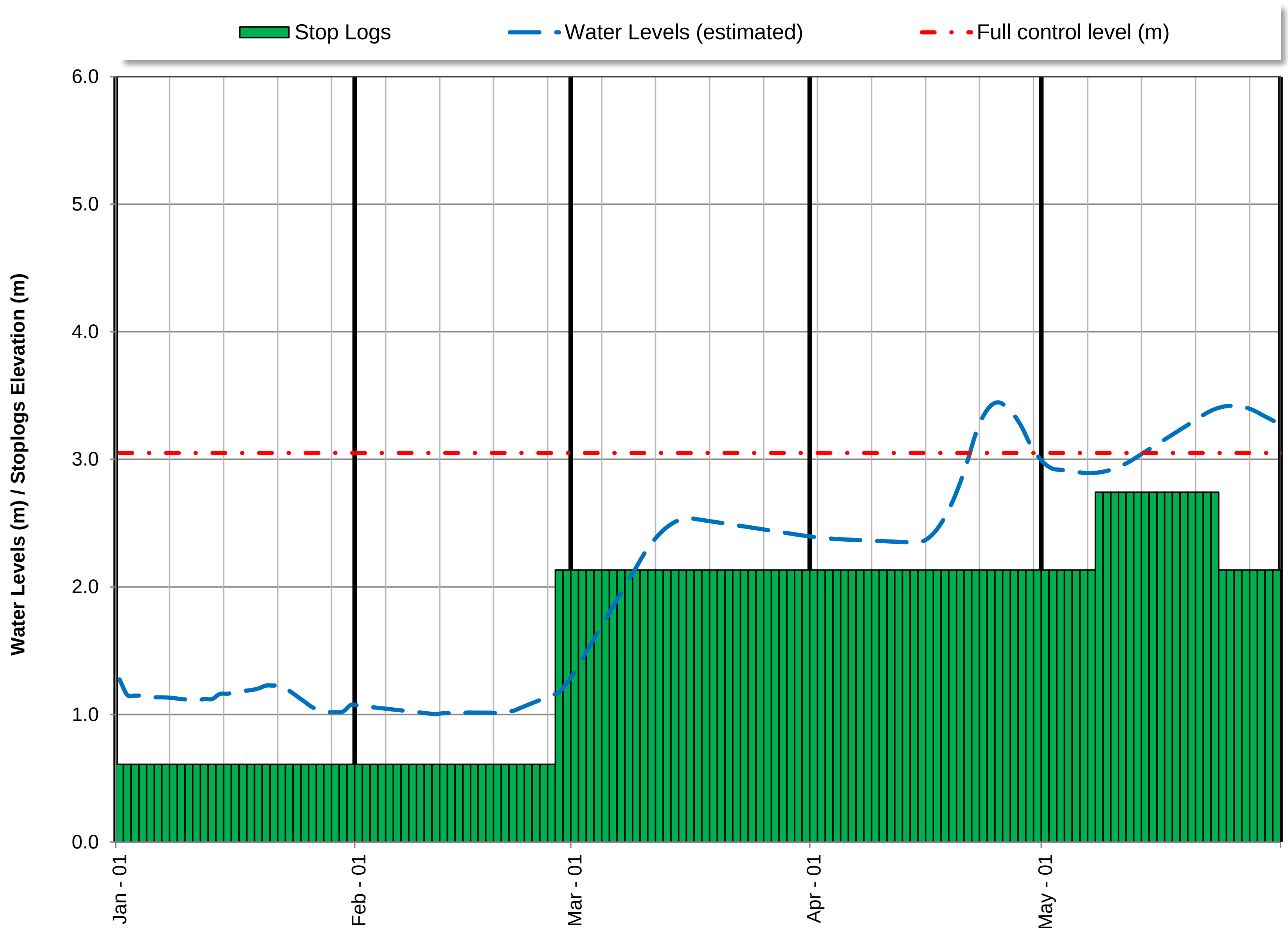


Figure C3 - Nunikani Lake Dam (Map 3) (Water Levels Estimated)

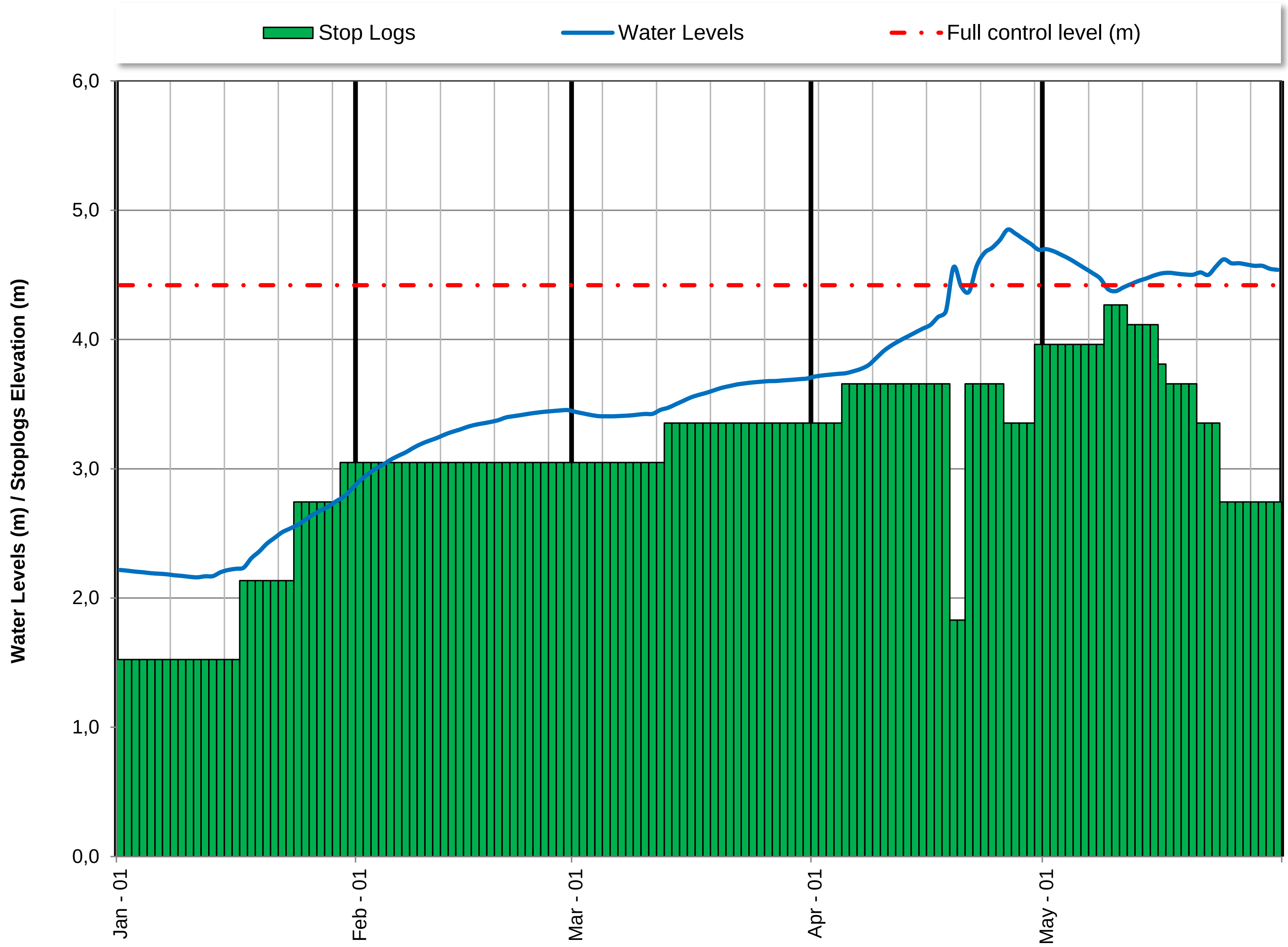


Figure C4 - Hawk Lake (Map 4)

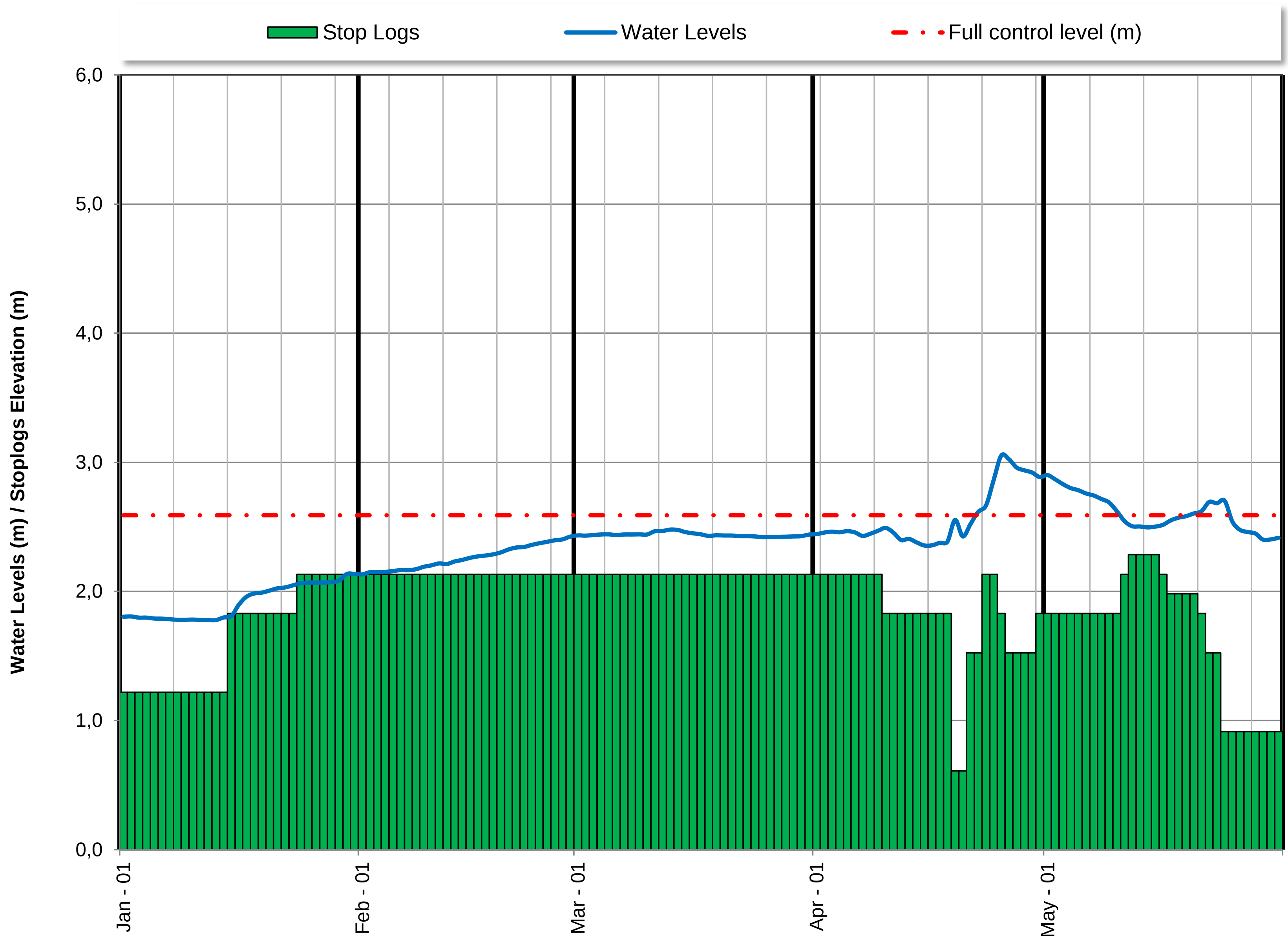


Figure C5 – Halls Lake (Map 5)

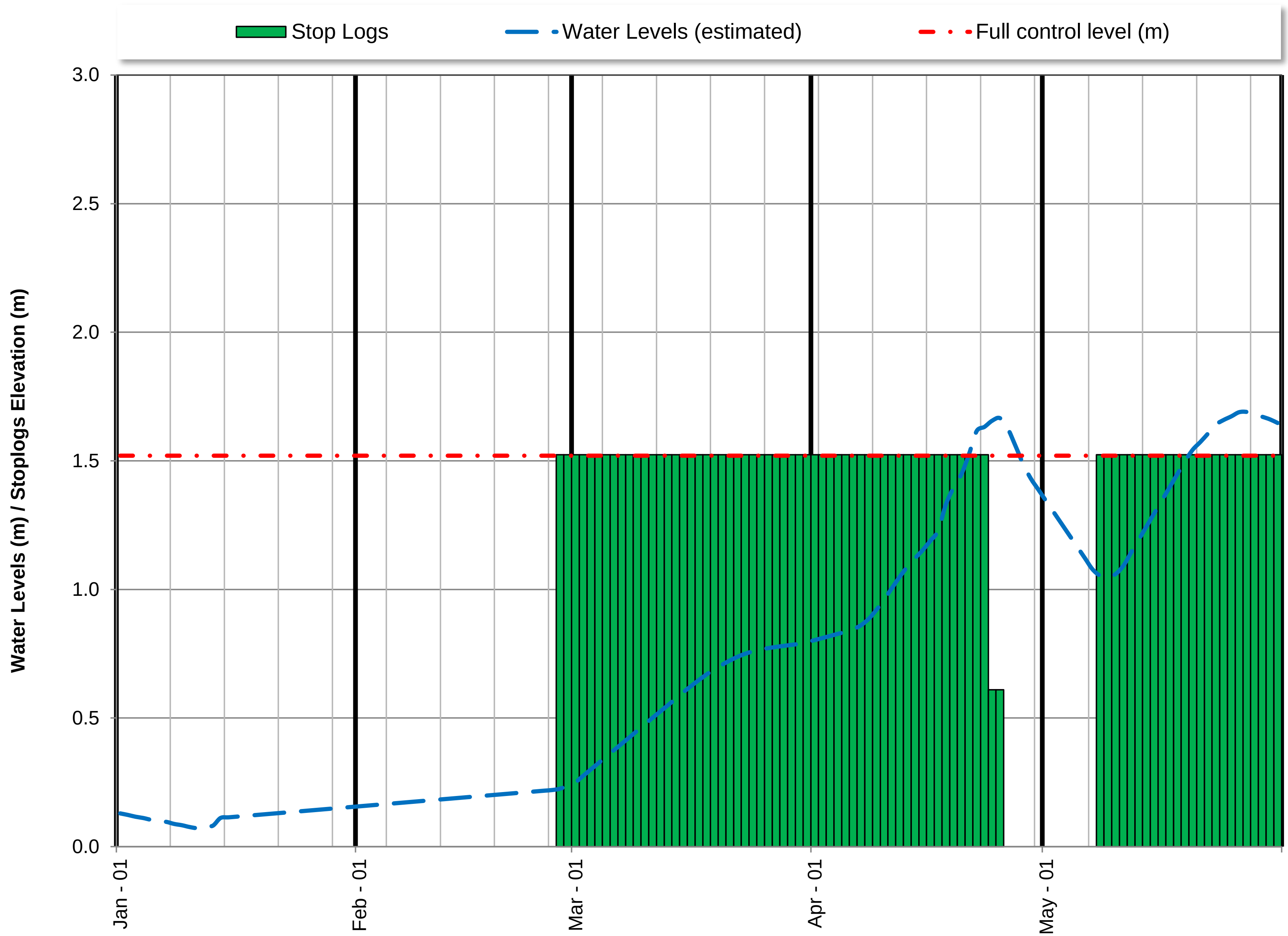


Figure C6 - Sherborne Lake Dam (Map 6) (Water Levels Estimated)

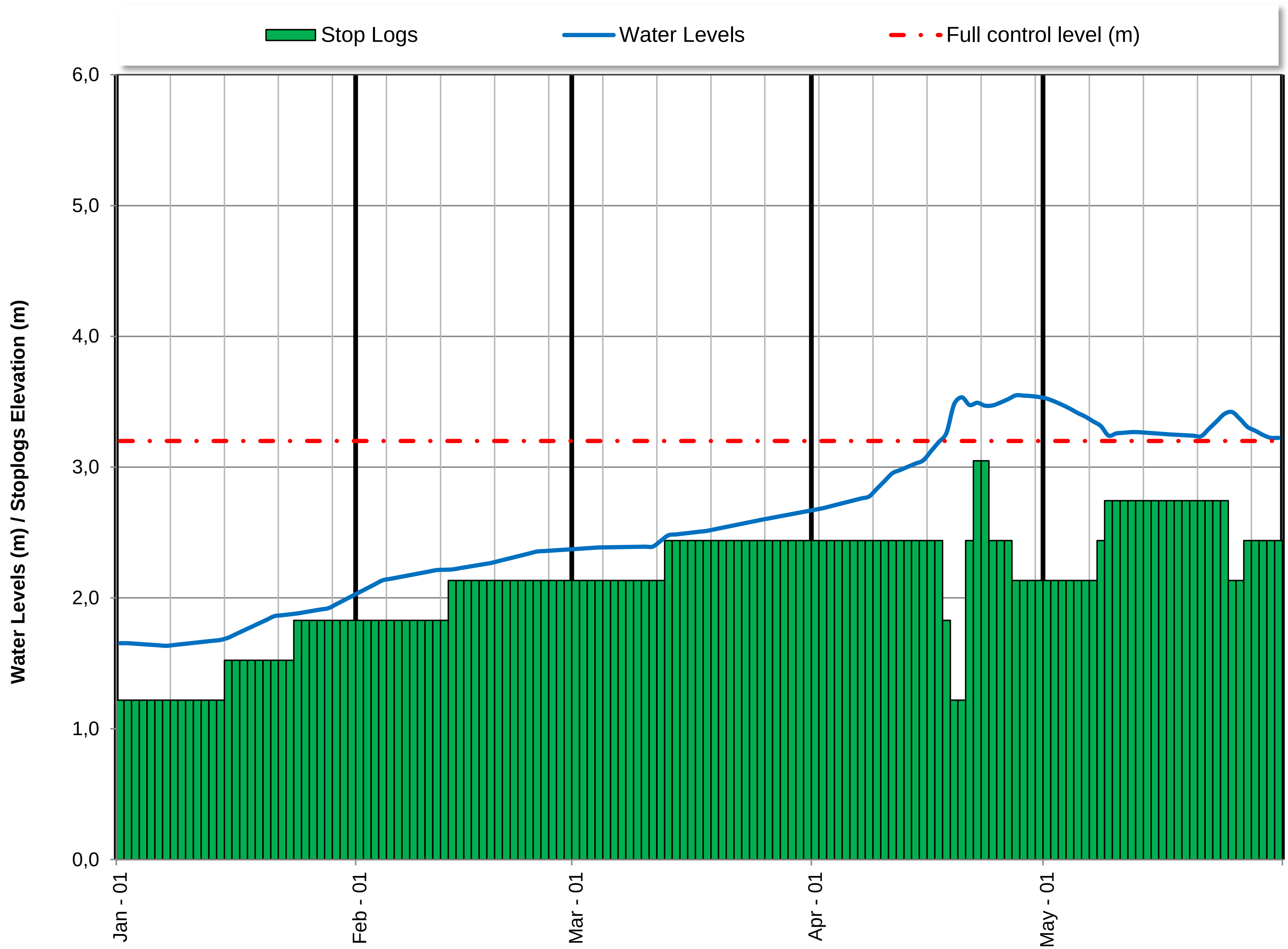


Figure C7 - Kushog Lake (Map 6)

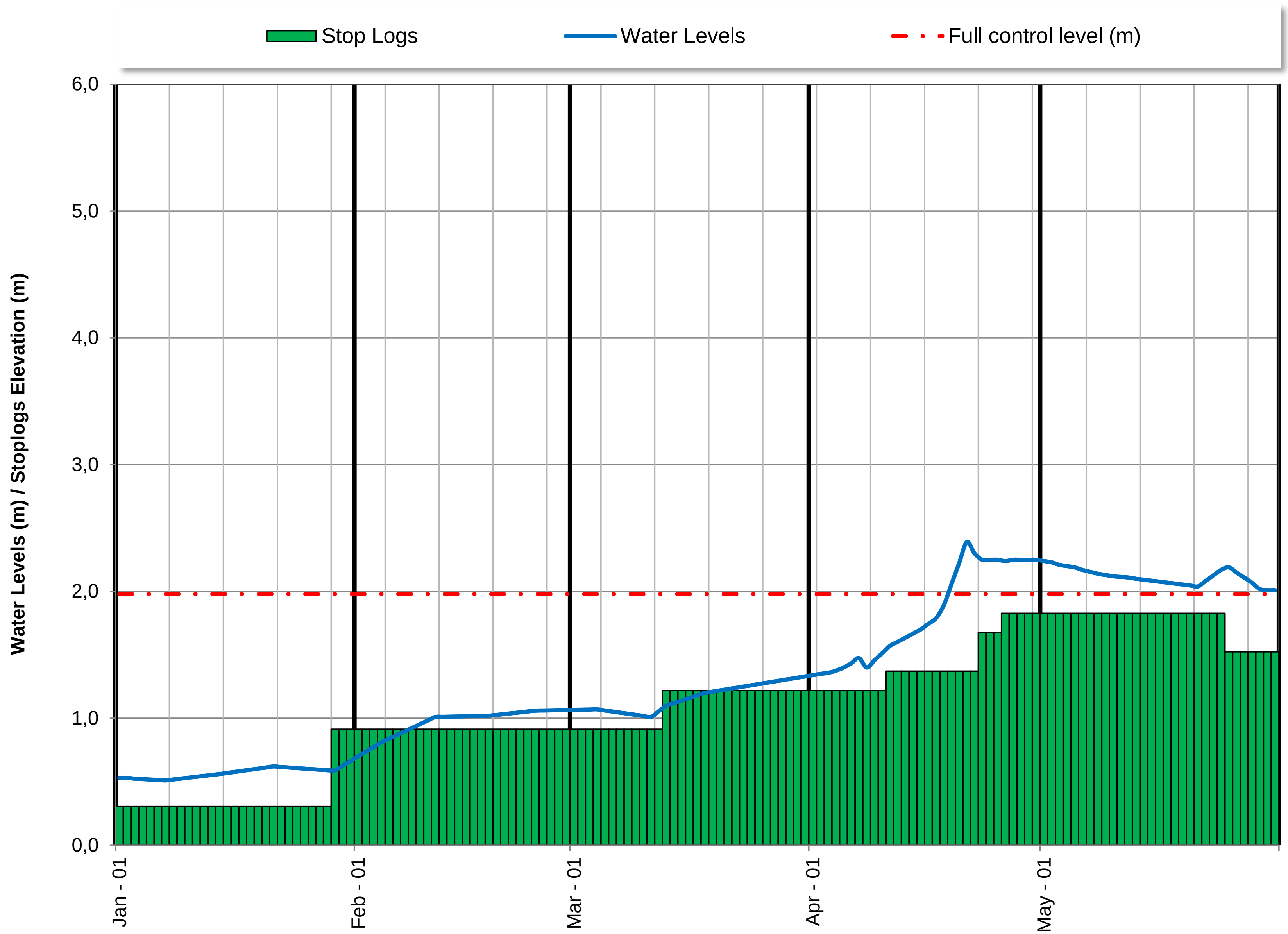


Figure C8 - Percy Lake (Map 7)

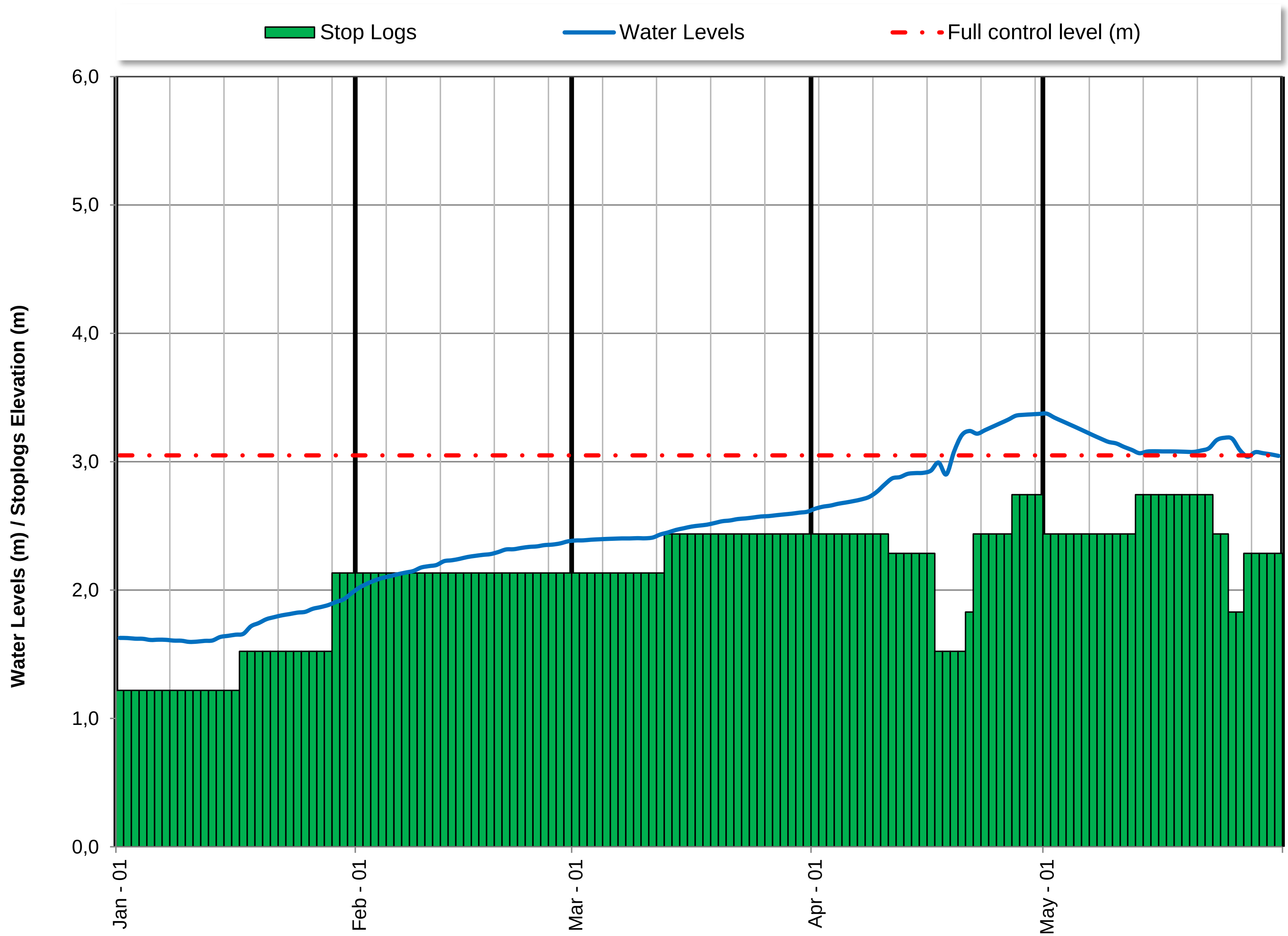


Figure C9 - Oblong Lake (Map 8)

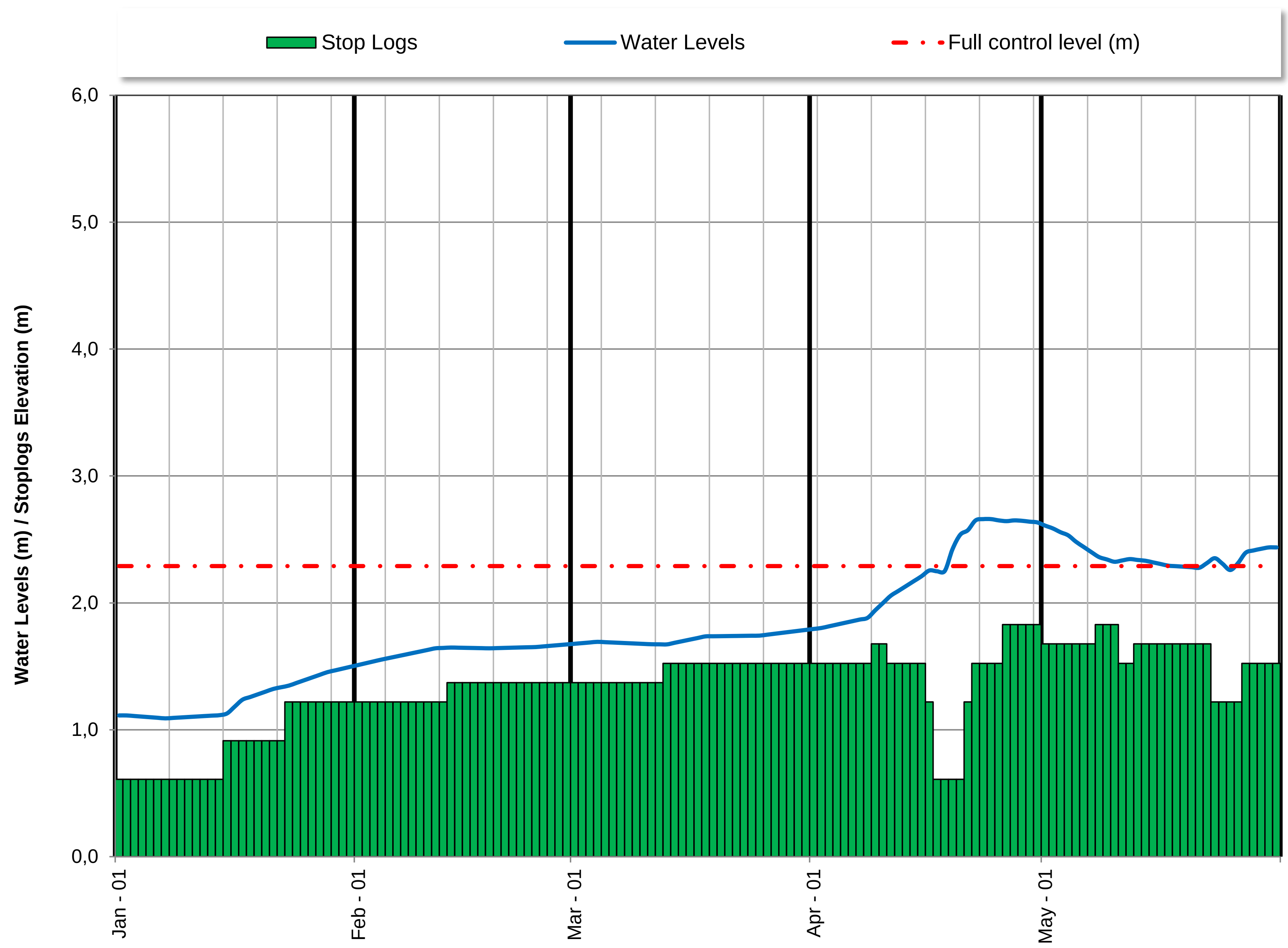


Figure C10 - Eagle Lake (Map 9)

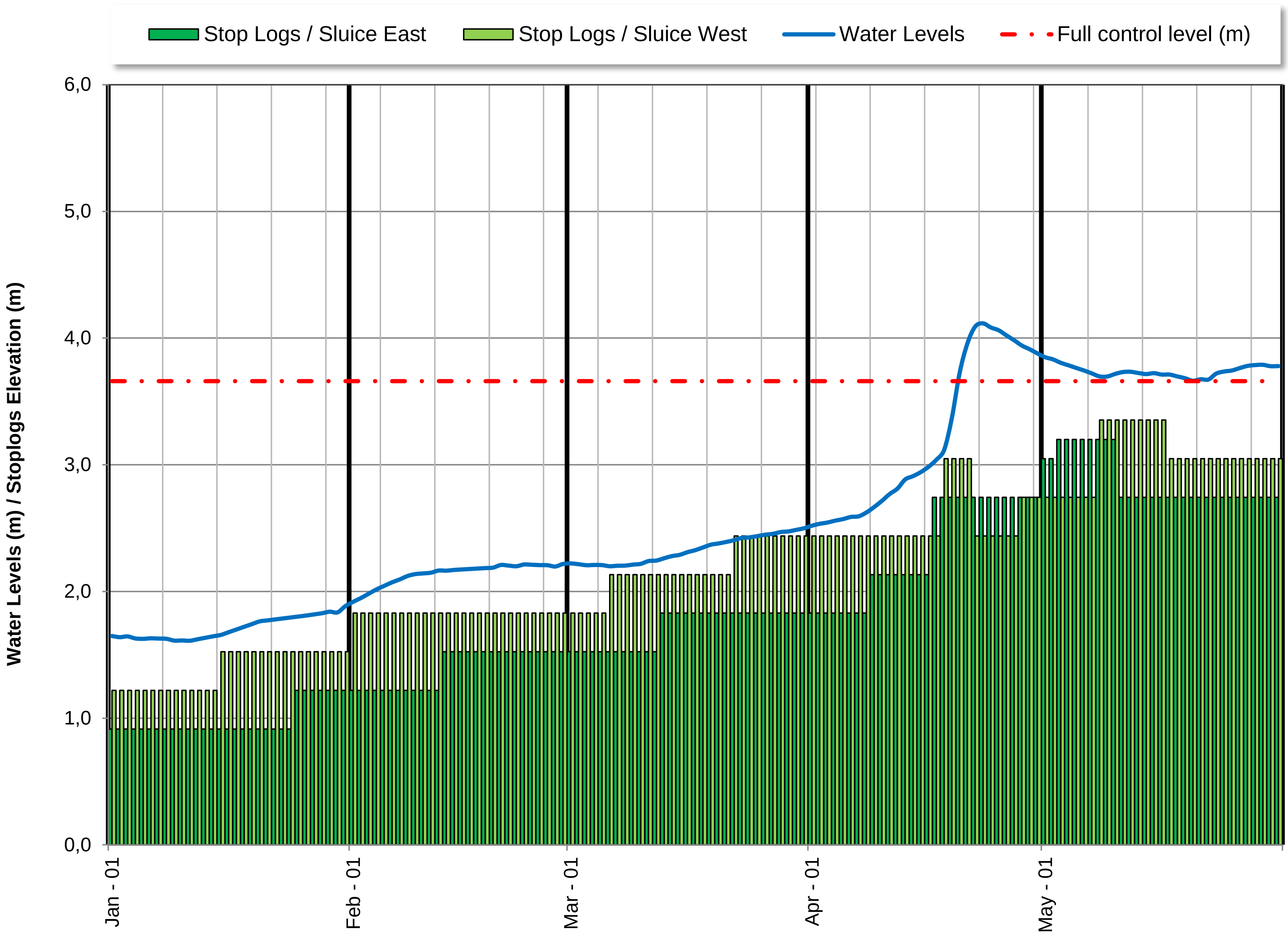


Figure C11 - Redstone Lake (Map 10)

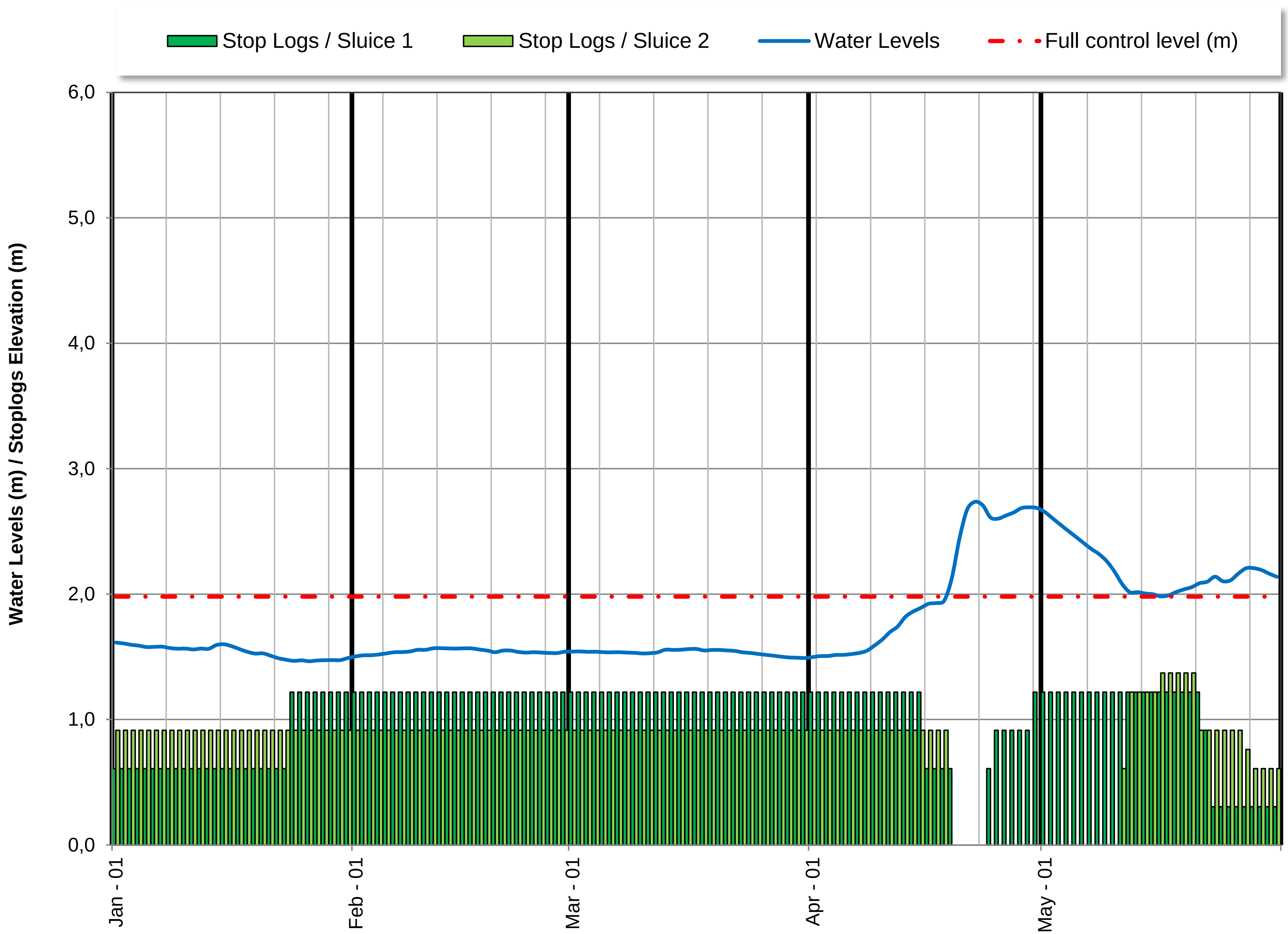


Figure C12 - Twelve Mile Lake (Map 12)

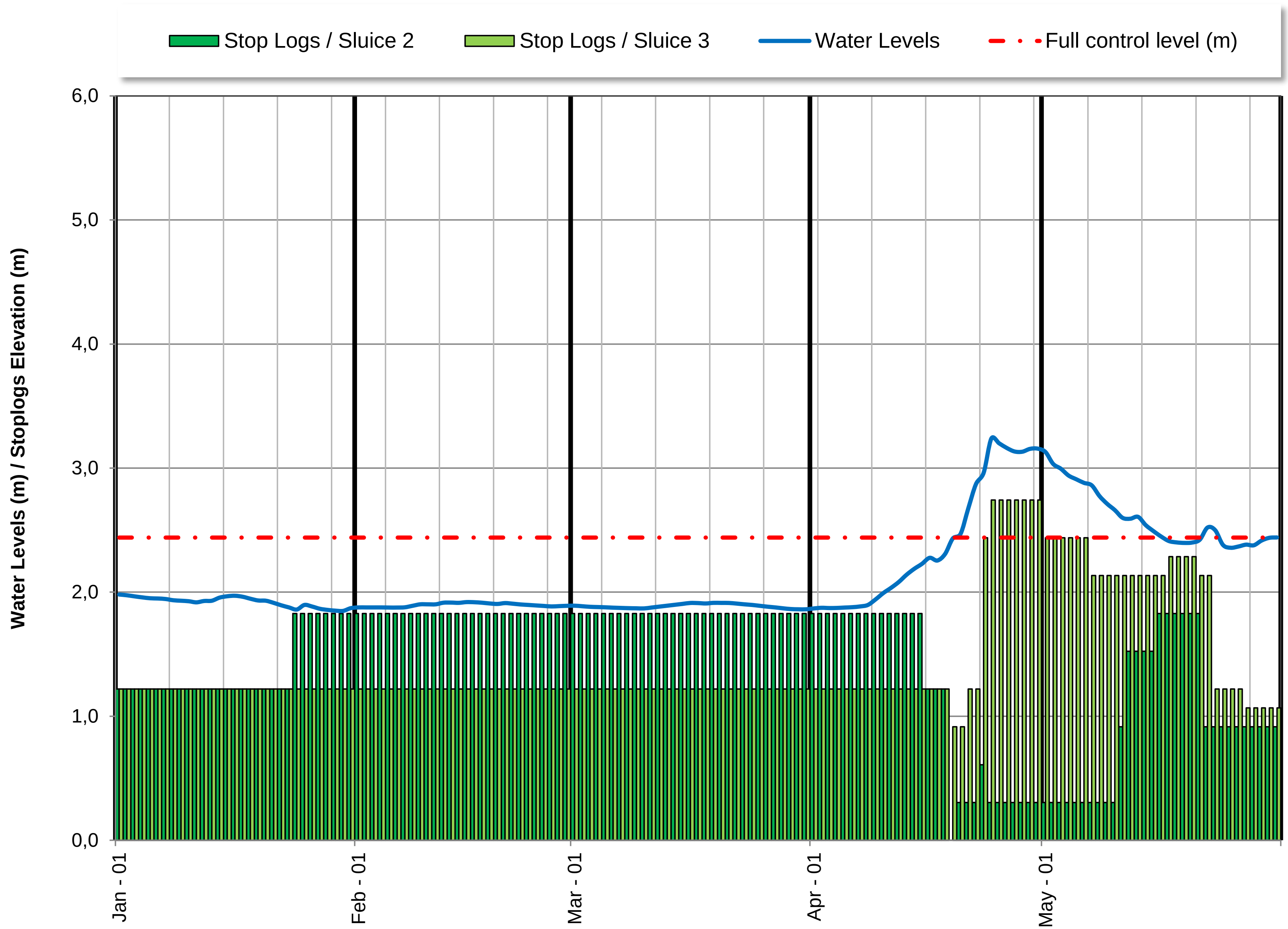


Figure C13 - Horseshoe Lake (Map 13)

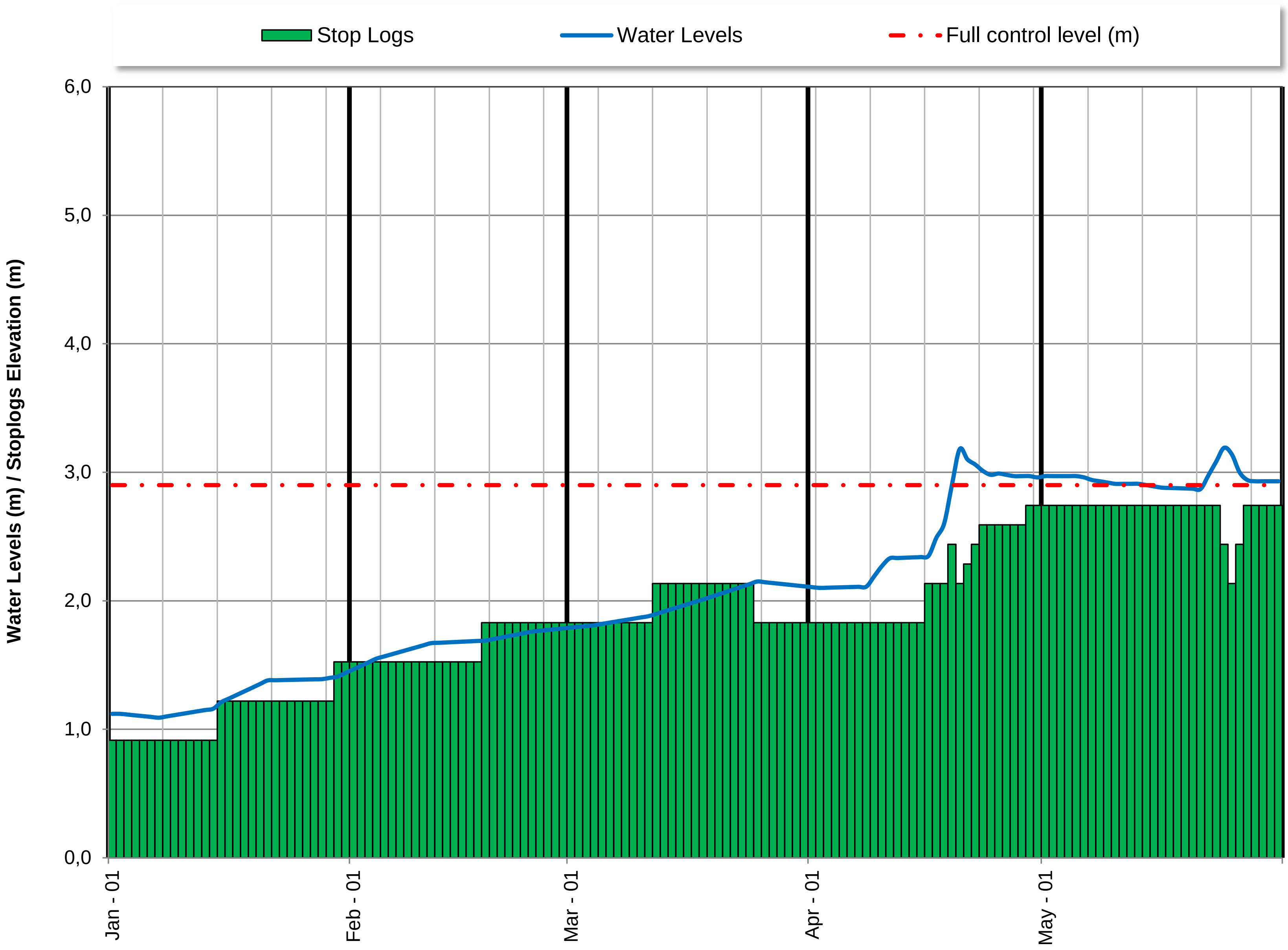


Figure C14 - Bob Lake (Map 14)

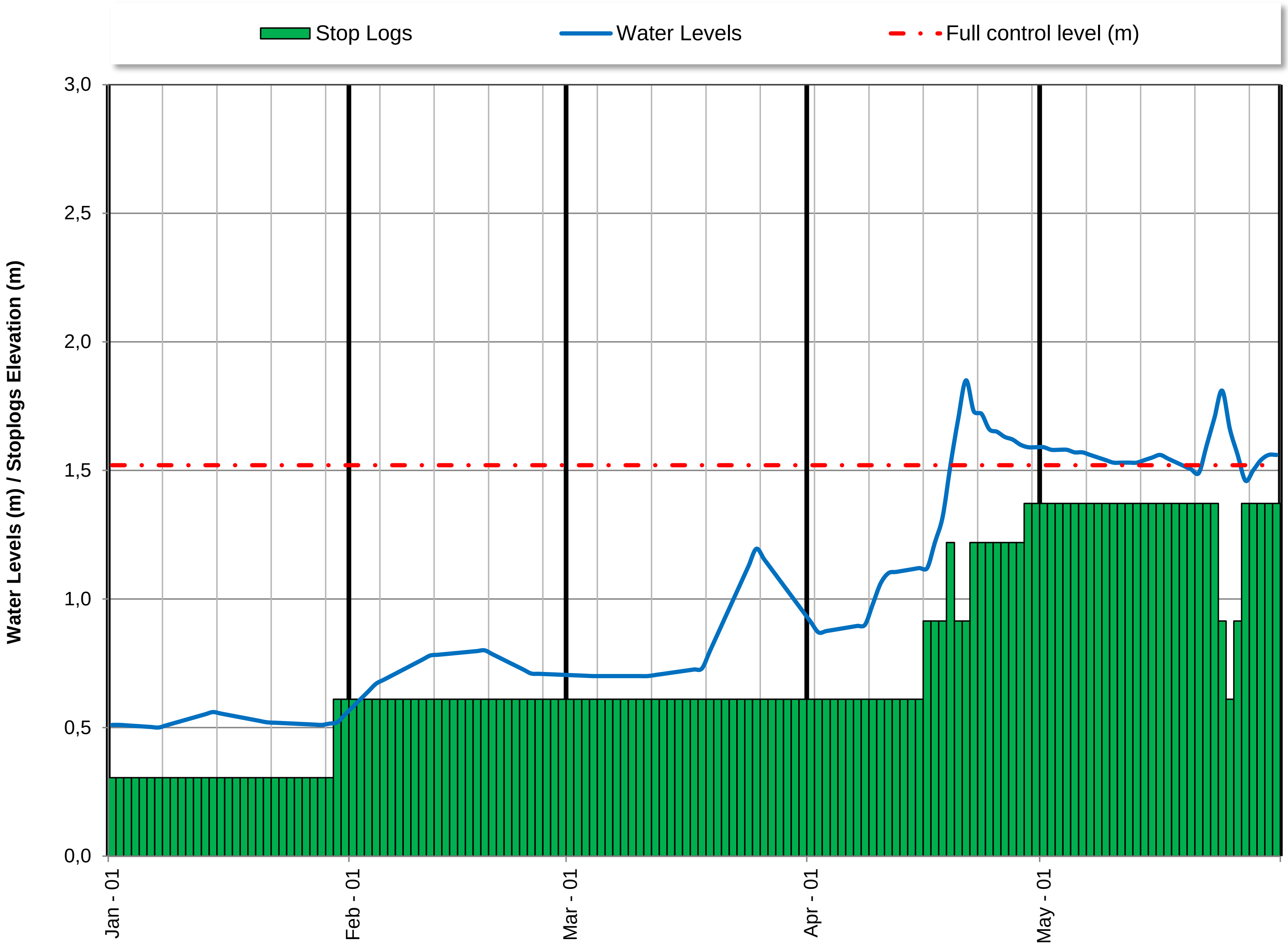


Figure C15 - Little Bob Lake (Map 15)

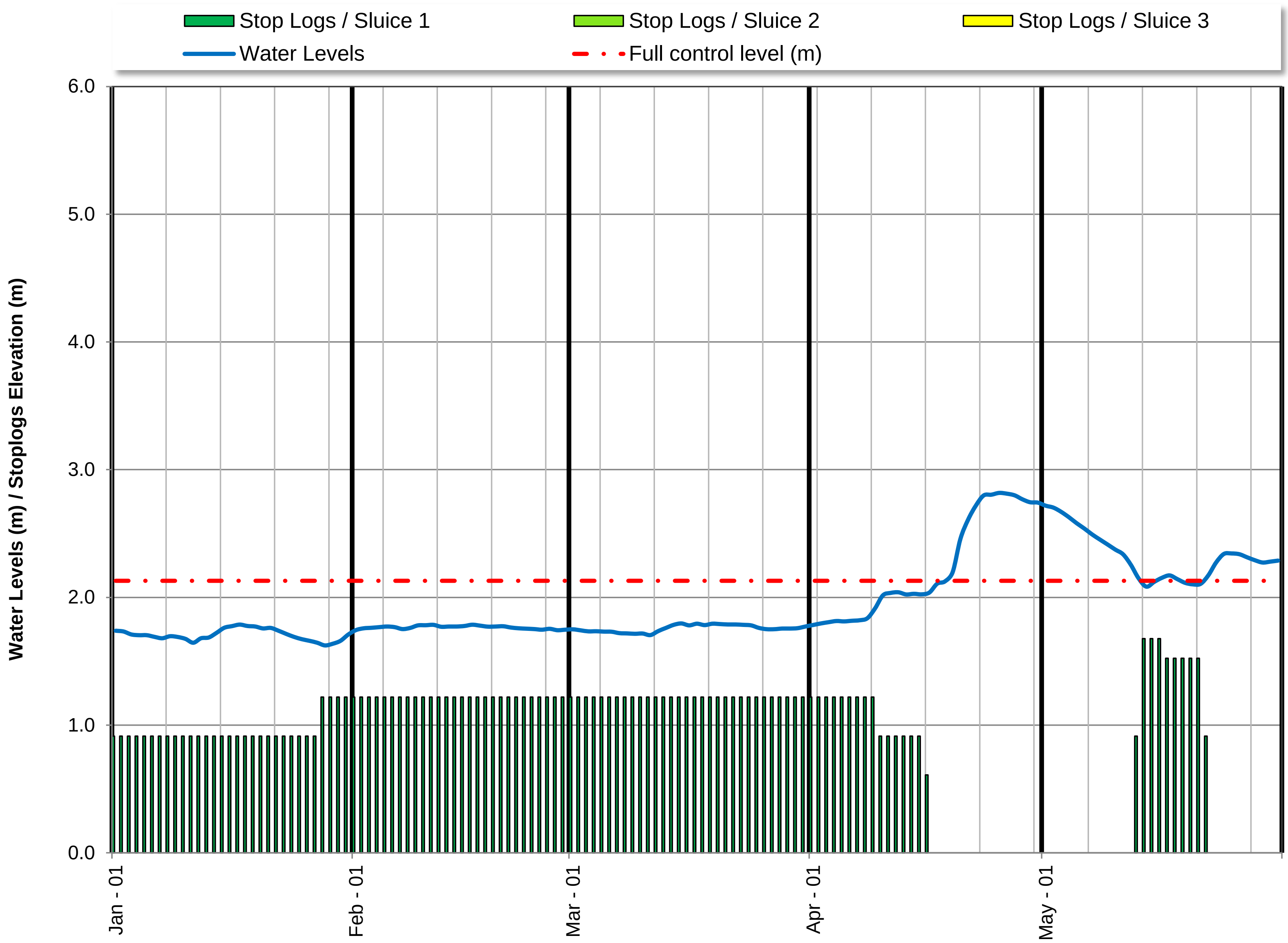


Figure C16 - Gull Lake (Map 16)

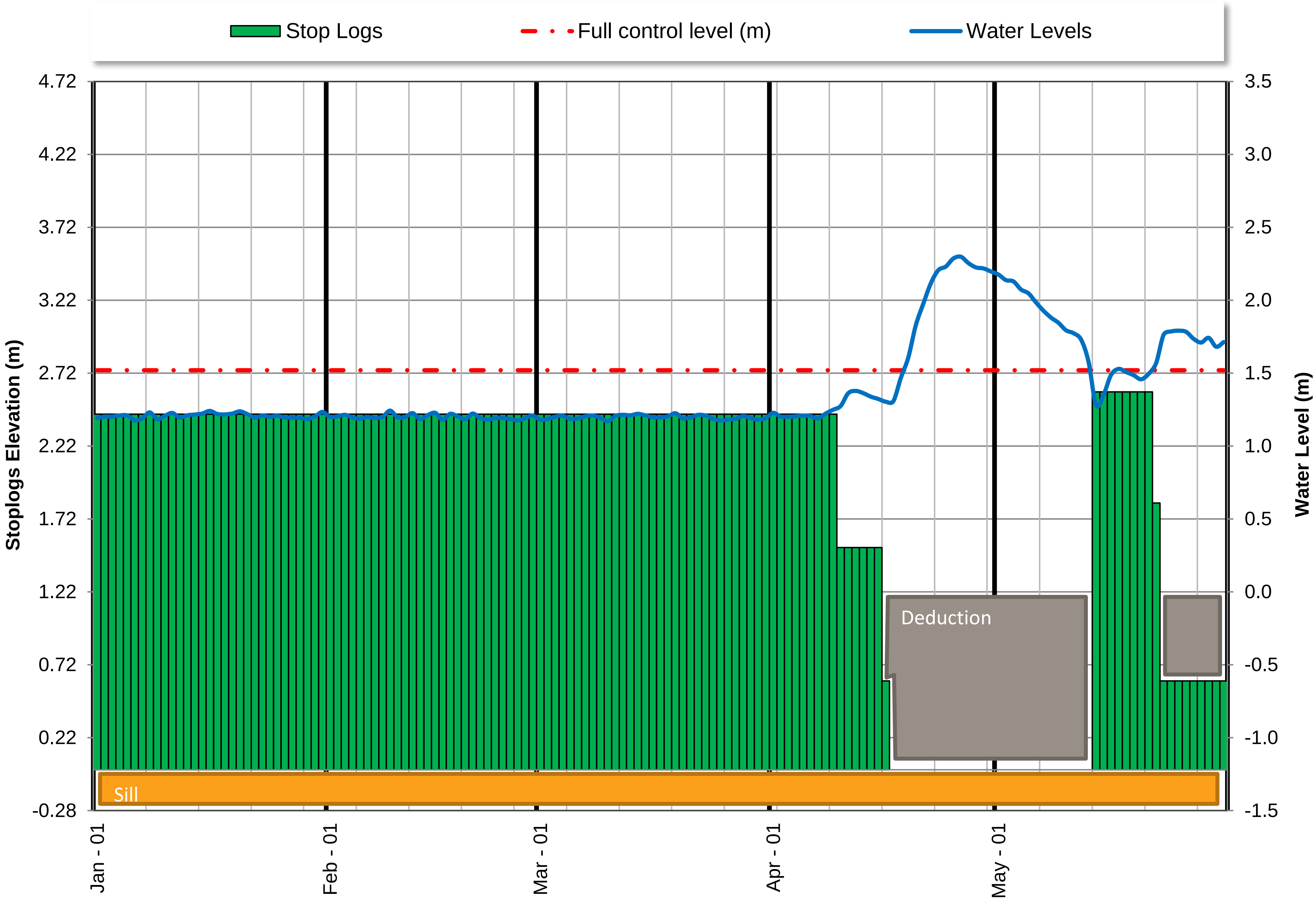


Figure C17 - Moore Lake (Map 17)

Appendix D
Stoplog Operation Chart for all Reservoir Lakes

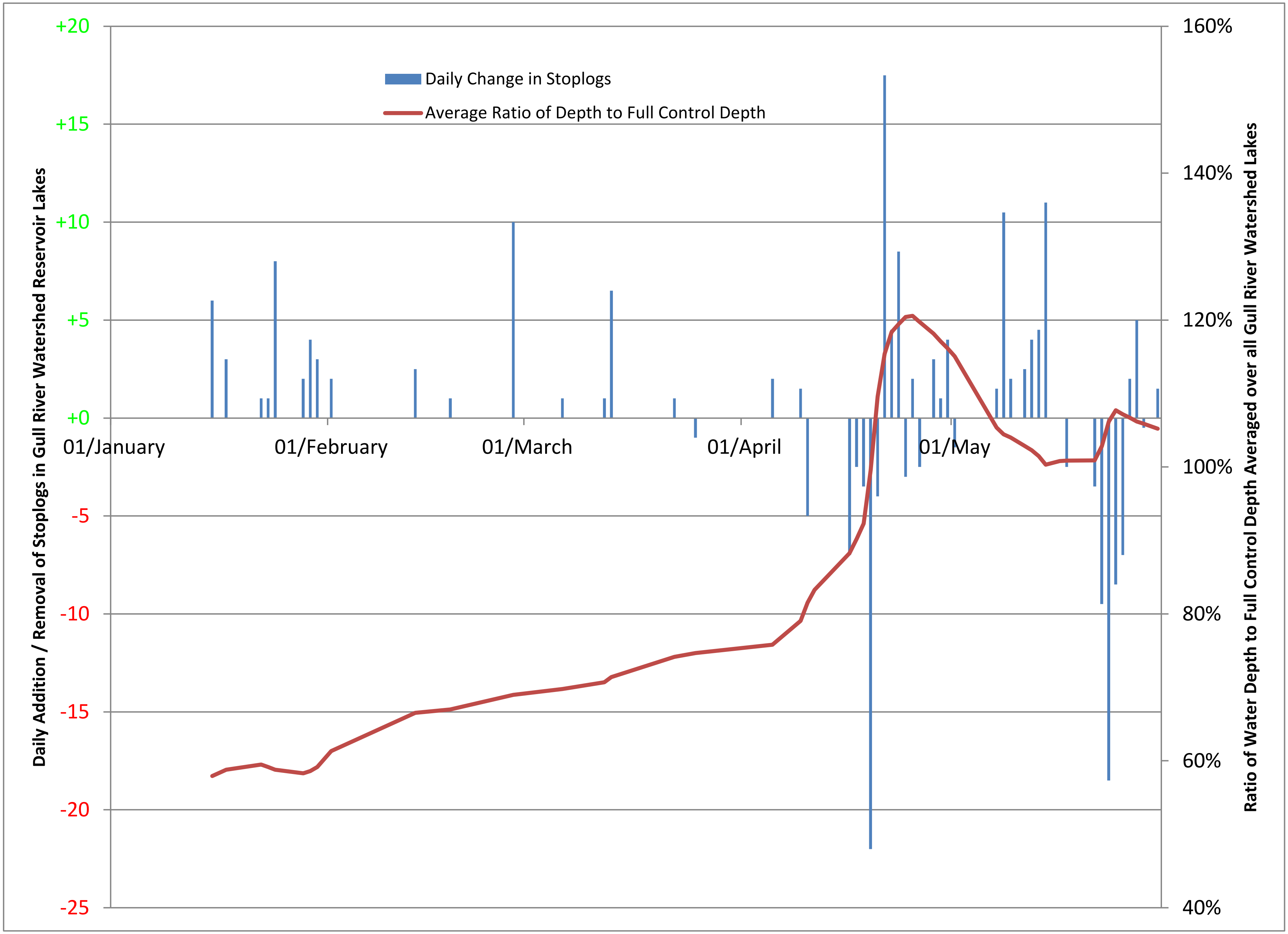


Figure D1 Quick Overview of the Operation of Stoplogs in the Gull River Watershed

Table D1 – Summary of Operation

+2	Number of stoplogs added or removed	Ken:	Kennesis	Haw:	Hawk	She:	Sherborne	RS:	Redstone	HS:	Horseshoe	Gu:	Gull
9	Number of stoplogs in place	RP:	Red Pine	Hal:	Halls	Per:	Percy	Eag:	Eagle	BB:	Big Bob	Moo:	Moore
58%	Ratio of depth / full control depth	Nun:	Nunikani	Kus:	Kushog	Obl:	Oblong	12M:	Twelve-Mile	LB:	Little Bob		

Winter # SL	Ken	RP	Nun	Haw	Hal	She	Kus	Per	Obl	RS e	RS w	Eag	12M-1	12M-2	HS-1	HS-2	BB	LB	Gu-1	Gu-2	Gu-3	Moo	Sum
	3	1	2	5	4	0	4	0	4	3	4	2	3	3	4	4	3	0	2	0	0	7	58
01 Jan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
	3	1	2	5	4	0	4	1	4	3	4	2	2	3	4	4	3	1	3	0	0	8	61
15 Jan	--	--	--	--	+2	--	+1	--	--	--	+1	+1	--	--	--	--	+1	--	--	--	--	--	+6
	3	1	2	5	6	0	5	1	4	3	5	3	2	3	4	4	4	1	3	0	0	8	67
	46%	70%	38%	50%	70%	8%	53%	29%	54%	53%	45%	49%	96%	81%	81%	81%	42%	36%	83%	83%	83%	45%	58%
17 Jan	--	--	--	+2	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	--	--	+3
	3	1	2	7	6	0	5	1	5	3	5	3	2	3	4	4	4	1	3	0	0	8	70
	46%	72%	39%	51%	76%	8%	55%	30%	54%	54%	46%	54%	93%	79%	80%	80%	44%	36%	84%	84%	84%	45%	59%
22 Jan	+1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+1
	4	1	2	7	6	0	5	1	5	3	5	3	2	3	4	4	4	1	3	0	0	8	71
	48%	76%	40%	57%	78%	8%	58%	31%	59%	56%	49%	58%	89%	75%	78%	78%	48%	34%	82%	82%	82%	44%	60%
23 Jan	--	--	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	+1
	4	1	2	7	6	0	5	1	5	3	5	4	2	3	4	4	4	1	3	0	0	8	72
	48%	72%	39%	57%	79%	8%	59%	31%	59%	57%	49%	59%	88%	75%	77%	77%	48%	34%	80%	80%	80%	44%	59%
24 Jan	--	--	--	+2	+1	--	+1	--	--	--	--	--	+2	--	+2	--	--	--	--	--	--	--	+8
	4	1	2	9	7	0	6	1	5	3	5	4	4	3	6	4	4	1	3	0	0	8	80
	48%	69%	37%	58%	80%	8%	59%	31%	60%	57%	49%	60%	88%	74%	76%	76%	48%	34%	79%	79%	79%	44%	59%
28 Jan	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	+1	--	--	--	+2
	4	1	2	9	7	0	6	1	5	4	5	4	4	3	6	4	4	1	4	0	0	8	82
	49%	59%	33%	61%	80%	8%	60%	30%	62%	58%	50%	63%	88%	74%	76%	76%	48%	34%	76%	76%	76%	44%	58%
29 Jan	--	--	--	--	--	--	--	+2	+2	--	--	--	--	--	--	--	--	--	--	--	--	--	+4
	4	1	2	9	7	0	6	3	7	4	5	4	4	3	6	4	4	1	4	0	0	8	86
	50%	58%	33%	62%	80%	8%	61%	30%	63%	58%	50%	64%	88%	74%	76%	76%	48%	34%	77%	77%	77%	43%	59%
30 Jan	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	--	+1	+1	--	--	--	--	+3
	4	1	2	10	7	0	6	3	7	4	5	4	4	3	6	4	5	2	4	0	0	8	89
	50%	59%	34%	63%	82%	8%	62%	32%	63%	58%	50%	65%	88%	74%	76%	76%	49%	34%	78%	78%	78%	44%	59%
01 Feb	+1	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	+2
	5	1	2	10	7	0	6	3	7	4	6	4	4	3	6	4	5	2	4	0	0	8	91
	53%	63%	35%	66%	82%	8%	64%	35%	66%	61%	52%	66%	90%	76%	77%	77%	51%	38%	82%	82%	82%	44%	61%

Winter # SL	Ken	RP	Nun	Haw	Hal	She	Kus	Per	Obl	RS e	RS w	Eag	12M-1	12M-2	HS-1	HS-2	BB	LB	Gu-1	Gu-2	Gu-3	Moo	Sum
	3	1	2	5	4	0	4	0	4	3	4	2	3	3	4	4	3	0	2	0	0	7	**58**
13 Feb	--	--	--	--	--	--	+1	--	--	+1	--	+1	--	--	--	--	--	--	--	--	--	--	**+3**
	5	1	2	10	7	0	7	3	7	5	6	5	4	3	6	4	5	2	4	0	0	8	**94**
	62%	*58%*	*33%*	*74%*	*86%*	*25%*	*69%*	*51%*	*73%*	*69%*	*59%*	*72%*	*94%*	*79%*	*79%*	*79%*	*58%*	*52%*	*83%*	*83%*	*83%*	*43%*	***67%***
18 Feb	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	**+1**
	5	1	2	10	7	0	7	3	7	5	6	5	4	3	6	4	6	2	4	0	0	8	**95**
	62%	*58%*	*33%*	*76%*	*88%*	*26%*	*71%*	*52%*	*75%*	*69%*	*60%*	*72%*	*93%*	*78%*	*78%*	*78%*	*58%*	*53%*	*83%*	*83%*	*83%*	*44%*	***67%***
27 Feb	--	--	+5	--	--	+5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**+10**
	5	1	7	10	7	5	7	3	7	5	6	5	4	3	6	4	6	2	4	0	0	8	**105**
	63%	*59%*	*84%*	*78%*	*93%*	*13%*	*74%*	*54%*	*78%*	*70%*	*60%*	*73%*	*91%*	*77%*	*77%*	*77%*	*61%*	*46%*	*82%*	*82%*	*82%*	*43%*	***69%***
06 Mar	--	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	**+1**
	5	1	7	10	7	5	7	3	7	5	7	5	4	3	6	4	6	2	4	0	0	8	**106**
	63%	*59%*	*83%*	*77%*	*94%*	*29%*	*75%*	*53%*	*79%*	*70%*	*60%*	*74%*	*92%*	*78%*	*77%*	*77%*	*63%*	*46%*	*81%*	*81%*	*81%*	*43%*	***70%***
12 Mar	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	**+1**
	5	1	7	10	7	5	7	3	7	5	7	5	4	3	6	4	7	2	4	0	0	8	**107**
	63%	*60%*	*82%*	*78%*	*95%*	*37%*	*76%*	*53%*	*80%*	*71%*	*61%*	*73%*	*92%*	*78%*	*77%*	*77%*	*65%*	*46%*	*82%*	*82%*	*82%*	*44%*	***71%***
13 Mar	+1	--	--	+1	--	--	+1	+1	+1	+1	--	+1	--	--	--	--	--	--	--	--	--	--	**+7**
	6	1	7	11	7	5	8	4	8	6	7	5	4	3	6	4	7	2	4	0	0	8	**113**
	64%	*61%*	*82%*	*79%*	*96%*	*38%*	*77%*	*56%*	*80%*	*72%*	*62%*	*73%*	*93%*	*79%*	*78%*	*78%*	*66%*	*47%*	*83%*	*83%*	*83%*	*44%*	***71%***
22 Mar	--	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	**+1**
	6	1	7	11	7	5	8	4	8	6	8	5	4	3	6	4	7	2	4	0	0	8	**114**
	68%	*52%*	*81%*	*83%*	*94%*	*50%*	*80%*	*63%*	*84%*	*76%*	*66%*	*76%*	*92%*	*78%*	*78%*	*78%*	*72%*	*66%*	*84%*	*84%*	*84%*	*44%*	***74%***
25 Mar	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-1	--	--	--	--	--	**-1**
	6	1	7	11	7	5	8	4	8	6	8	5	4	3	6	4	6	2	4	0	0	8	**113**
	69%	*51%*	*80%*	*83%*	*93%*	*51%*	*81%*	*64%*	*84%*	*77%*	*67%*	*76%*	*91%*	*77%*	*77%*	*77%*	*74%*	*79%*	*83%*	*83%*	*83%*	*43%*	***75%***
05 Apr	+1	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**+2**
	7	1	7	12	7	5	8	4	8	6	8	5	4	3	6	4	6	2	4	0	0	8	**115**
	71%	*54%*	*81%*	*85%*	*95%*	*55%*	*85%*	*71%*	*88%*	*82%*	*70%*	*80%*	*91%*	*77%*	*77%*	*77%*	*73%*	*58%*	*85%*	*85%*	*85%*	*44%*	***76%***
09 Apr	--	--	--	--	--	--	--	--	--	+1	--	+1	--	--	--	--	--	--	--	--	--	--	**+2**
	7	1	7	12	7	5	8	4	8	7	8	6	4	3	6	4	6	2	4	0	0	8	**117**
	74%	*53%*	*81%*	*87%*	*95%*	*63%*	*89%*	*74%*	*91%*	*85%*	*73%*	*85%*	*95%*	*80%*	*80%*	*80%*	*76%*	*64%*	*90%*	*90%*	*90%*	*46%*	***79%***
10 Apr	--	--	--	--	-1	--	--	--	--	--	--	--	--	--	--	--	--	--	-1	--	--	-3	**-5**
	7	1	7	12	6	5	8	4	8	7	8	6	4	3	6	4	6	2	3	0	0	5	**112**
	75%	*55%*	*82%*	*89%*	*96%*	*67%*	*90%*	*76%*	*93%*	*86%*	*74%*	*87%*	*98%*	*83%*	*82%*	*82%*	*78%*	*70%*	*95%*	*95%*	*95%*	*47%*	***82%***
11 Apr	+1	--	--	--	--	--	--	+1	-1	--	--	-1	--	--	--	--	--	--	--	--	--	--	
	8	1	7	12	6	5	8	5	8	7	8	5	4	3	6	4	6	2	3	0	0	5	**112**
	77%	*57%*	*83%*	*90%*	*95%*	*69%*	*92%*	*79%*	*94%*	*88%*	*76%*	*90%*	*101%*	*86%*	*83%*	*83%*	*80%*	*72%*	*96%*	*96%*	*96%*	*50%*	***83%***
16 Apr	--	--	--	--	--	--	--	--	--	--	--	-1	-2	--	-2	--	+1	+1	-1	--	--	-3	**-7**
	8	1	7	12	6	5	8	5	8	7	8	4	2	3	4	4	7	3	2	0	0	2	**105**
	84%	*61%*	*84%*	*93%*	*91%*	*84%*	*98%*	*88%*	*96%*	*95%*	*82%*	*98%*	*115%*	*97%*	*93%*	*93%*	*81%*	*74%*	*96%*	*96%*	*96%*	*48%*	***88%***

Winter # SL	Ken	RP	Nun	Haw	Hal	She	Kus	Per	Obl	RS e	RS w	Eag	12M-1	12M-2	HS-1	HS-2	BB	LB	Gu-1	Gu-2	Gu-3	Moo	Sum
	3	1	2	5	4	0	4	0	4	3	4	2	3	3	4	4	3	0	2	0	0	7	**58**
17 Apr	--	--	--	--	--	--	--	--	-3	+2	--	-2	--	--	--	--	--	--	-2	--	--	-2	**-7**
	8	1	7	12	6	5	8	5	5	9	8	2	2	3	4	4	7	3	2	0	0	2	**98**
	86%	*65%*	*86%*	*94%*	*92%*	*87%*	*100%*	*90%*	*98%*	*96%*	*83%*	*98%*	*115%*	*97%*	*92%*	*92%*	*86%*	*80%*	*99%*	*99%*	*99%*	*48%*	***90%***
18 Apr	+1	--	--	--	--	--	-2	--	--	--	+2	--	--	--	--	--	--	--	--	--	--	--	+1
	8	1	7	12	6	5	6	5	5	9	10	2	2	3	4	4	7	3	0	0	0	0	**99**
	88%	*69%*	*88%*	*95%*	*92%*	*91%*	*102%*	*95%*	*95%*	*99%*	*85%*	*98%*	*116%*	*98%*	*95%*	*95%*	*90%*	*87%*	*100%*	*100%*	*100%*	*54%*	***92%***
19 Apr	-4	--	--	-6	-4	--	-2	--	--	--	--	--	--	-3	-4	-1	+1	+1	--	--	--	--	**-22**
	4	1	7	6	2	5	4	5	5	9	10	2	2	0	0	3	8	4	0	0	0	0	**77**
	95%	*85%*	*94%*	*103%*	*99%*	*94%*	*109%*	*104%*	*101%*	*107%*	*92%*	*106%*	*127%*	*107%*	*100%*	*100%*	*100%*	*100%*	*103%*	*103%*	*103%*	*59%*	***100%***
20 Apr	--	-1	--	--	--	--	--	--	--	--	--	--	-2	--	+1	--	-1	-1	--	--	--	--	**-4**
	4	0	7	6	2	5	4	5	5	9	10	2	0	0	1	3	7	3	0	0	0	0	**73**
	99%	*148%*	*109%*	*100%*	*94%*	*97%*	*110%*	*112%*	*105%*	*118%*	*102%*	*111%*	*146%*	*124%*	*101%*	*101%*	*110%*	*112%*	*115%*	*115%*	*115%*	*67%*	***110%***
21 Apr	--	--	--	+6	+3	--	+4	--	+1	--	--	+2	--	--	--	+1	+1	--	--	--	--	--	**+18**
	4	0	7	12	5	5	8	5	6	9	10	4	0	0	1	4	8	3	0	0	0	0	**90**
	102%	*165%*	*111%*	*99%*	*97%*	*101%*	*109%*	*121%*	*106%*	*126%*	*108%*	*112%*	*160%*	*135%*	*110%*	*110%*	*107%*	*122%*	*122%*	*122%*	*122%*	*72%*	***115%***
22 Apr	--	--	--	--	--	--	+2	--	+2	--	-2	+1	--	--	--	--	+1	+1	--	--	--	--	**+5**
	4	0	7	12	5	5	10	5	8	9	8	5	0	0	1	4	8	4	0	0	0	0	**95**
	103%	*176%*	*112%*	*103%*	*101%*	*104%*	*109%*	*116%*	*106%*	*130%*	*112%*	*116%*	*163%*	*138%*	*118%*	*118%*	*106%*	*114%*	*128%*	*128%*	*128%*	*77%*	***118%***
23 Apr	--	--	--	--	+2	--	--	+1	--	--	--	--	--	--	+1	+4	+1	--	--	--	--	--	**+9**
	4	0	7	12	7	5	10	6	8	9	8	5	0	0	2	8	9	4	0	0	0	0	**103**
	103%	*177%*	*112%*	*106%*	*103%*	*107%*	*108%*	*114%*	*106%*	*131%*	*112%*	*116%*	*162%*	*137%*	*121%*	*121%*	*104%*	*113%*	*131%*	*131%*	*131%*	*81%*	***119%***
24 Apr	--	--	--	--	--	-3	-2	--	--	--	--	--	+2	--	-1	+1	--	--	--	--	--	--	**-3**
	4	0	7	12	7	2	8	6	8	9	8	5	2	0	1	9	9	4	0	0	0	0	**100**
	101%	*180%*	*112%*	*107%*	*110%*	*111%*	*109%*	*114%*	*107%*	*130%*	*112%*	*116%*	*156%*	*132%*	*133%*	*133%*	*103%*	*109%*	*132%*	*132%*	*132%*	*81%*	***120%***
25 Apr	+2	--	--	--	-1	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	**+2**
	6	0	7	12	6	2	8	6	8	9	8	5	3	0	1	9	9	4	0	0	0	0	**102**
	100%	*180%*	*112%*	*108%*	*118%*	*108%*	*109%*	*114%*	*108%*	*129%*	*111%*	*116%*	*155%*	*131%*	*131%*	*131%*	*103%*	*109%*	*132%*	*132%*	*132%*	*83%*	***121%***
26 Apr	--	--	--	-1	-1	-2	--	+1	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	**-3**
	6	0	7	11	5	0	8	6	8	9	8	6	3	0	1	9	9	4	0	0	0	0	**100**
	102%	*167%*	*111%*	*110%*	*117%*	*105%*	*110%*	*113%*	*109%*	*128%*	*110%*	*115%*	*157%*	*133%*	*130%*	*130%*	*103%*	*107%*	*132%*	*132%*	*132%*	*84%*	***120%***
27 Apr	--	--	--	--	--	--	-1	--	+1	--	--	--	--	--	--	--	--	--	--	--	--	--	
	6	0	7	11	5	0	7	6	9	9	8	6	3	0	1	9	9	4	0	0	0	0	**100**
	101%	*161%*	*110%*	*109%*	*114%*	*102%*	*111%*	*114%*	*110%*	*126%*	*109%*	*116%*	*158%*	*134%*	*128%*	*128%*	*102%*	*107%*	*131%*	*131%*	*131%*	*82%*	***119%***
28 Apr	+2	--	--	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	**+3**
	8	0	7	11	5	0	7	6	9	9	9	6	3	0	1	9	9	4	0	0	0	0	**103**
	100%	*155%*	*110%*	*108%*	*113%*	*99%*	*111%*	*114%*	*110%*	*125%*	*108%*	*116%*	*160%*	*136%*	*128%*	*128%*	*102%*	*105%*	*130%*	*130%*	*130%*	*81%*	***118%***
29 Apr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		+1	--	--	--	--	**+1**
	8	0	7	11	5	0	7	6	9	9	9	6	3	0	1	9	9	5	0	0	0	0	**104**
	102%	*140%*	*108%*	*107%*	*113%*	*96%*	*111%*	*114%*	*110%*	*124%*	*107%*	*115%*	*161%*	*136%*	*129%*	*129%*	*102%*	*105%*	*129%*	*129%*	*129%*	*81%*	***117%***

Winter # SL	Ken	RP	Nun	Haw	Hal	She	Kus	Per	Obl	RS e	RS w	Eag	12M-1	12M-2	HS-1	HS-2	BB	LB	Gu-1	Gu-2	Gu-3	Moo	Sum
	3	1	2	5	4	0	4	0	4	3	4	2	3	3	4	4	3	0	2	0	0	7	**58**
30 Apr	--	--	--	+2	+1	--	--	--	--	--	--	--	+1	--	--	--	--	--	--	--	--	--	**+4**
	8	0	7	13	6	0	7	6	9	9	9	6	4	0	1	9	9	5	0	0	0	0	**108**
	102%	*129%*	*107%*	*106%*	*111%*	*93%*	*111%*	*114%*	*111%*	*123%*	*106%*	*115%*	*160%*	*136%*	*129%*	*129%*	*102%*	*105%*	*129%*	*129%*	*129%*	*80%*	***116%***
01 May	--	--	--	--	--	--	--	--	-1	+1	--	-1	--	--	--	-1	--	--	--	--	--	--	**-2**
	8	0	7	13	6	0	7	6	8	10	9	6	4	0	1	8	9	5	0	0	0	0	**106**
	102%	*121%*	*106%*	*106%*	*112%*	*90%*	*110%*	*113%*	*111%*	*122%*	*105%*	*114%*	*159%*	*134%*	*128%*	*128%*	*102%*	*105%*	*128%*	*128%*	*128%*	*79%*	***115%***
07 May	--	+2	--	--	--	--	--	--	--	+1	--	--	--	--	--	-1	--	--	--	--	--	--	**+2**
	8	2	7	13	6	0	7	6	8	11	9	6	4	0	1	7	9	5	0	0	0	0	**108**
	102%	*87%*	*85%*	*102%*	*106%*	*73%*	*105%*	*109%*	*105%*	*118%*	*102%*	*105%*	*141%*	*119%*	*117%*	*117%*	*101%*	*103%*	*117%*	*117%*	*117%*	*70%*	***105%***
08 May	--	--	+2	--	--	+5	+1	--	--	--	+2	+1	--	--	--	--	--	--	--	--	--	--	**+11**
	8	2	9	13	6	5	8	6	8	11	11	6	4	0	1	7	9	5	0	0	0	0	**118**
	101%	*89%*	*94%*	*101%*	*105%*	*70%*	*104%*	*108%*	*104%*	*117%*	*101%*	*103%*	*139%*	*117%*	*114%*	*114%*	*101%*	*102%*	*115%*	*115%*	*115%*	*69%*	***104%***
09 May	--	--	--	+1	--	--	+1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**+2**
	8	2	9	14	6	5	9	6	8	11	11	6	4	0	1	7	9	5	0	0	0	0	**120**
	101%	*91%*	*102%*	*99%*	*104%*	*77%*	*101%*	*108%*	*103%*	*117%*	*101%*	*102%*	*135%*	*114%*	*111%*	*111%*	*101%*	*101%*	*113%*	*113%*	*113%*	*67%*	***104%***
11 May	--	--	--	--	+1	--	--	--	--	-2	--	-1	--	+2	+2	--	--	--	--	--	--	--	**+3**
	8	2	9	14	7	5	9	6	8	9	11	5	4	2	3	7	9	5	0	0	0	0	**123**
	102%	*97%*	*103%*	*100%*	*98%*	*93%*	*102%*	*107%*	*102%*	*118%*	*102%*	*102%*	*124%*	*105%*	*107%*	*107%*	*100%*	*101%*	*110%*	*110%*	*110%*	*65%*	***103%***
12 May	--	--	--	-1	+1	--	--	--	--	--	--	--	--	+2	+2	--	--	--	--	--	--	--	**+4**
	8	2	9	14	8	5	9	6	8	9	11	5	4	4	5	7	9	5	0	0	0	0	**127**
	101%	*99%*	*103%*	*100%*	*97%*	*101%*	*102%*	*107%*	*101%*	*119%*	*102%*	*102%*	*120%*	*102%*	*106%*	*106%*	*100%*	*101%*	*106%*	*106%*	*106%*	*63%*	***102%***
13 May	--	--	--	--	--	--	--	--	+1	--	--	+1	--	--	--	--	--	--	+3	--	--	--	**+5**
	8	2	9	14	8	5	9	6	9	9	11	6	4	4	5	7	9	5	3	0	0	0	**131**
	101%	*101%*	*103%*	*101%*	*97%*	*102%*	*102%*	*106%*	*101%*	*118%*	*102%*	*102%*	*120%*	*102%*	*107%*	*107%*	*100%*	*101%*	*101%*	*101%*	*101%*	*58%*	***101%***
14 May	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+3	--	--	+9	**+11**
	8	2	9	14	8	5	9	6	9	9	11	6	4	4	5	7	9	5	6	0	0	9	**142**
	101%	*101%*	*103%*	*101%*	*96%*	*103%*	*102%*	*106%*	*101%*	*118%*	*102%*	*102%*	*120%*	*101%*	*104%*	*104%*	*100%*	*101%*	*98%*	*98%*	*98%*	*47%*	***100%***
16 May	--	--	--	-1	-1	--	--	--	--	--	--	--	--	+1	+1	--	--	--	--	--	--	--	
	8	2	9	13	7	5	9	6	9	9	11	6	4	5	6	7	9	5	6	0	0	9	**142**
	101%	*102%*	*103%*	*102%*	*97%*	*106%*	*102%*	*105%*	*101%*	*118%*	*101%*	*101%*	*118%*	*100%*	*100%*	*100%*	*99%*	*103%*	*101%*	*101%*	*101%*	*54%*	***101%***
17 May	-1	--	--	-1	-1	--	--	--	--	--	-1	--	--	--	--	+1	--	--	-1	--	--	--	**-3**
	8	2	9	12	7	5	9	6	9	9	10	6	4	5	6	8	9	5	5	0	0	9	**140**
	101%	*102%*	*103%*	*102%*	*98%*	*106%*	*102%*	*105%*	*101%*	*118%*	*101%*	*100%*	*119%*	*101%*	*99%*	*99%*	*99%*	*102%*	*102%*	*102%*	*102%*	*56%*	***101%***
21 May	--	--	--	-1	-1	--	--	--	--	--	--	--	--	-2	--	-1	--	--	--	--	--	--	**-4**
	8	2	9	11	6	5	9	6	9	9	10	6	4	3	6	7	9	5	5	0	0	9	**136**
	99%	*108%*	*104%*	*102%*	*101%*	*107%*	*101%*	*103%*	*101%*	*117%*	*100%*	*99%*	*125%*	*105%*	*99%*	*99%*	*99%*	*98%*	*99%*	*99%*	*99%*	*55%*	***101%***
22-May	--	--	--	--	-1	--	--	--	--	--	--	--	-1	--	-3	--	--	--	-2	--	--	-3	**-10**
	8	2	9	11	5	5	9	6	9	9	10	6	3	3	3	7	9	5	3	0	0	6	**127**
	99%	*111%*	*104%*	*102%*	*104%*	*105%*	*103%*	*105%*	*102%*	*117%*	*100%*	*101%*	*125%*	*106%*	*103%*	*103%*	*103%*	*105%*	*102%*	*102%*	*102%*	*57%*	***103%***

Winter # SL	Ken	RP	Nun	Haw	Hal	She	Kus	Per	Obl	RS e	RS w	Eag	12M-1	12M-2	HS-1	HS-2	BB	LB	Gu-1	Gu-2	Gu-3	Moo	Sum
	3	1	2	5	4	0	4	0	4	3	4	2	3	3	4	4	3	0	2	0	0	7	**58**
23-May	-2	-2	--	--	--	--	--	--	-1	--	--	-2	-2	--	--	-3	--	--	-3	--	--	-4	**-19**
	6	0	9	11	5	5	9	6	8	9	10	4	1	3	3	4	9	5	0	0	0	2	**108**
	104%	*124%*	*110%*	*103%*	*104%*	*110%*	*105%*	*107%*	*104%*	*118%*	*102%*	*103%*	*128%*	*108%*	*102%*	*102%*	*106%*	*112%*	*107%*	*107%*	*107%*	*64%*	***106%***
24-May	--	--	-2	-2	-2	--	--	--	--	--	--	--	--	--	--	--	-1	-2	--	--	--	--	**-9**
	6	0	7	9	3	5	9	6	8	9	10	4	1	3	3	4	8	3	0	0	0	2	**100**
	103%	*144%*	*108%*	*105%*	*104%*	*113%*	*106%*	*110%*	*104%*	*119%*	*102%*	*101%*	*126%*	*106%*	*98%*	*98%*	*110%*	*119%*	*110%*	*110%*	*110%*	*65%*	***108%***
25-May	--	--	--	--	--	--	-2	-1	-2	--	--	--	--	--	--	--	-1	-1	--	--	--	--	**-7**
	6	0	7	9	3	5	7	5	6	9	10	4	1	3	3	4	7	2	0	0	0	2	**93**
	103%	*152%*	*109%*	*104%*	*98%*	*111%*	*107%*	*111%*	*104%*	*119%*	*102%*	*99%*	*126%*	*107%*	*97%*	*97%*	*108%*	*109%*	*110%*	*110%*	*110%*	*65%*	***107%***
26-May	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	+1	+1	--	--	--	--	**+2**
	6	0	7	9	3	5	7	5	6	9	10	4	1	3	3	4	8	3	0	0	0	2	**95**
	103%	*153%*	*109%*	*104%*	*96%*	*111%*	*105%*	*109%*	*101%*	*119%*	*103%*	*101%*	*129%*	*109%*	*97%*	*97%*	*103%*	*103%*	*110%*	*110%*	*110%*	*65%*	***107%***
27-May	--	--	--	--	--	--	+1	--	+2	--	--	+1	--	-1	--	-1	+1	+2	--	--	--	--	**+5**
	6	0	7	9	3	5	8	5	8	9	10	5	1	3	3	4	9	5	0	0	0	2	**100**
	102%	*153%*	*109%*	*104%*	*95%*	*111%*	*103%*	*107%*	*100%*	*120%*	*103%*	*105%*	*132%*	*111%*	*98%*	*98%*	*101%*	*96%*	*109%*	*109%*	*109%*	*63%*	***106%***
28-May	--	--	--	--	--	--	--	--	--	--	--	--	--	-1	--	--	--	--	--	--	--	--	**-1**
	6	0	7	9	3	5	8	5	8	9	10	5	1	2	3	4	9	5	0	0	0	2	**99**
	100%	*152%*	*109%*	*103%*	*95%*	*110%*	*102%*	*105%*	*101%*	*120%*	*103%*	*105%*	*132%*	*111%*	*97%*	*97%*	*101%*	*99%*	*108%*	*108%*	*108%*	*62%*	***106%***
30-May	+2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**+2**
	7	0	7	9	3	5	8	5	8	9	10	5	1	2	3	4	9	5	0	0	0	2	**101**
	98%	*148%*	*109%*	*103%*	*93%*	*108%*	*101%*	*102%*	*100%*	*120%*	*103%*	*106%*	*129%*	*109%*	*100%*	*100%*	*101%*	*103%*	*107%*	*107%*	*107%*	*61%*	***105%***

Note: Stoplogs may be standard stoplogs or half stoplogs. The numbers were rounded to the unit in this table.

About AECOM

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