Rideau Valley Conservation Authority
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Technical Memorandum

Date: August 9, 2011

Subject: **Analysis of Regulatory Flood Level on the Shoreline of Otty Lake, for the purposes of administering Ontario Regulation 174/06**

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Abstract

This memo provides a summary of the background information, simplifying assumptions and hydrologic and hydraulic analysis methods used to generate a reasonable estimate of the Regulatory (1:100 year) Flood Level for Otty Lake. As found earlier for other lakes, it was not possible to identify the approximate extent of lands that may be inundated under that water level, due to the limitations of available topographical information. This study supports the plotting of Regulation Limits Mapping for the Lake. The study area, consisting of the Otty Lake watershed is depicted in Figures 1 and 2.

The completed analysis meets or exceeds the standards for "approximate methods for estimating flood plains" as provided for in "Guidelines for Developing Schedules of Regulated Areas" (Conservation Ontario, 2005).

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[1] The guidance and technical review provided by Bruce Reid are gratefully acknowledged.

Introduction

The development and site alteration control provisions of Ontario Regulation 174/06 apply in all areas within the RVCA area of jurisdiction meeting criteria set out in Ontario Regulation 97/04 (the so-called “generic regulation”), including areas that are adjacent to inland lakes and could be affected by flooding under 1:100 year flood conditions, or by erosion and slope failure processes. Over time, and as resources enable it, RVCA is working to complete its inventory of regulation limits mapping to explicitly delineate the areas that are subject to the regulation. Doing so will better inform the general public, landowners and RVCA staff as to where the regulations are in effect and are to be enforced.

There are numerous inland lakes in the RVCA area of jurisdiction for which there has been no previous attempt to define regulatory (1:100 year) flood levels and corresponding estimated flood lines. Otty Lake was selected as a test case for the development of an approximate method for determining the flood level that is suitable for use on lakes that perform no artificial flow regulation or water storage function, and where the historical record of outflow discharge or annual maximum water level is insufficient for the use of statistical methods (single station frequency analysis). A three step process has been developed:

Step 1 – estimation of the 1:100 year flow at the lake’s outlet. Initially, flood flows at the outlets of all the lakes in the RVCA’s area of jurisdiction were estimated using a number of methods (RVCA, 2010). Various methods, borrowed from scientific research papers, handbooks and guideline documents, were applied and compared with a view to identifying a probable range of values for the 1:100 year discharge for each lake. The selection of a recommended 1:100 year discharge value for any particular lake (e.g., Otty Lake) would then be made through closer examination of all of the available streamflow and water level information that is available for that lake and its receiving stream, and consideration of its natural runoff storage and release function (which depends on the lake’s area and the physical characteristics of its outlet).

Step 2 – computation of the lake level that corresponds with the 1:100 year flow at the lake’s outlet, using information about the physical characteristics of the lake’s outlet that determine it’s hydraulic (flow) capacity, as well as the lake’s runoff storage capacity. For Otty Lake, surveys of the bridge under Rideau Ferry Road were completed.

Step 3 – estimated flood lines corresponding to the 1:100 year water surface elevation are then plotted using available topography of the shorelines around the lake. For most of the lakes in the RVCA area of jurisdiction, the best available topographic information is available in two formats:

- 1:10,000 scale OBM (Ontario Base Mapping) with a 5 m contour interval
- 10 m x 10 m Digital Elevation Model (DEM) compiled by MNR in 2006

Floodline plotting can be automated using computer programs and the DEM, or done manually by interpolating between the 5 metre contours. The two methods may yield differing results (in terms of the plotted position of the flood line in plan view), but neither line would be considered to more accurately reflect the true position of the flood line on the ground than the other. As found earlier for other lakes, plotting the flood line using the DEM was not possible due to the limitations of available data. The resolution of the DEM (10x10m) is such that local topographic features at the scale of typical shoreline properties may not be accurately reflected in the DEM. Also, the stated vertical accuracy of the DEM is ±2.5 metres. Accordingly the flood lines estimated this way would only be a crude approximation, compared to the accuracy that has in the past been required for engineered flood line mapping. They may therefore not be suitable for RVCA regulation limits mapping purposes or for use in designating hazard lands for municipal zoning purposes.

Study Area

Otty Lake has a surface area of 640.5 hectares and a shoreline length of 41.4 km. The catchment area draining to the lake is 49.6 km^2.

The study area includes the watershed of Otty Lake as shown in Figures 1 (aerial photo base) and Figure 2 (DEM base). Ideally, regulation limits are to be produced for the entire shoreline of Otty Lake and adjacent low-lying areas based (in part) on the estimated flood lines for the 1:100 year water surface elevation. Rideau Ferry Road was assumed to act as the “hydraulic control” for lake levels during extreme runoff events and is therefore the downstream boundary of the study area.

The entire study area is within the townships of Tay Valley and Drummond-North Elmsley. There is no major centre of settlement around the lake or in the study area, but many (≈500) lakeside cottages and rural residences.

Hydrological Analysis

There are no historical streamflow records for Jebb’s Creek, the outlet of Otty Lake. Local residents have been recording water levels of Otty Lake on a non-continuous basis since 1982. These data may or may not include actual annual maximum water levels; the period of record is short (19 years); the channel bed might also have undergone (undocumented) changes during that time; and outlet conditions during that time were variable as a result of beaver activity in the outlet channel downstream of Rideau Ferry Road. Furthermore, the measurements were rather course and of low accuracy, and the geodetic datum used was only roughly estimated. Statistical analysis methods (frequency analysis) can not be used because of these limitations in the historical records.

As described in RVCA (2010), flood flows for the Otty Lake outlet were previously computed using a number of methods, as follows (Table 1, Figure 3):

- FDRP regression (Ontario)
- FDRP regression (Eastern Ontario)
- FDRP regression (Northern Ontario)
- Gingras et al.’s equation (Region 2)
- Gingras et al.’s equation (Region 6)
- Gingras et al.’s equation (Region 7)
- Gingras et al.’s equation (Ontario/Quebec)
- Mike11 long term simulation (1940 to 2007)

- Area-prorating using Rideau River flow at Carleton

Details of these methods and their computation are described in RVCA (2010), and are not repeated here. That analysis concluded that in general, and in the absence of more rigorous hydrologic analysis for any given lake, the 1:100 year discharge should be selected from amongst the range of values derived from the three “FDRP” regression equations, based on local considerations. In this examination of the Otty Lake situation, the 1:100 year flood discharge derived from long term hydrologic simulation using RVCA’s Mike11 model was also considered (see Figure 3).

The original Mike11 model, encompassing the whole Tay River subwatershed, was done at a regional scale and did not account for the Otty Lake outlet (the existing bridge under Rideau Ferry Road). As a part of this study, this bridge was included in this regional model[2]. Part of the model encompassing the Otty-Jebb’s system is shown in Figure 9. The cross-sections of the Otty Lake and Jebb’s Creek were derived from 1970 bathymetry and 2006 10m x 10m DEM respectively[3]. Using this model, streamflow and water surface profiles were simulated on a continuous basis, with observed climatic data recorded at the Ottawa Airport from 1940 to 2007. Within this arrangement, the water level of the Tay River simulated by the model supplied the downstream boundary condition for the Jebb’s Creek, thus automatically capturing temporal and spatial nuances of hydrologic response and hydrodynamic routing. Ignoring the first three years to avoid effects of initial conditions, the remaining 65 years of simulated flow data (1943 to 2007) at the outlet of Otty Lake were used for flood frequency analysis using the CFA program of Environment Canada (Pilon and Harvey, 1993). The flood quintiles derived from this analysis are listed in Table 1 and plotted in Figure 3.

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[2] It should be mentioned that the water level of the Tay River influences the hydraulics of Jebb’s Creek and Otty Lake, i.e., they form a ‘coupled’ system. Therefore, a local scale model of only the Otty Lake and Jebb’s Creek with the water level of Tay as boundary condition was not feasible.

[3] There was a mismatch between these two sources, with the DEM being about 2 m lower. The bridge is therefore represented as “perched” in the model. Nonetheless, its inclusion in the model gives more realistic results. Without the bridge, the (DEM-derived) cross-sections downstream of Otty Lake, being 2 m lower, allow artificially high flows and also substantial backflow. It also allows the lake water level to drop substantially below the bridge invert – obviously wrong because it contradicts the measured data.

The design flows estimated by this regional-scale Mike11 model[4] that takes into account the hydraulics of the outlet channel and Jebb's Creek, including the Rideau Ferry Road bridge, was found to be the most defensible estimate, based on the following:

1. Located to the south and east of the "Frontenac Arch" extension of the Precambrian Shield, Otty Lake's catchment area is more characteristic of the Eastern Ontario hydrologic region, than the Northern Ontario hydrologic region. Therefore the FDRP (Northern) equation was deemed inappropriate for use on Otty Lake.
2. Based on the 19 years (1982-2010) of measured water level data for Otty Lake (Figure 4), one might expect roughly 14 occurrences of a 1:2 year flow (or higher) to have been observed during that period. Noting that Mike11 (with outlet bridge) produced the lowest flows and that the 1:2 year flow produced therefrom (132.20 m corresponding to 2.38 cms) is exceeded only once by the observed data, we infer that other flow estimates are too high and are not supported by water level observations.
3. The 1:2 year flow derived from the Mike11 (with outlet bridge) model is 2.38 cms with an associated water level of 132.20 m. This level was exceeded only once during the last 19 years, which is much fewer than the 14 occurrences expected from simple statistical considerations. Therefore, even this flow estimate is on the conservative (high) side. However, the Mike11 (with outlet bridge) estimate was, although conservative, the least incongruent with the measurements.
4. The Mike11 model (without outlet bridge) gives flows which are roughly twice of those estimated when the bridge is taken into account. This is attributed to the artificial lowering of the outlet channel and Jebb's Creek as a result of the using the DEM, which is roughly 2 m lower than the

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[4] We have designated this as Mike11 (with outlet bridge) as opposed to the original Mike11 model designated as Mike11 (without outlet bridge). For, as we found, the presence of the bridge, along with the entire Jebb's Creek and the Tay River water level at the confluence, influences the outflow from the lake and thus the design flood. Therefore, lake outlet structures not only pass the design flood but also determines its magnitude to a certain extent.

"true" elevation. This leads to quick draining of the lake with high peak flows and lower lake water level, all of these incongruent with the available information. The outlet bridge also controls, to a lesser extent, the water level of the lake and the outflow from it. Therefore, the model accounting for the bridge is superior to the model not accounting for it.

5. In a recent study on Otter Lake (RVCA, 2011), we also used the Mike11 model for flow estimation, and found that accounting for the outlet control improves flow estimation and lowers the design flow by half. Considering the obvious similarities of these two lake-dominated basins, the Mike11 model (with outlet control) gives very consistent and reasonable results. In fact, area-prorating between these basins produces almost the same flows as Mike11.

6. Finally, the volume of runoff required to raise the lake level to the estimated flood level (expressed as a depth of water over the entire catchment area of the lake), was compared with the magnitude of a 1:100 year snowmelt plus rain event over the catchment, as a check on the reasonableness of discharge prediction. The runoff volume required to raise the water level to the water level associated with the higher discharge estimate from the FDRP equations was found to be well in excess of any reasonable estimate of the runoff volume for a 1:100 year event. It appears that while the FDRP equations generally account for the area of the catchment that is controlled by lake storage (ACLS), that term in the regression equation does not apply well to small watersheds where the outflow location (or flow calculation node) is at outlet of a lake with a relatively large surface area in relation to the total area of the catchment – as is the case here, where the surface area of Otty Lake is 13% of the catchment area. Meanwhile, Mike 11's hydrodynamic river flow simulation inherently accounts for the flow attenuating effect of the lake by treating it as a long river reach with an extra wide cross-section.

Considering all information available and based on the considerations outlined above, it is recommended that the discharge estimates derived from the Mike11 (with outlet bridge) long-term simulation be used as the most appropriate for flood risk determination on the shorelines of Otty Lake. The design flows are shown in Table 3.

The flows listed in Table 3 have been used in the hydraulic analysis to determine the corresponding flood levels.

Data Used

Aerial Photo: The available DRAPE aerial photo was collected in May and June of 2008 for the entire RVCA area of jurisdiction. This high quality colored photo (Figure 1) clearly shows the rivers, creeks, land use, houses, buildings, roads, infrastructure, vegetation and other details.

Historic Aerial Photo: As shown in Figure 5, historical photos in this vicinity since the 1950s are available. These photos show lakeshore, watercourses and road layouts. These photos were helpful in gaining insight into the lake outlet, creek, the road crossing, and the surroundings.

DEM: The 10 x 10 m grid DEM was provided by MNR in 2006 (Figure 2). It has an accuracy of 1.5 m horizontally and 2.5 m vertically. Ideally, given a high enough quality of DEM, contour lines at 1 m intervals, and also corresponding to any specified elevation (e.g., 1:100 year flood elevation), can be generated from this DEM using GIS software to enable automated plotting of the flood line instead of more labour intensive interpolation between the 5 metre contours of the OBM maps.

Outlet Culvert: The 5.96 m wide and 2.63 m high concrete bridge under the Rideau Ferry Road acts as the outlet control of the lake under high flow conditions (Figures 6 and 7). The length of the bridge is 12.4 m across the road. Information on the culvert and the associated road profile is available from as-built drawings, and was supplemented by field surveys undertaken by RVCA technologists.

Measured Water Level: Since 1982, periodic water level measurements of the lake water level of Otty Lake have been taken by local residents[5]. This information (Figure 4) has been utilized in the present study. As mentioned earlier, these data may or may not include actual annual maximum water levels. Furthermore, the measurements were rather course and of low accuracy, and the geodetic datum used was only roughly estimated. Therefore, our use of this data was limited to verification rather than direct analysis.

Hydraulic Calculations

For a given estimate of the discharge, the headwater level is determined by the tailwater level (i.e. the water level at the outlet of the bridge), and the hydraulic head required to overcome the energy losses associated with expansion and contraction of the flow at the bridge inlet and outlet, and friction along the length of the bridge (see Figure 10). The HEC-RAS model, which is now almost exclusively used for flood mapping projects in Canada and the USA, can make this calculation. We have used HEC-RAS for the current project too[6].

The tail water, however, is a requirement of this calculation and must be estimated beforehand. In our case, we first estimated the water level at the Tay River corresponding to the design flow using the stage-discharge relationship[7] (Figure 10) derived from the Mike11 model. Then, assuming a typical cross section of Jebb's Creek (10 m bottom, 1:2 side slope), we estimated the change in water level[8] of the Jebb's Creek between the confluence with Tay River and the downstream side of Rideau Ferry

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[5] RVCA has only recently installed a water level logger at Otty Lake that will record continuous water level data. This logger needs to be tested before the collected data can be used.

[6] HEC-RAS has three options (momentum balance, energy balance, and WSPRO). We found that the momentum balance gives the highest amount of head loss across the bridge. Therefore, we used this as the most conservative estimate of head loss.

[7] Due to the changing log settings at the Beveridges Dam, considerable scatter is present in this plot, with higher points indicating more logs in place. Since during severe floods, logs will be taken out, the rating curve under such circumstances will fall near the lower points. Therefore, the rating curve we have drawn is valid for only high flows when logs are pulled out.

[8] We set up a very crude HEC-RAS model of the Jebb's Creek from the confluence with Tay to the bridge and used it to estimate this change in water level. The results were very close (within a few cm).

Road Bridge using the Manning's equation for uniform flow. This was then used as the tail water for the headwater computation in Otty Lake.

The hydraulic calculations are summarized in Table 2. It indicates that the 1:100 year flood level in Otty lake is 132.69 m above mean sea level. The computed water levels and the regulatory flood level of Otty Lake are listed in Table 3.

Calculation of wave rush-up is recommended by MNR (1986, 2002) for flood plain delineation on inland lakes with an effective fetch length longer than 3 km. The Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario, 2005) do not require accounting for wave rush-up on lakes that are less than 100 km^2 in surface area. The effective fetch length for Otty Lake is estimated to be in the range of 1.0-1.6 km using US Corps of Engineers' (1975) method. Therefore, consideration of wave rush-up is not necessary for Otty Lake, regardless of which Guideline is followed.

Summary of Conclusions from Hydrologic and Hydraulic Analyses

The recommended regulatory flood level for Otty Lake is 132.69 metres above sea level, and is associated with a discharge of 5.37 cms at the Rideau Ferry Road bridge, the present configuration of the bridge and downstream channel, and an estimated tail water level of 132.55 metres above sea level.

This regulatory flood level is 0.926 m (36½ inches) below the bottom chord of the bridge and 1.69 m (66½ inches) above the river bed.

The regulatory flood level (132.69 m) can also be expressed relative to the range of water levels (131.35 to 132.20) observed over the last 19 years. The flood level is about 0.49 m (19⅓ inch) above the highest observed water level of 132.20 m, or about 1.34 m (52¾ inch) above the lowest observed water level of 131.35 m (Figure 4).

The highest recorded water level (in the 1982-2010 period) was 132.186 metres above sea level. This level was recorded on April 14, 2008 when beaver dams were present in the outlet channel, corresponds to a 1:2 year event (Table 2), and was only 0.49 m (19¼ inches) lower than the estimated 1:100 year flood level. During that event and throughout the year, RVCA received many complaints regarding high water level and responded by removing 8 beavers and 3 beaver dams. Elsewhere in the Rideau River watershed, the April 2008 spring freshet generated streamflows in the 1:5 year to 1:10 year return period range. These observations lead to these conclusions:

- there is a need for ongoing attention to the beaver activity (dams) on Jebb’s Creek to avoid excessive tailwater levels at the Rideau Ferry Road bridge at the onset of extreme runoff events
- under 1:100 year flood conditions, even with maintenance of the outlet channel, some of the shoreline properties can be expected to be affected to a greater extent than they were in April 2008

The “head loss” (i.e., the difference between upstream and downstream water levels) through the Rideau Ferry Road bridge under 1:100 year flood conditions has been estimated to be 0.14 metres (5½ inches) and is typical of any bridge or culvert of similar size passing similar flow.

Flood Line Delineation and Regulation Limits

Ideally, once the Regulatory Flood Level is established, the plotting of 1:100 year flood lines or flood risk limits around the lake is a relatively straightforward matter. As previously noted, limitations of the available topographical information (the 10 x 10 m DEM received from MNR in 2006) did not allow accurate plotting of contour lines at 1 metre intervals or the estimated flood line at 132.69 metres above sea level. If this were not the case, the Regulation Limit line would then be plotted the prescribed 15 metres upland of the estimated flood line, wherever the extent of the flood hazard area limit is greater than the extent of wetlands or erosion and slope stability hazards.

However, because of the low horizontal resolution and stated vertical accuracy of the digital elevation model, it does not accurately represent the actual topography of shoreline properties, and the resulting estimated flood lines do not accurately identify areas that are affected by flooding under regulatory flood conditions and are, therefore, subject to the regulations.

Until topographic mapping or digital elevation models of better accuracy and resolution becomes available, identifying the boundaries of hazardous lands with reasonable confidence will require on-site inspections and/or aerial photograph interpretation if suitable imagery is available.

The Regulatory Flood Level of 132.69 metres above sea level should be used when assessing the safe access/egress and flood proofing aspects of development applications in the regulated area.

Regulation Policy Recommendations

Because of the large surface area of Otty Lake relative to its catchment area, the lake has a considerable flow attenuating effect during major runoff events. The runoff storage volume associated with inundated low-lying lakeshore properties is insignificant compared with the storage volume on the lake itself. It follows that the flood hydrograph attenuating function of the lake will not be significantly diminished by the minor loss of storage capacity that would be associated with typical shoreline development.

In general, therefore, development of shoreline properties will not have an adverse effect on the control of flooding provided the design of the development meets the following requirements:

1. The estimated regulatory flood level of 132.69 m.a.s.l. should be used in the design of any structures in the regulated area around Otty Lake. Any new structure (or addition to an existing structure) within the regulated area should be flood-proofed to prevent damage to the structure or its contents under 1:100 year flood conditions. The design of flood-proofing measures should include a minimum 30 cm freeboard above the regulatory flood level to provide an additional margin of safety, in consideration of uncertainties in the derivation of the regulatory flood level. The drawings submitted with the application should identify the proposed geodetic elevation of the structure and its foundation elements, and the flood

proofing provisions in the design will be determined by the structure’s relationship to the regulatory flood level.

2. Applications for approval of new residential buildings or additions that would enable an increase in the occupancy of existing residential buildings, in the regulated area will need to be accompanied by information on the access route to the building. Safe access to and egress from the site will be required under 1:100 year conditions. 30 cm (or less) of flood waters on access roads has typically been accepted as meeting safe access requirements, where flow velocities are not significant. Topographic surveys of access routes may be required.

3. In general, lot grading and site alteration should be designed to minimize the need for importation fill from off-site, and in all cases shall be designed so as to ensure no degradation – and enhancement where possible – of the ecological integrity and water quality protection functions of the shoreline and riparian zone.

Closure

The hydrotechnical procedures used in this study to determine a regulatory flood level for Otty Lake conform to present day standards for flood hazard delineation, as set out in the MNR Natural Hazards Technical Guide (MNR, 2002). The computed flood elevations will be useful in the evaluation of applications for approval of development or site alteration in the regulated area and will also be of value in the flood forecasting and warning services of the RVCA.

The 1:100 year flood limits could not be drawn due to the inaccuracies of the available topographical information. In the absence of topographic mapping or digital elevation models of better accuracy and resolution, identifying the boundaries of hazardous lands with reasonable confidence will require on-site inspections and/or aerial photograph interpretation if suitable imagery is available.

The analysis has also provided information regarding the influence of the Rideau Ferry Road bridge and the downstream reach of Jebb's Creek on lake levels under extreme events, which may be of interest and use to the municipalities and lakeside residents.

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4. MMAH (2005). 2005 Provincial Policy Statement. Ontario Ministry of Municipal Affairs and Housing, Queen’s Printer, Toronto, Ontario, 2005.
5. MNR (1986). Flood Plain Management in Ontario – Technical Guidelines. Ontario Ministry of Natural Resources, Conservation Authorities and Water Management Branch, Toronto.
6. MNR (2002). Technical Guide – River & Stream systems: Flooding Hazard Limit. Ontario Ministry of Natural Resources, Water Resources Section, Peterborough, Ontario, 2002.
7. RVCA (2007). Rideau River Watershed Modeling Using Mike11, Draft Report, Rideau Valley Conservation Authority, Manotick, Ontario, March 2007.
8. RVCA (2010). Estimation of Design Flows for RVCA Lakes. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, November 2010.
9. RVCA (2011). Analysis of Regulatory Flood Level on the Shoreline of Otter Lake, for the purposes of administering Ontario Regulation 174/06. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, June 2010.
10. US Corps of Engineers (1975). Shore Protection Manual. 2nd edition. US Army Coastal Research Center, Fort Belvoir, VA, USA, 1975.

Table 1: Estimated Flood Flows at Otty Lake Outlet

Return Period (years)	METHOD									
	Mike11[1] (with outlet bridge)	Mike11[1] (without outlet bridge)	FDRP[2]			Gingras et al.[3]				Area Pro-rating Method[4]
			Northern Ontario	Eastern Ontario	Ontario	Region: 7	Region: ON/QC	Region: 2	Region: 6	
2	2.38	9.25	4.69	9.91	4.48	9.62	11.55	24.52	3.93	
5	3.14	9.93	6.95	12.50	6.60					
10	3.66	10.30	8.54	14.12	8.09					
20	4.17	10.60	10.12	15.62	9.56	21.70	24.46	50.66	8.09	
50	4.85	11.00	12.94	18.22	12.21					
100	5.37	11.30	15.24	20.20	14.37	28.07	30.44	61.88	10.48	25.11
200	5.90	11.50								
500	6.63	11.80								

1. Mike11 output, using a Three Parameter Log Normal Frequency Distribution
2. MNR (1986). Flood Plain Management in Ontario – Technical Guidelines. Ontario Ministry of Natural Resources, Conservation Authorities and Water Management Branch, Toronto.
3. Gingras, D., Adamowski, K., and Pilon, P.J. (1994) Regional Flood Equations for the Provinces of Ontario and Quebec. Water Resources Bulletin 30(1):55-67.
4. Area Pro-rating method using streamflow measurements from the gauge: Rideau River at Carleton University (Station ID 02AL004; drainage area 3830 km2)

Source: RVCA (2010), Estimation of Design Flows for RVCA Lakes

Table 2: Computation of Headwater

Return Period	Otty Lake Outflow[1]	Tay River Flow at Jebbs Creek confluence[1]	Tay River Water Level at Jebbs Creek confluence[2]	Change in Water Level along Jebbs Creek from Tay River confluence to Rideau Ferry Rd Bridge[3]	Tail Water Level D/S of Rideau Ferry Road Bridge	Head loss through the Bridge[4]	Headwater Elevation at Otty Lake
years	cms	cms	m	cm	m	cm	m
2	2.38	47.8	131.36	70	132.06	14	132.20
5	3.14	63.1	131.61	55	132.16	14	132.30
10	3.66	73.7	131.75	50	132.25	14	132.39
20	4.17	84.2	131.91	43	132.34	14	132.48
50	4.85	98.5	132.06	41	132.47	14	132.61
100	5.37	110	132.15	40	132.55	14	132.69
200	5.9	121	132.37	31	132.68	14	132.82
500	6.63	137	132.55	28	132.83	14	132.97

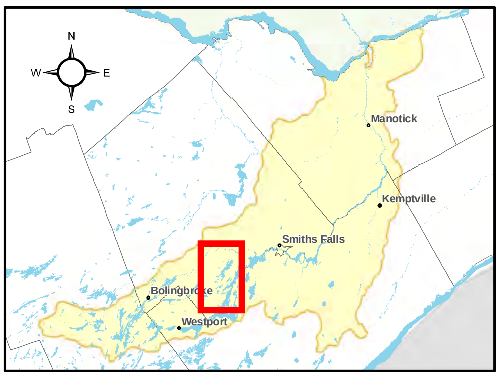
Source:

1. Mike11 (with outlet bridge).
2. Estimated from the stage-discharge relationship of the Tay River at Jebbs Creek confluence using Mike 11 model results (with outlet bridge).
3. Estimated using Manning's equation for normal flow.
4. Estimated by HEC-RAS (momentum balance).

Table 3: Computed Water Levels and Regulatory Flood Level (RFL) for Otty Lake

Return Period	Flow	Computed Water Surface Elevation	RFL
years	cms	m	m
2	2.38	132.20	
5	3.14	132.30	
10	3.66	132.39	
20	4.17	132.48	
50	4.85	132.61	
100	5.37	132.69	132.69
200	5.9	132.82	
500	6.63	132.97	

Figure 1: Location Map



0 0.5 1 2 Km

Legend

Name

🟨 Otty Lake

Transportation

- Freeway
- Expressway / Highway
- Collector
- Local / Street
- Private/Rural

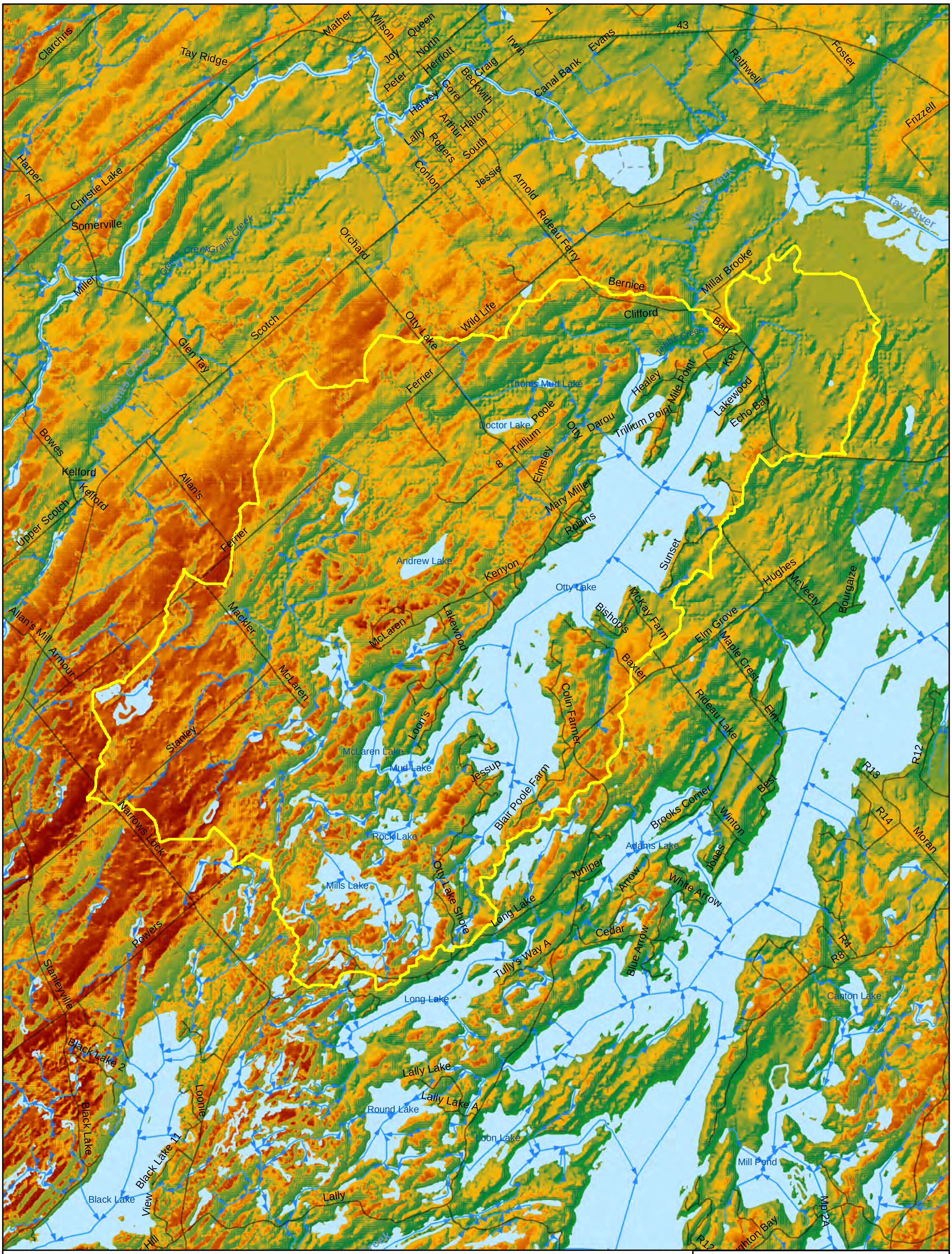
RIDEAU VALLEY CONSERVATION AUTHORITY

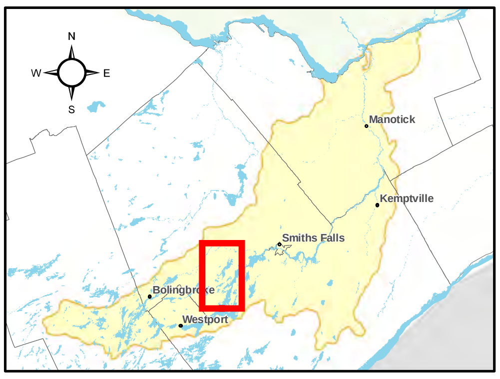
Projection note:	U.T.M. Zone 18 - NAD 83 Datum
Map Scale:	1:50,000

Date Modified: 6/17/2011

Created by: apetit

Figure 2: Otty Lake Basin





Legend

🟨 Otty Lake

→ Water Flow

DEM

High : 350

Low : 50

RIDEAU VALLEY CONSERVATION AUTHORITY

Projection note:	U.T.M. Zone 18 - NAD 83 Datum
Map Scale:	1:50,000

Date Modified: 6/17/2011

Created by: apetit

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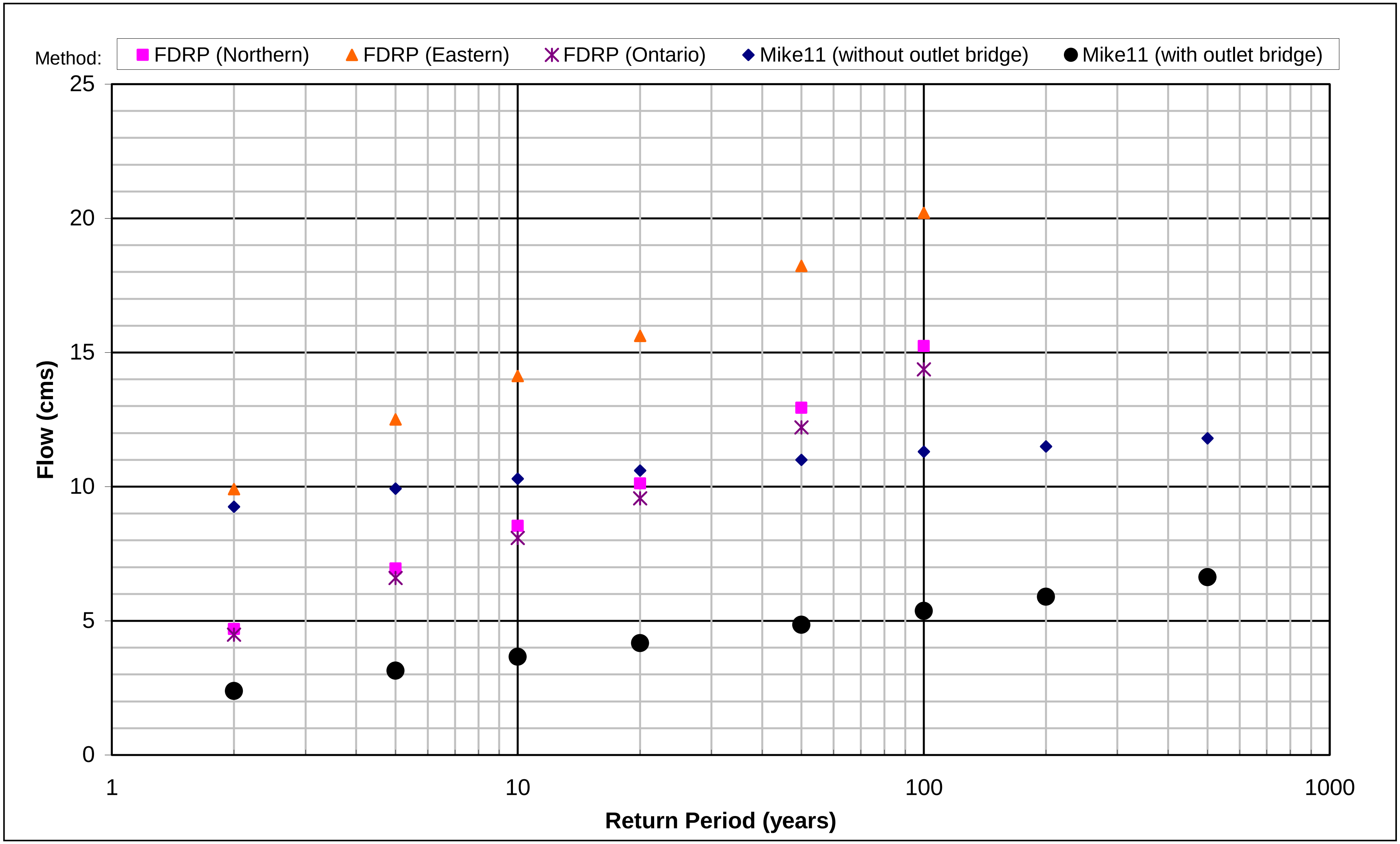
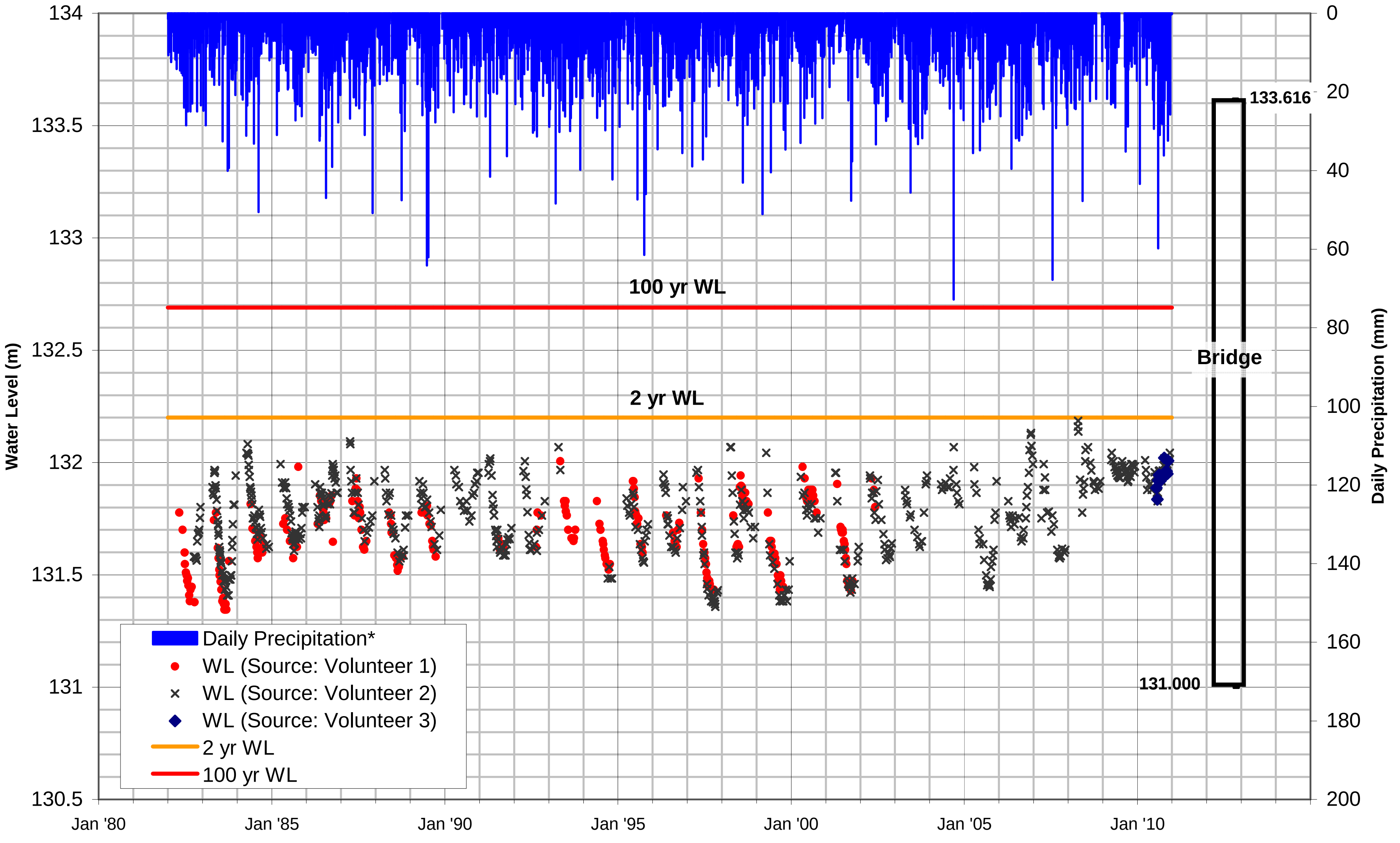


Figure 3: Estimated Flood Flows



* Daily Precipitation data from January 1981 to December 2005 is from the Smiths falls TS (6107836) station using the MNR Data Gap Filling Project, data from January 2006 to the Sept 17, 2008 is from the Ottawa airport station (6106000) and data from September 2008 to December 2010 are from the Smith Falls STP station, operated by RVCA.

Figure 4: Water Level Measurements on Otty Lake and Recorded Precipitation

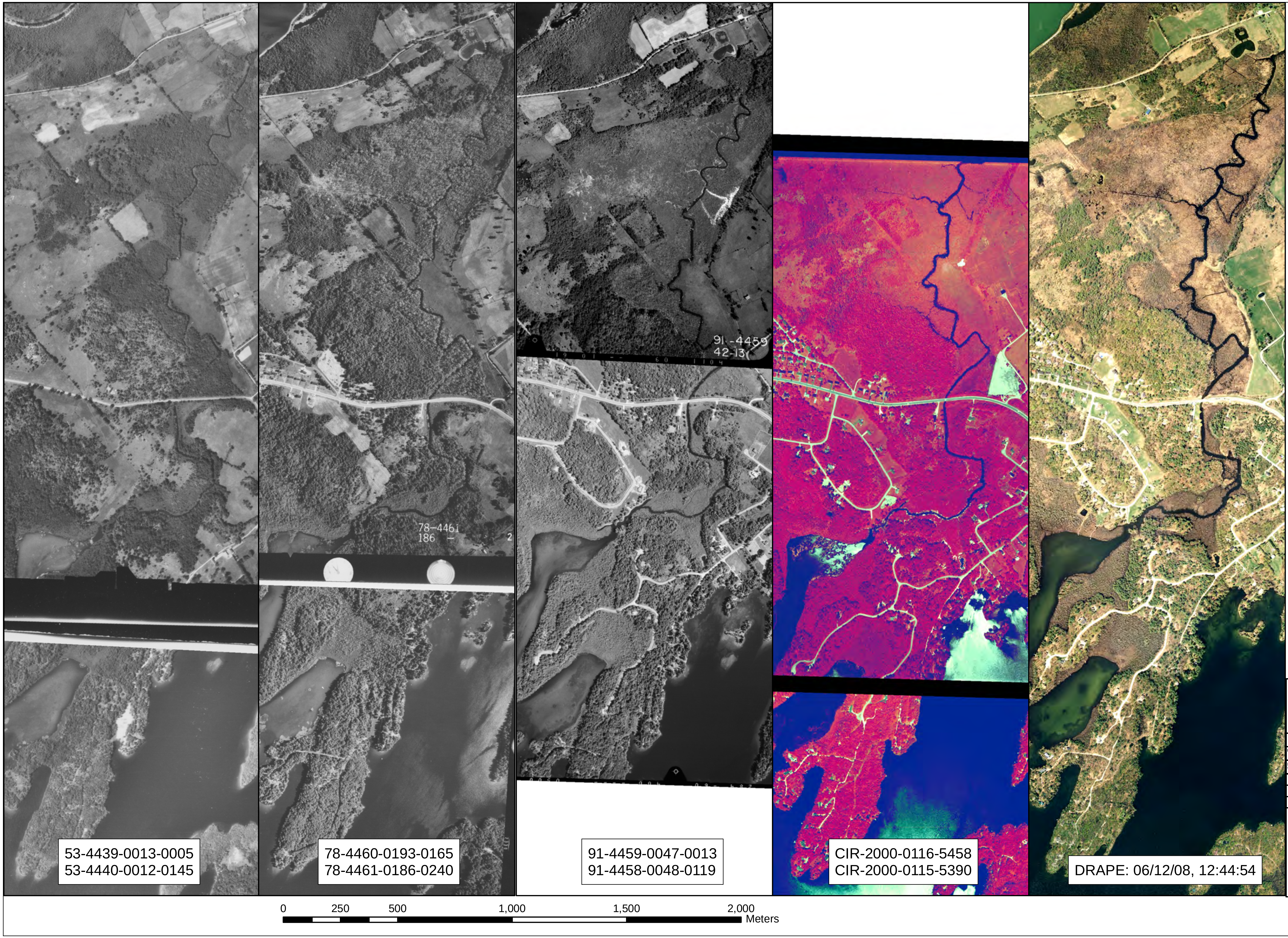


Figure 5:
Otty Lake Outlet, Historical Air Photos

RIDEAU VALLEY
CONSERVATION AUTHORITY

Map Scale: 1:15,000

Projection note:
U.T.M. Zone 18 - NAD 83 Datum

File Location:
\\Rvcastorage1\rvcahydrology\Alain Petit\Otty lake\OttyLake_Historical_AirPhotos_11x17.mxd

Created by: jforget

Modified by: dinnes

Date Modified: 5/26/2011 1:39:11 PM

Published by: apetit

Date Published: 6/22/2011

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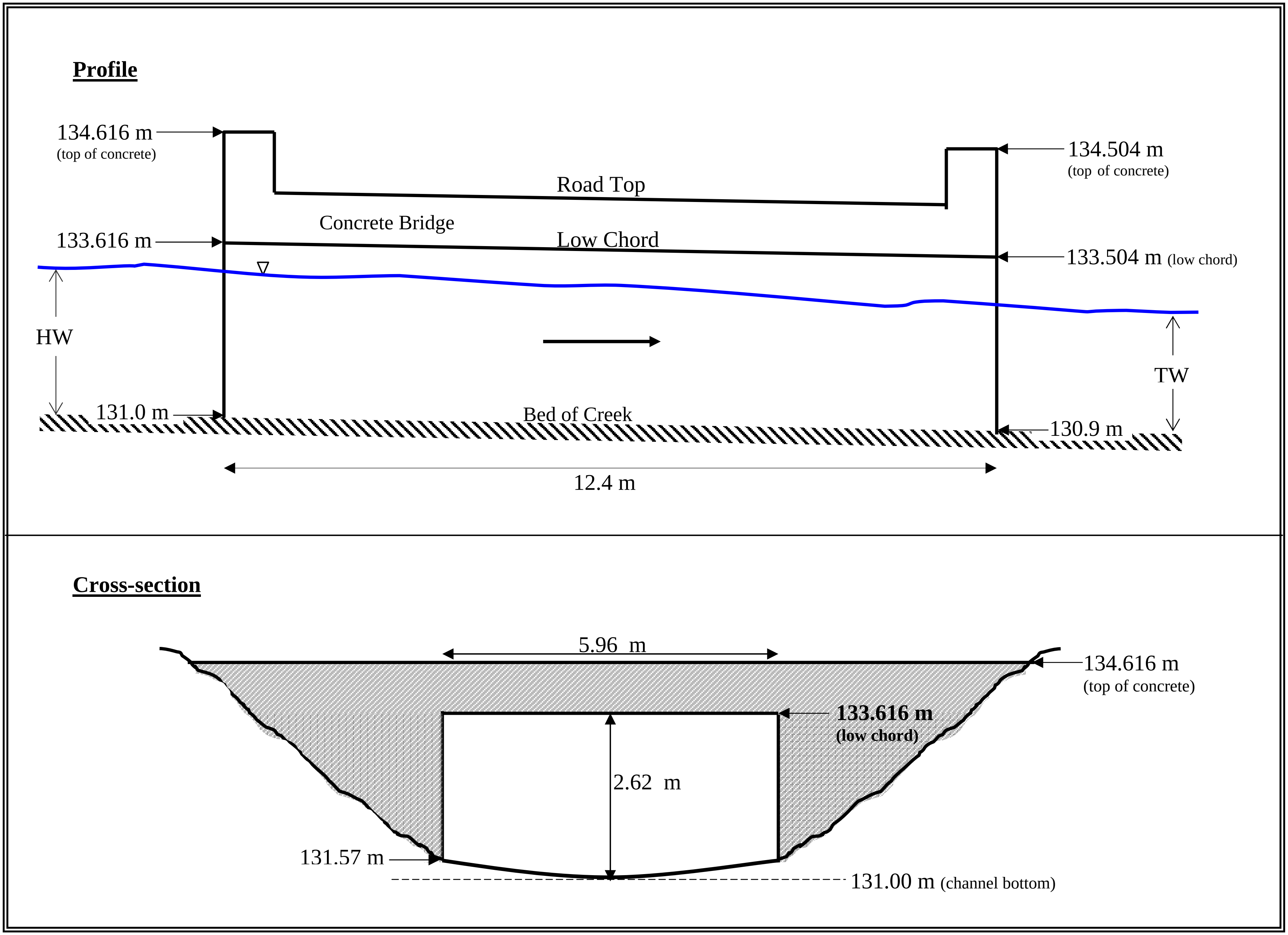

Figure 6: Bridge under Rideau Ferry Road (Otty Lake Outlet)

Otty Lake Inlet

Rideau Ferry Road (looking west)

Otty Lake outlet

Rideau Ferry Road (looking east)

Figure 7: Otty Lake Outlet, Rideau Ferry Road Bridge (taken June10, 2011)

RIDEAU VALLEY
CONSERVATION AUTHORITY

Projection note: U.T.M. Zone 18 - NAD 83 Datum

Map Scale: 1:25,000

Date Modified: 6/20/2011

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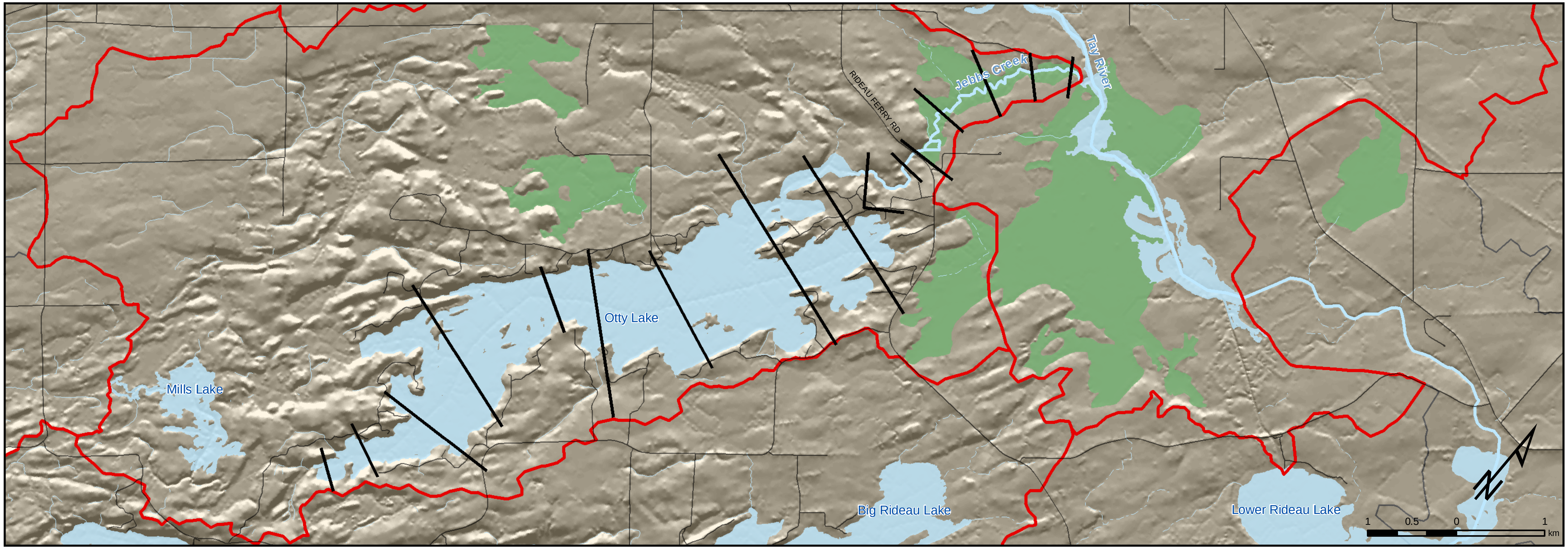
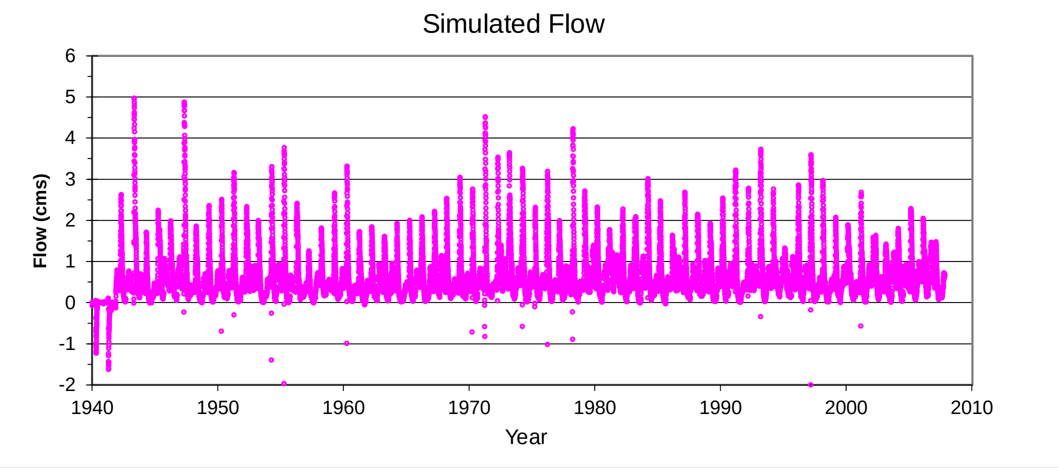
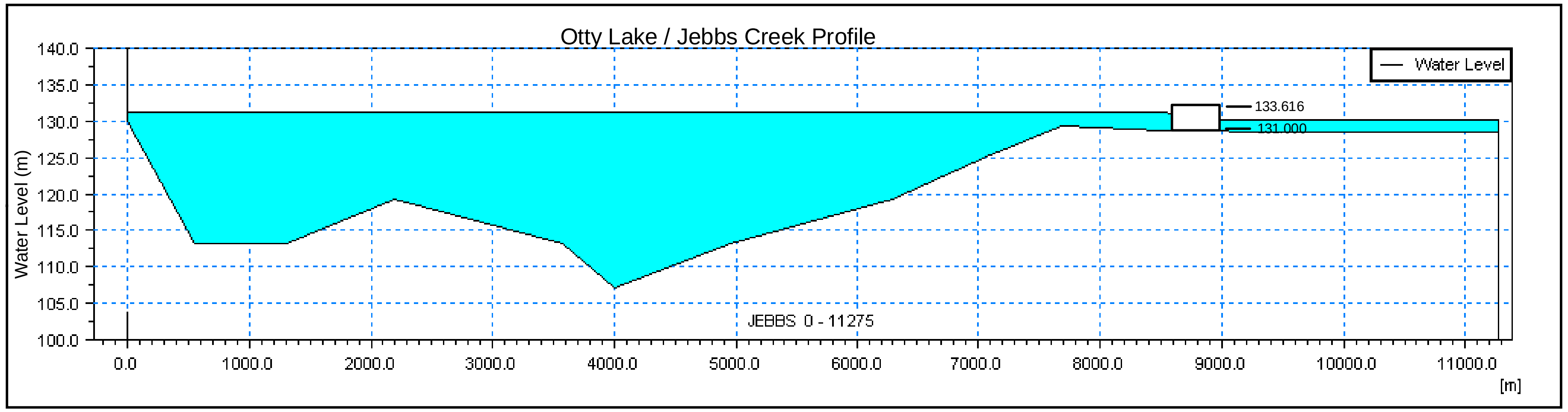
Figure 8: Regulatory Flood Elevation on Otty Lake







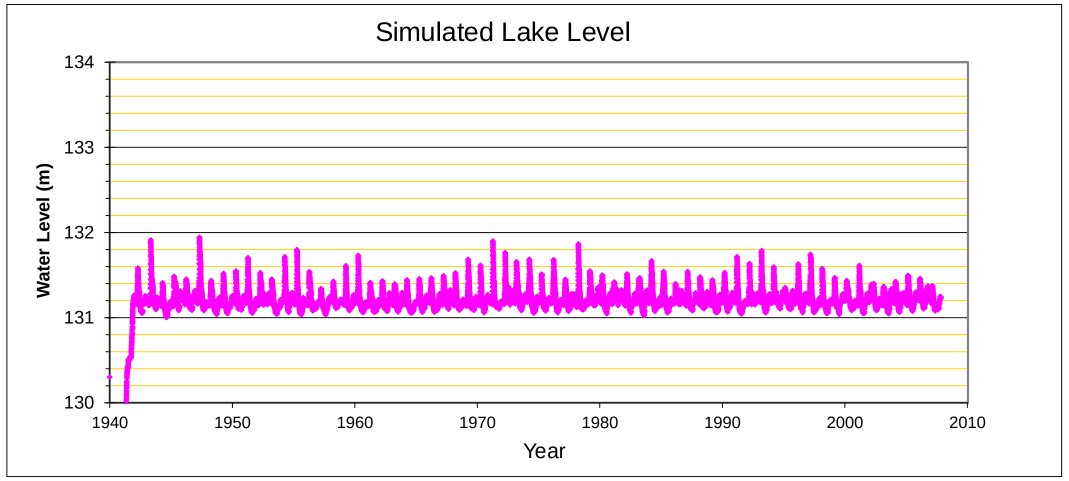


Figure 9
Mike 11 Model for Otty-Jebbs System

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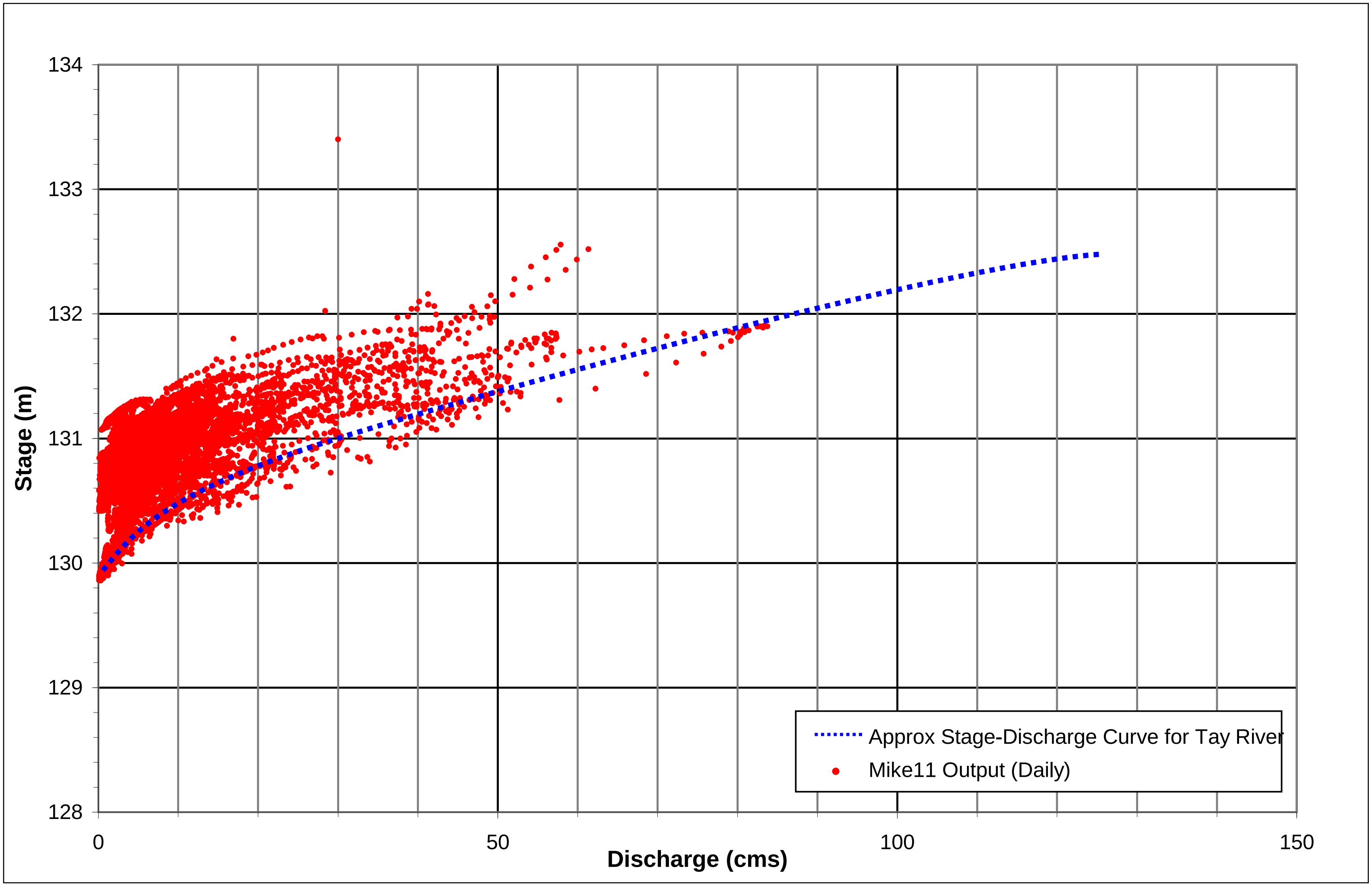

Figure 10: Stage Discharge Relationship of Tay River at the Confluence of Jebbs Creek