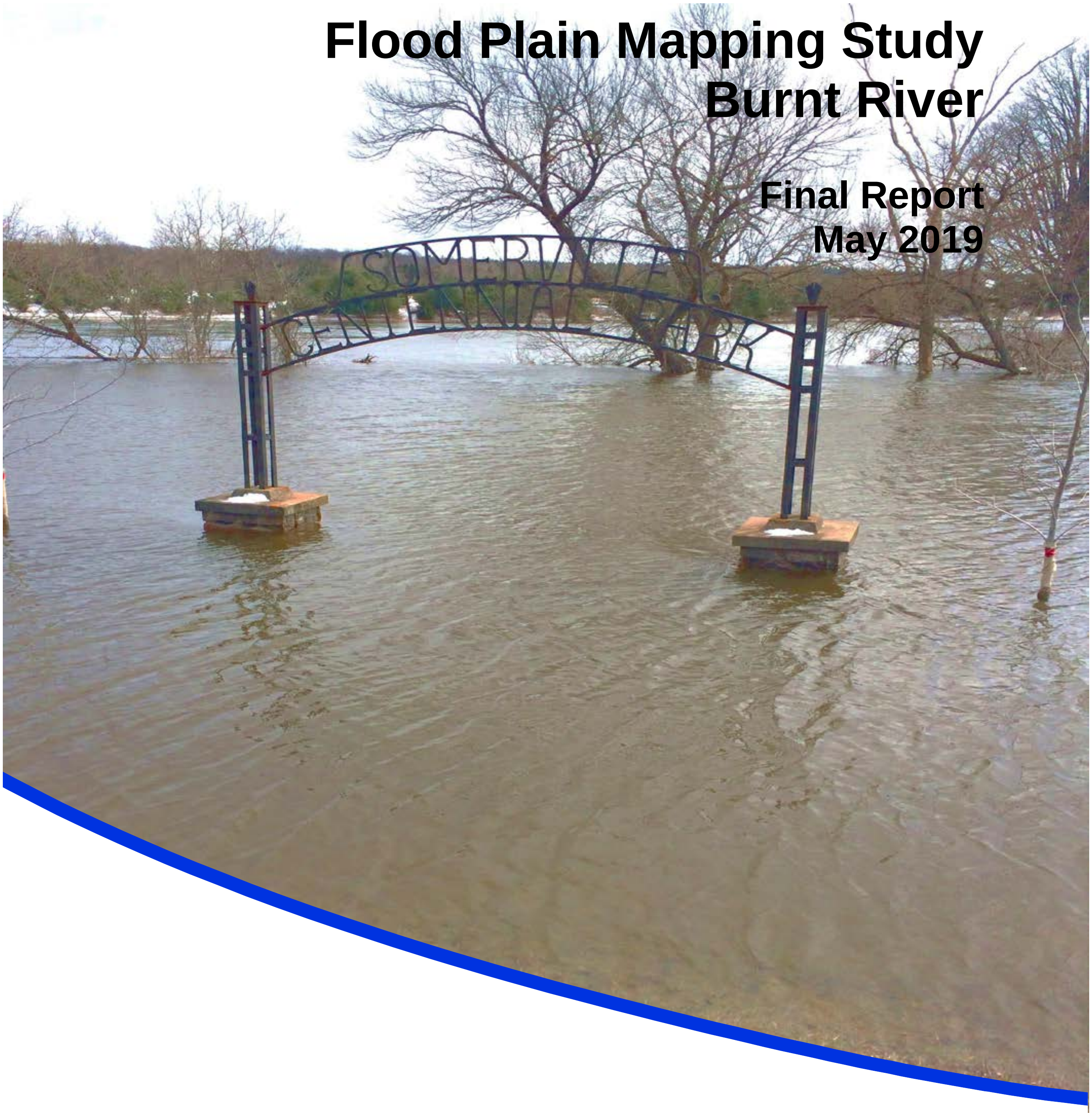
Flood Plain Mapping Study
Burnt River

Final Report
May 2019



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Executive Summary

The primary goals of this study are to create hydrologic and hydraulic models of the watershed and produce flood plain mapping for Burnt River from the outlet to Cameron Lake to the hamlet of Burnt River. The mapping will allow the City of Kawartha Lakes and Kawartha Conservation staff to make informed decisions about future land use and identify flood hazard reduction opportunities.

The Burnt River Flood Plain Mapping Study was subject to a comprehensive peer review for core components: data collection, data processing, hydrologic modeling, hydraulic modeling, and map generation. The process was supported throughout by a Technical Committee consisting of technical/managerial staff from Ganaraska Conservation, the City of Kawartha Lakes, and Kawartha Conservation.

Topics discussed in this study include:

- Previous studies in the area
- Collection of LiDAR, bathymetry and orthophoto data
- Proposed land use
- Delineation of hydrology subcatchments
- Creation of a Visual OTTHYMO hydrology model for Regional (Timmins) Storm
- Calculation of subcatchment hydrology model parameters
- Derivation of flow peaks at key nodes along the watercourse
- Flood Frequency Analysis for the 2, 5, 10, 25, 50 and 100 year events
- Creation of a HEC-RAS hydraulic model
- Creation of flood plain maps

Key elements of this study include:

- The Timmins storm is the Regulatory Event for the watercourse
- Flood plain maps are to be created based on the highest flood elevation of the calculated water surface elevations

Key recommendations of this study:

- The maps created from the results of the HEC-RAS model for Burnt River Creek should be endorsed by the Kawartha Conservation Board.
- Update the FFA to include peak flow experienced in 2019.
- Confirm current dam operations and corresponding stage-storage-discharge data and update if necessary.
- Calibrate the new hydrologic model based on more recent events and analysis (e.g. 2013, 2016 and 2019) to validate any adjustments to hydrologic parameters i.e. time to peak.

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1. Introduction

1.1. Objective

The objective of this study is to generate updated floodplain mapping for the Burnt River watercourse to protect the public from flooding hazards. This is the sixth flood plain study in a multi-year flood line mapping update project undertaken by the City of Kawartha Lakes (CKL). The mapping will allow the City of Kawartha Lakes staff to make informed decisions about future land use and identify flood hazard reduction opportunities.

1.2. Study Process

At the project beginning, the Technical Committee (consisting of one representative from each of the City of Kawartha Lakes, Kawartha Conservation, and Ganaraska Conservation) created quality assurance (Q/A) and quality control (Q/C) processes to be applied to all projects in the multi-year initiative. The Q/A methodology for each component ensures that the project design meets industry standards, and that the work outline and planned deliverables are valid. The three goals of the Q/C component are: that the product is consistent with standards and generally accepted approaches; that the study results meet the Technical Committee's requirements, and that the products and results are scientifically defensible. Each methodology was peer-reviewed for Q/A and Q/C by an external firm or agency. Four separate components of the project were established for Q/A and Q/C:

- Mapping and air photo
- Survey data collection and integration
- Hydrology modeling
- Hydraulic modeling

For the mapping and air photo portion of the project Q/A, the City of Kawartha Lakes and Kawartha Conservation created a request for proposal (RFP) for geographic data acquisition using LiDAR technology. For the survey data collection and integration, Kawartha Conservation purchased new digital survey equipment and established procedures for survey collection. For the Q/C portion, Ganaraska Conservation's GIS staff performed accuracy checks on the LiDAR-derived Base DEM and orthoimagery using the Terms of Reference found in **Appendix L**. For accuracy check results, refer to the "*Digital Elevation Model and Orthoimagery Data Accuracy Assessment Report – Flood Plain Mapping Study – Burnt River*" in **Appendix J**.

For the Q/A portion of the hydrology and hydraulic modeling components, a hydraulic/hydrologic modeling procedures document was created that: established data input parameters to meet municipal and provincial standards; put in place data collection and extraction procedures; and short-listed computer models. The document was peer-reviewed by Greck and Associates and was found to be satisfactory.

1.3. Watercourse Context and Description

The Burnt River watershed forms part of the Haliburton reservoir lakes area that services the Trent Severn Waterway. It is shaped roughly like an ice cream cone; whose northern bulbous area lies in the Canadian Shield. Its northwestern tributary is the Drag River system, which consists mainly of a series of lakes connected by short river sections. Flowing from the east is the Irondale River whose flow is augmented from numerous lakes draining into its channel.
The two tributaries join just north of Kinmount and flow south in a meandering fashion to Cameron Lake on the Trent Severn Waterway.

North of Kinmount the topography is typical of the Canadian Shield; it is rocky, wooded, and littered with many lakes. On the Drag River system are six (6) lakes controlled by dams operated by the Trent Severn Waterway (TSW). On the Irondale branch the TSW operates dams on nine (9) lakes. The two branches join about six km north of Kinmount, flowing south to Cameron Lake. A dam operated by Ontario's Ministry of Natural Resources and Forestry (MNRF) is within Kinmount village limits.

The Drag River system drains 513 km^2 while the Irondale River drains 547 km^2. The total drainage area at the outlet to Cameron Lake is about 1438 km^2 (determined by Kawartha Conservation staff using ArcGIS), compared to 1470 km^2 obtained by OBM maps with a scale of 1:10000 (MacLaren Plansearch). To put this in perspective, it is equivalent to roughly one quarter the size of Prince Edward Island.

The size of the watershed, numerous lakes and wetlands, several of which are large, have significantly influenced flood flow rates in the watershed. The lower watershed of the Burnt River through the area of floodplain mapping is very sinuous. There are a number of Oxbows, lakes on low depressions in the table lands which are susceptible to flooding but don't contribute to the conveyance of flow

Please refer to **Figure 1.1**.

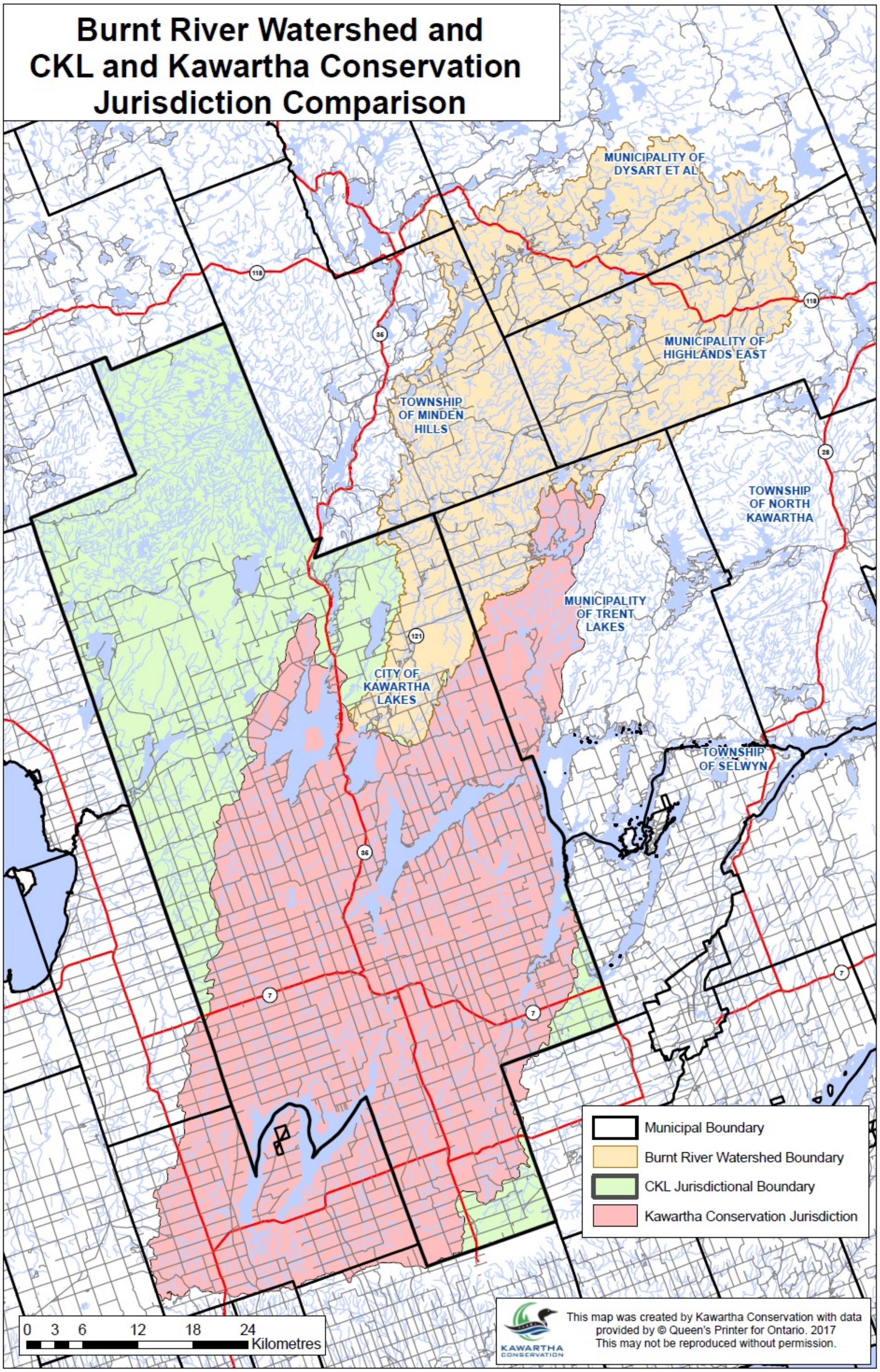


Figure 1.1: Burnt River Study Area

1.4. Background Information

The Burnt River has experienced flooding in the past, as recently as 2013 and 2016 and has been of particular concern in the hamlet of Burnt River. Record flood conditions exist in April, 2019 at the time of finalizing this report.

The engineering firm MacLaren Plansearch was retained by the Township of Somerville to carry out the *Burnt River Floodline Mapping Study* as part of the Canada-Ontario Flood Damage Reduction Program. The March 1992 report detailed the hydrologic and hydraulic analyses undertaken to calculate the floodlinemaps for two sections of the river: the portion of the river between the village of Burnt River and Cameron Lake, and the area immediately upstream and downstream of Kinmount. For return period events, the flood frequency analyses were carried out using data from three flow gauges for the 2-100 year events. For the Regional event, a Visual-OTTHYMO model was created for Timmins Storm simulation. A HEC-II model was created for the hydraulic analysis. Relevant excerpts can be found in **Appendix K**.

While the floodline mapping study was underway, a significant flood event occurred in April 1991 along the Burnt River watercourse and several adjacent rivers. MacLaren Plansearch was commissioned to evaluate the cause of flooding in the lower reaches of the Burnt River watershed. The January 1992 report, *Report on the 1991 Burnt River Flood Analysis* analyzed rainfall data, reviewed snowpack information, carried out frequency analyses for both flow gauges and reservoir levels, examined TSW reservoir operations, and verified the HEC-II model for the flood event. Relevant excerpts can be found in **Appendix K**.

In June of 1992 MacLaren Plansearch released the *Preliminary Flood Damage Reduction Study of the Burnt River Flood Risk Mapping Area* report. The objectives of this study were to:

- recommend a flood forecasting and warning system
- prepare a plan outline for flood emergency measures
- undertake a preliminary flood damage cost analysis, and
- investigate options to alleviate flood impacts

Relevant excerpts can be found in **Appendix K.**

The engineering firm Cummings Cockburn Limited (CCL) was retained by the Ministry of Natural Resources and Forest (MNRF) to carry out a dam safety review of the Kinmount dam, whose findings were summarized in the April 2000 *Dam Safety Assessment* report. The MNRF's 2002 document, *Burnt River Dam, Operation Plan and Maintenance Manual – Volume 1 of 4 – Dam Operations Manual* stated the normal operating water level of the dam is 248.2m.

The TSW commissioned the engineering firm AECOM Canada Ltd. to undertake a Water Management Study. The results are contained in four separate reports dated May 2011:

- Water Management Manual
- Data Collection and Management Guide
- Evaluation of the Current Approach to Water Management
- Review of Water Management Systems and Models

All reports were reviewed by Conservation Authority staff as background information to the current study.

1.5. Modeling Approach

In this report, peak flows were derived using flood frequency analysis for the 2-100 year events. The Timmins (Regional) Storm was simulated using standard unsteady flow methods using Visual OTTHYMO Suite 5.0 (VH Suite 5). Flooding throughout the Burnt River in the project area was determined by conducting standard step steady flow methods using HEC-RAS Version 5.03.

The Burnt River watershed has three flow gauges: a TSW gauge on the Irondale River at Furnace Falls, a TSW gauge on the upper Burnt River at Gelert, and a WSC gauge on the Burnt River downstream of the junction of the Irondale River and the Drag Lake catchments. Their locations are shown on (**Figure 1.2**.)

Over 100 years of flow data has been collected at the WSC gauge. A flood frequency analysis has been carried out to calculate the 2-100 year flood peaks based on these historic flows.

The analysis was carried out using the Consolidated Frequency Analysis (CFA) software package, which is a MS-DOS program which performs both parametric and non-parametric analysis of extreme daily and instantaneous data from the HYDAT database maintained by the Water Survey Canada. However, the graphing was completed in Microsoft Excel.

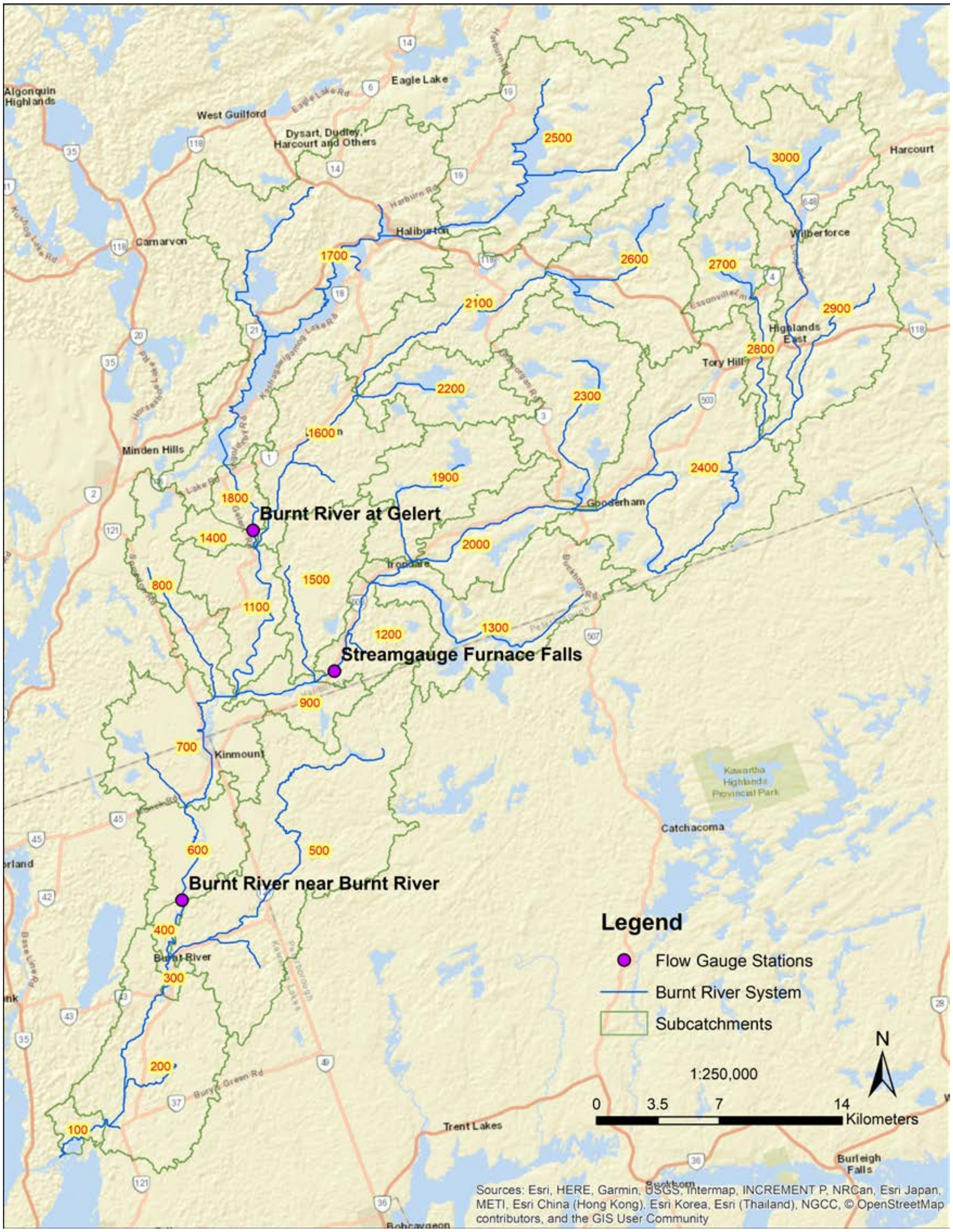


Figure 1.2: Flow Gauges

For the Timmins event, however, a hydrologic model was set up to calculate the corresponding flows. Geographic data (such as subcatchment area, land use, topography, and soil types) was extracted from GIS for each subcatchment to obtain the parameters described in the Hydrology Modeling Parameters Selection document (refer to **Appendix A**), and to calculate values such as imperviousness, SCS Curve Numbers (CN), time to peak (T_p), and time of concentration (T_c).

For all events, the HEC-RAS hydraulic model (U.S. Army Corp of Engineers) was used to calculate the water surface elevations at every cross-section. The results of the HEC-RAS model were mapped to provide updated flood elevations for the Regional and 100 year events.

1.6. Snowmelt and Snowmelt/Rainfall Events

These analyses were not carried out for this report for the Timmins event, but snowmelt and snowmelt/rainfall affect would be reflected in the results of the flood frequency analyses of the return period events.

1.7. Climate Change

Climate change considerations were not included within the terms of reference for this study.
Any changes in river flows due to climate change would have already been considered in the flood frequency analysis, however cannot be applied to estimate future changes in flows due to climate change.

1.8. Land Use

The analyses for the 2-100 year events were undertaken based on existing land use since there is no way to reflect future development in the flood frequency analysis. For the Timmins storm however, future development based on the Municipality’s Official Plan was modelled in the hydrologic model.

2. Hydrology Input Parameters

2.1. Overview

In 2012, the City of Kawartha Lakes and Kawartha Conservation produced a standardized methodology for undertaking their flood plain mapping studies. This approach was peer-reviewed by Greck and Associates Limited, and their findings concluded the methodology is valid. All parameters and modeling approaches described within this report follow the recommendations presented in **Appendix A** unless otherwise noted. For this study Kawartha Conservation extracted hydrologic parameters from LiDAR elevation data, Arc Hydro watershed boundaries, and Official Plan and field surveys.

2.2. Flood Frequency Analysis (FFA) – 2 to 100 year events

Flow in the Drag River branch is captured by the flow gauge at Galert. The TSW historically operated the gauge from 1915-1950, and again from 1975-present. The technical appendices from the 1992 MacLaren Plansearch report were the source of data for 1915-1950 and 1977-1989; the flow data is the peak daily flow. TSW provided a spreadsheet of peak daily flows for the years 1988-2017.

Flow is measured in the Irondale branch at Furnace Falls by a gauge operated by the TSW. It was initially in place below the falls from 1916-1950; after 1950 the gauge was re-located above the falls and is still in operation. TSW provided spreadsheet data of peak daily flows to the model team for the years from 1988-2017.

On the main channel a gauge has been in place continuously at the Village of Burnt River since 1912. Until 1962 it was operated by TSW. In 1963 ownership changed to Water Survey Canada (WSC). The technical appendices from the 1992 MacLaren Plansearch report provided key data for the years prior to 1964. Data for this gauge was exported from the WSC website for the years 1964-2016 and provided both daily peak flow and annual maximum daily flow.

Instantaneous maximum peak flow is the peak flow at any one moment during a day. The average daily flow is the average over a 24-hour period; for any given year the 365 average daily flows are analyzed and the highest (peak) value extracted.

Because there is 104 years of flow data (from 1913 to 2017) an annual peak flow frequency analysis can be carried out to determine the 2-100 year flood flow estimates. The initial flow data was recorded once daily; according to the *Burnt River Floodline Mapping Study* flows were collected daily at 8:00am. When the WSC took responsibility of the Burnt River gauge in 1963, flows were collected hourly.

At the writing of this report, the Burnt River was experiencing record high flows on April 21, 2019, which will be included in the flood frequency analysis at a later date. However, due to the extensive record of flow data in this watershed, it is not anticipated that there will be a significant change, if any, to the Flood Frequency Analysis.

2.3. Regional Storm

The Timmins storm occurred in 1961 with a total rainfall of 193mm and this event is the Regional storm event for this part of Ontario. The full storm is defined by Chart 1.04 of the *MTO Drainage Manual*. The Ontario Ministry of Natural Resources (MNR) technical manuals provide a rainfall reduction table for the Timmins storm. The areal reduction is based on the size of the equivalent circle method and resulted in a reduction factor of 66%.

Antecedent Moisture Condition II, referred to as AMC (II), was applied. A CN value of 50 was applied to lakes to account for low gradient waterbodies what would provide some attenuation of flows in the sub-catchments (MTO Drainage Management Manual, 1997 Chapter 8 p/23).

2.3.1. Digital Elevation Model (DEM)

LiDAR and orthoimagery full-suite remote sensing data were acquired by the City of Kawartha Lakes in 2012. The acquisition included orthoimagery, LiDAR-derived point cloud data, elevation raster files, and other geospatial/non-geospatial datasets produced by the vendor. At the time of the acquisition, the *2009 Ontario Imagery and Elevation Acquisition Guidelines* was the technical document that set geospatial data acquisition specifications in Ontario and defined geospatial data accuracy targets based on levels or risk.

For the length of the Burnt River watercourse study area, two points per square meter LiDAR data was acquired. However, this area of interest had to be extended for hydrology purposes, necessitating the use of existing pixel-autocorrelation elevation data holdings derived from South Central Ontario Orthophotography Project 2013 (SCOOP2013) acquisition deliverables. ArcGIS version 10.5.1 and LP360 computer software programs were to be used to produce bare earth Base DEM using best available raster and point cloud data which preserved the LiDAR acquisition data where possible and effectively added supplementary pixel-autocorrelated data where needed. The Base DEM was produced at a 0.5m cell resolution within the LiDAR acquisition area, and 2m cell resolution in the supplementary pixel-autocorrelation data areas.

A Sound Navigation and Ranging (SONAR) bathymetric survey was also conducted to acquire cross-section information within the channel. The data acquisition was performed using a survey-grade RTK GNSS SONAR setup mounted on a small manually operated watercraft. Data was delivered in ESRI shapefile format.

2.3.2. Subcatchment Discretization

In order to discretize subcatchments, watershed flow paths were generated using ArcHydro version 10.2 software. Surveyed bridge and/or culvert data was integrated into the Base DEM to create a hydrologically-conditioned DEM (referred to as a Hydro DEM) at a 0.5m cell resolution. This allows flow connections under road barriers to a downstream channel or subcatchment; flow barriers and other impediments were therefore removed from GIS calculations.

Critical nodes within the watershed were selected by the engineer as the basis to delineate the initial subcatchments in ArcHydro. ArcHydro is suitable for the delineation of rural subcatchments.

For urban subcatchments the ArcHydro tool cannot account for sub-surface pipe networks nor can it determine overland flow pathways where the topography forms a concave shape. To overcome this gap, field visits were carried out to verify urban subcatchment boundaries. Manual adjustments of the urban subcatchments were carried out under the direction of the engineer and approval of the technical committee. **Figure 2.1** illustrates the creek subcatchments.

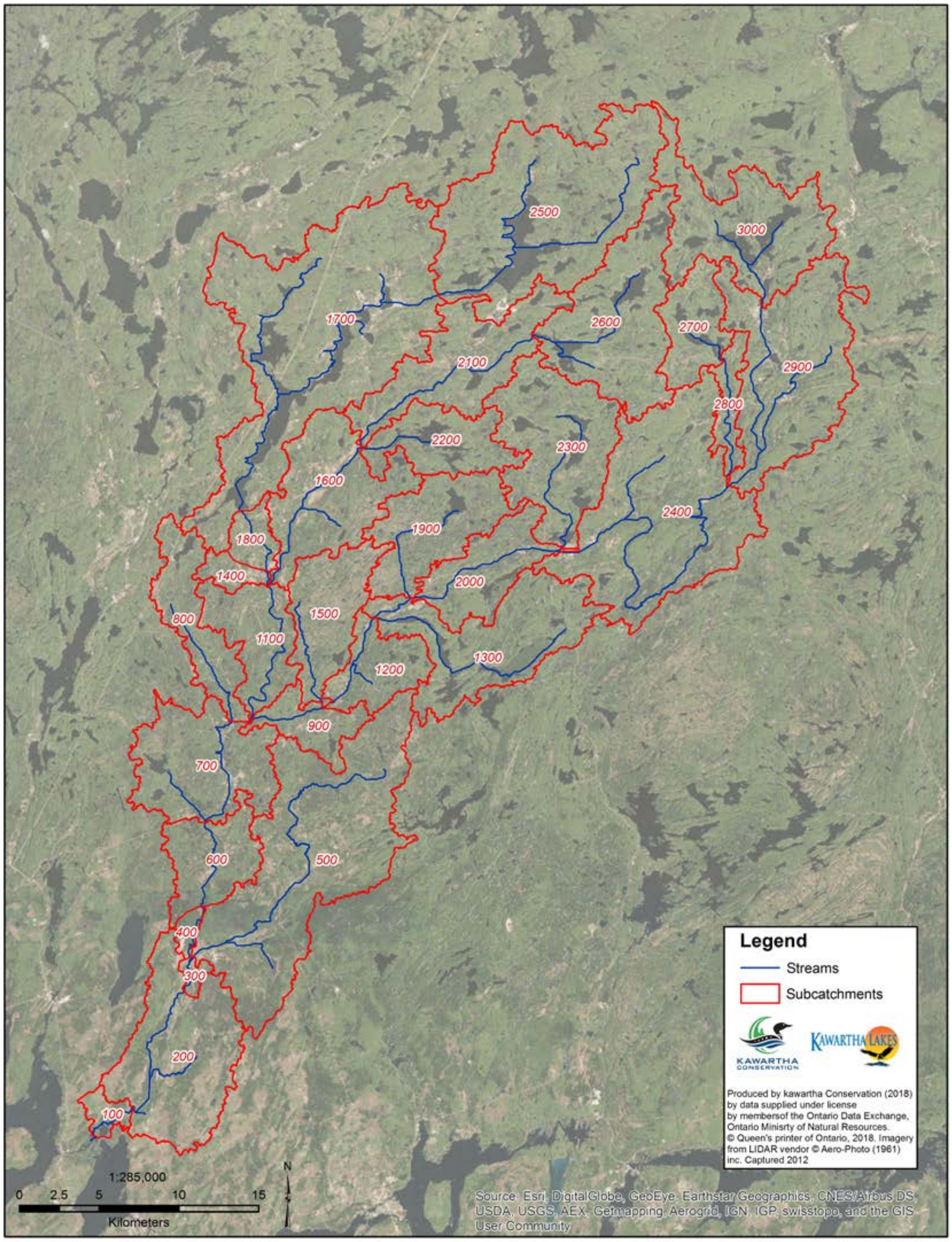


Figure 2.1: Subcatchment Boundaries

2.3.3. Land Use

The draft April 2013 Schedule ‘F-4’ Land Use map version from the Secondary Plan Project, Burnt River Settlement Area is the base data referenced for land use patterns. The January 2008 Schedule ‘A’ zoning map from the Village of Burnt River Zoning By-Law 1993-15 is also used for reference.

Land values in the hydrology model do not reflect current land use; instead, the model assumes that all developable areas indicated in the Official Plan are fully built out. The rationale for this decision is that the City has approved in principle the proposed land use and therefore the flood lines should reflect the most conservative flood scenario. Copies of the schedules’ maps are found in **Appendix F**.

2.3.4. Subcatchment Flow Paths

The longest flow paths of each rural subcatchment were derived using ArcHydro. In this process, the downstream node was selected, and ArcHydro calculated the longest overland and channel flow paths. **Appendix C** contains a figure showing the subcatchments and their respective lengths.

2.3.5. Calculation of Slope

For rural subcatchments, spreadsheets were created that calculate channel and subcatchment slopes, based on overland and channel flow data. Details can be found in **Appendix B**.

2.3.6. CN Values

The Soil Conservation Service (SCS) curve number (CN) is used in the determination of the runoff. Users must choose which antecedent moisture condition (AMC I, II, or III) is relevant for the model. The Timmins Storm occurred under AMC II conditions. Improved CN method (CN*) was applied as per MTO Drainage Manual (1997). A weighted CN (AMC II) value was calculated, as shown in **Appendix B**.

Figure 2.2 provides soils information while **Figure 2.3** shows the future land use of the watershed based on Official Plan data. Spreadsheets with the calculations are provided in **Appendix B**.

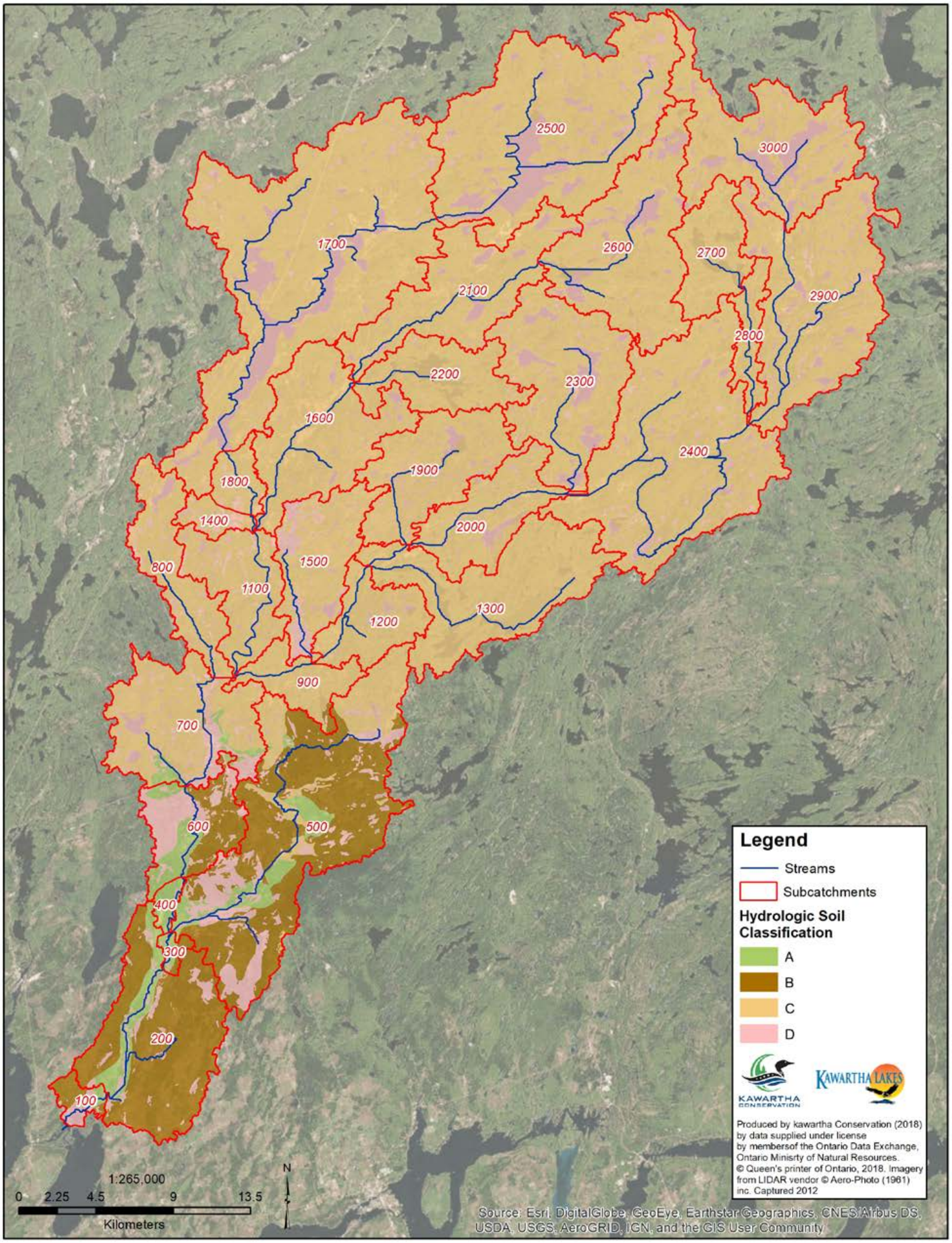


Figure 2.2: Soils

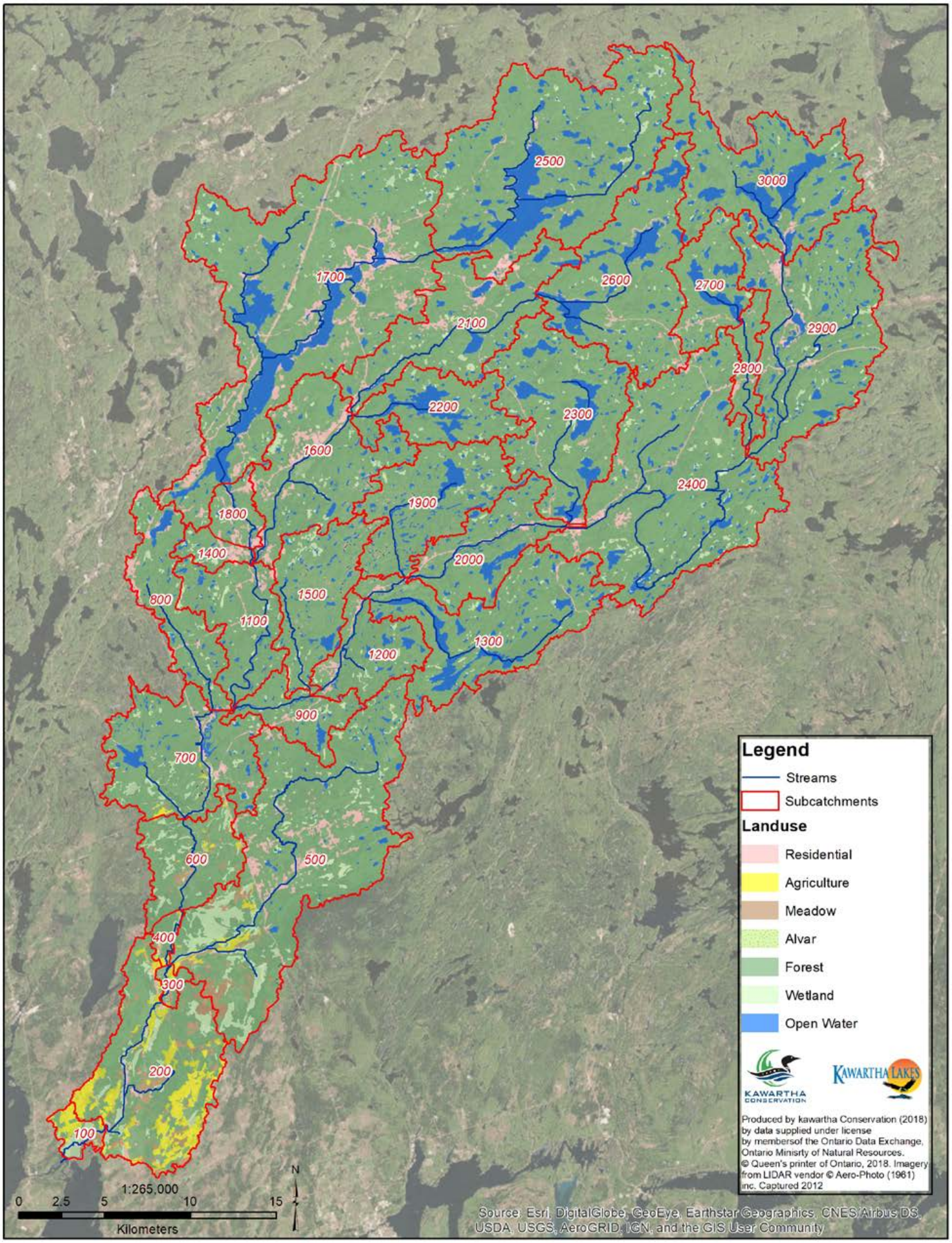


Figure 2.3: Land Use

2.3.7. Impervious Land Use & Runoff Coefficients

The detailed land use denoted in the Official Plan determines the weighted total impervious area (T_{imp}), and runoff coefficient (C) for each subcatchment using the tables from the Hydrologic Parameters List in **Appendix A**.

Subcatchments with a T_{imp} value greater than 20% were modeled with the StandHYD command; otherwise the NashHYD command was used. Spreadsheets with the calculations are provided in **Appendix B**.

2.3.8. Time of Concentration

Time of concentration (T_c) is a key variable for calculating peak flow in rural subcatchments. This is the time it takes for the flow wave to travel from the hydraulically farthest point of a subcatchment to where it joins the watercourse.

Time of concentration was calculated using the Airport method for subcatchments with a C value less than 0.4; the Bransby-Williams method was chosen if the C value exceeded 0.4.

The Time to Peak (T_p) is the length of time in hours from the start of the hydrograph to the peak flow and is defined by VH SUITE 5 model via the equation: $T_p = (^2/_3) * T_c$

Time to peak is used in the NashHYD command only. Spreadsheets with the T_c and T_p calculations are found in **Appendix B**, using the flow lengths shown in the subcatchment figure found in **Appendix C**. It should be noted that the Tp value in this report is multiplied by 3 (Table 2.1) in order to be consistent with Maclaren Plansearch Burnt River Floodline Mapping Study (1992).

The time to peak values for subcatchments were calculated and adjusted to result in hydrographs which are calibrated to known hydrologic events, this is consistent with the McLaren Plansearch study, 1992.

2.3.9. Channel Routing

Channel routing in VH SUITE 5 accounts for the time lag of flows being routed in the main channel. HEC-RAS cross sections are input to the Route Channel command within VH SUITE 5. One representative cross-section was used for each channel reach. Reach channel and overbank Manning's n values were averaged, as were the channel and overbank slopes.

The Burnt River watershed is part of the Trent Severn Waterway System (TSW). The flow is regulated by 14 reservoirs for low flow augmentation, recreation and minor flood control purposes. Two dams, at Billings Lake and Kinmount, are for recreation purposed and provide insignificant flood storage. Approximately 40% of the entire watershed is regulated by the TSW.

As per Maclaren Plansearch Burnt River Floodline Mapping Study (1992), the drainage areas of reservoirs have been lumped into stage-storage-discharge relationships (Figure 5-2/Table 5-1-Appendix N). The similar approach is carried to this study and model with variations in discretization of subcatchments (**Appendix C**)

2.3.10. Model Input Data

The input parameters were calculated as described above, and are summarized in **Table 2.1** below.

Table 2.1: OTTHYMO Model Input Parameters for the Timmins Storm Event

Catchment	Area (Ha)	C	T_p (hr)	Tp *3	CN (II)	CN* (II)	X_{imp}	T_{imp}
100	615.4	0.29	1.84	5.53	60	53	0.01	0.01
200	7004.9	0.26	5.07	15.22	62	55	0.01	0.02
300	300.7	0.20	1.10	3.31	53	42	0.01	0.01
400	364.2	0.14	1.23	3.69	42	26	0.03	0.01
500	12896.9	0.28	7.76	23.28	64	59	0.02	0.02
600	2951.6	0.29	4.75	14.25	66	60	0.01	0.01
700	5439.4	0.32	3.60	10.81	73	72	0.02	0.02
800	3125.5	0.30	5.00	15.01	74	73	0.02	0.03
900	1824.2	0.30	4.07	12.22	73	72	0.01	0.02
1100	3229.6	0.28	4.47	13.42	73	72	0.01	0.02
1200	2472.1	0.31	3.85	11.55	75	73	0.02	0.03
1300	6417.0	0.36	4.98	14.93	77	76	0.01	0.02
1400	698.1	0.28	2.27	6.80	73	72	0.02	0.03
1500	3641.7	0.31	4.20	12.60	74	73	0.03	0.03
1600	5488.9	0.29	4.28	12.84	74	73	0.02	0.03
1700	16794.7	0.34	6.46	19.39	76	76	0.02	0.03
1800	1008.7	0.28	2.61	7.83	75	73	0.03	0.04
1900	3249.4	0.37	3.71	11.13	77	76	0.03	0.03
2000	3268.3	0.34	1.41	4.22	76	76	0.02	0.03
2100	5333.5	0.33	4.38	13.14	75	73	0.02	0.02
2200	3089.2	0.40	3.32	9.96	78	78	0.01	0.01
2300	6277.0	0.36	4.59	13.76	76	76	0.01	0.01
2400	11213.0	0.30	4.14	12.42	74	73	0.02	0.02
2500	12059.3	0.37	4.82	14.47	66	60	0.01	0.01
2600	6847.7	0.38	4.15	12.46	66	60	0.01	0.01
2700	2465.8	0.37	3.16	9.49	77	76	0.01	0.01
2800	1188.8	0.27	2.39	7.17	74	73	0.01	0.02
2900	8136.8	0.33	2.28	6.85	76	76	0.01	0.02
3000	6379.7	0.40	3.42	10.26	78	78	0.01	0.01
Total Area	143,782.3	*Ha*						
	1,437.8	*km²*						

3. Flood Frequency Analysis Output

3.1. Flow Frequency Curve

Figure 3.1 shows the flows frequency curve for the 2-100 year flows that were calculated by the CFA program.

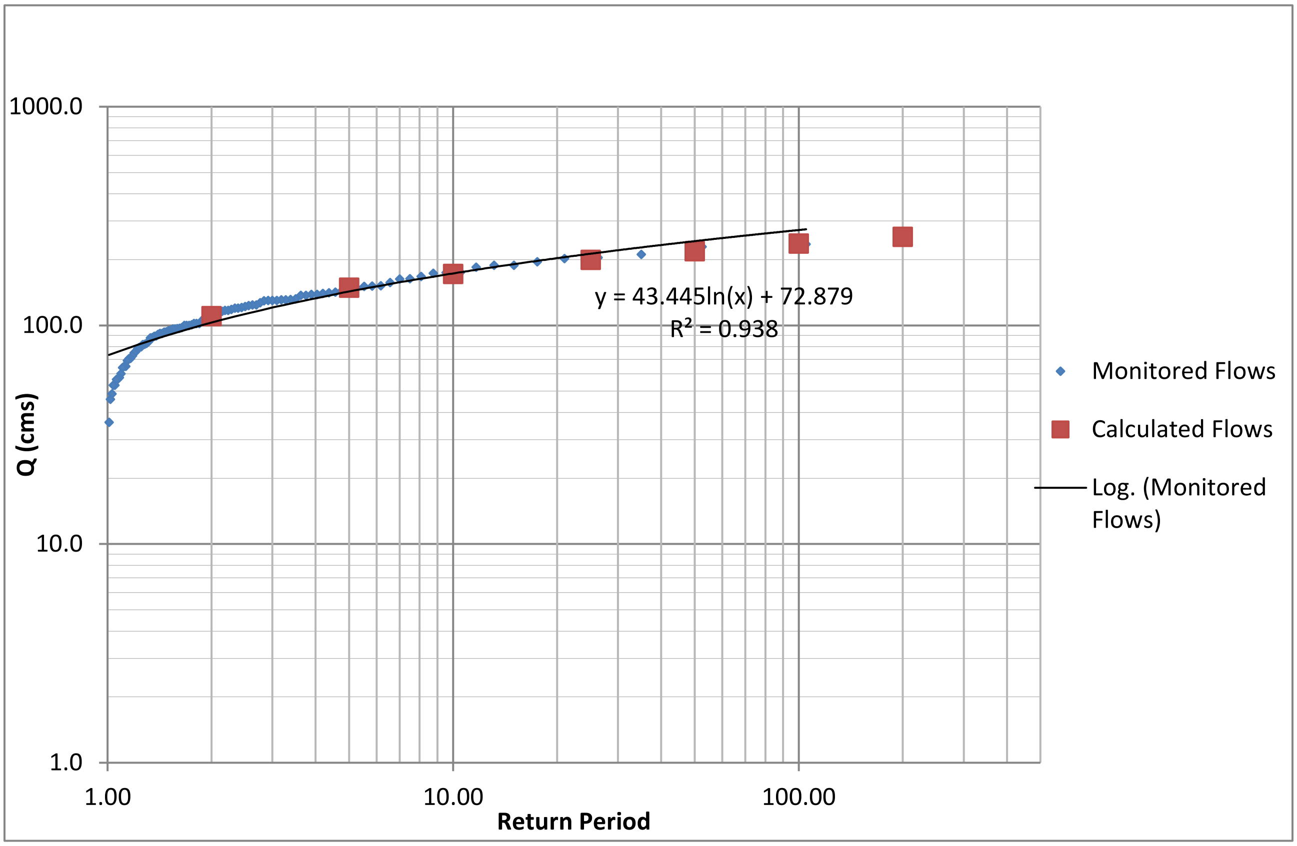


Figure 3.1: Flow Frequency Discharge Curve Burnt River Near Burnt River

Table 3.1 compares previous flood frequency analyses, which were undertaken previously; specifically, by MacLaren Plansearch in 1988 and by MNR in 2011. The updated results reflect flows to and including 2016 (including two significant runoff events in 2013 and 2016). Our results are slightly higher as expected due to significant events in 2013 and 2016.

Table 3.1.: Comparing the results of the different FFA Analyses

Return Period	Burnt River Gauge Near Burnt River Flood Estimates from Study (cms)		
	MacLaren (1913-1988) 76 years	**MNR** (1963-2011) 49 years	**KRCA** (1913-2016) 104 years
2-year	112	108	110
5-year	147	139	147
10-year	168	157	170
25-year	186	175	191
50-year	209	196	217
100-year	226	212	236

3.2. Prorating of Flows

As the flood frequency analysis was undertaken at the Burnt River gauge, which is upstream of the study search, it was necessary to pro-rate the flows to reflect additional area contributing to the runoff at the river's confluence with Cameron Lake.

Interpolation of flows from the known stream gauge at Burnt River (122,600 ha) is done based on the Modified Index Flood method as follows:

$$Q_2 = Q_1 [A_2 / A_1]^{0.75}$$

Where:

Q_1 = Known peak discharge
Q_2 = Unknown peak discharge
A_1 = Known basin area
A_2 = Unknown basin area

with the following results in Table 3.2- Prorated flows:

Table 3.2: Pro-rated Flows

Location	Area (ha)	Flow at Key HEC-RAS Locations (cms)					
		2-year	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
Hillside Bridge	135,861	118.73	158.77	183.61	206.29	234.38	254.90
Burnt River Bridge	136,162	119.01	159.03	183.92	206.64	234.76	255.32
Northline Bridge	143,167	123.57	165.13	190.97	214.56	243.77	265.11
Outlet	143,782	123.97	165.66	191.58	215.25	244.55	265.71

3.3. Schematic

The information gathered in the preceding sections was used to build a VH SUITE 5 model of the watershed, as shown schematically in Appendix D.

4. Regional Storm Model Output

4.1. Flow Results

As can be seen in **Figure 4.1** below, most of the sub-catchments have similar response time between 10 and 15 hours from the start of the Timmins storm with the flow peak occurring around 15 hours after the beginning of the Timmins event. Sub-catchments 500 (Green) & 1700 (Violet), being so much larger, takes longer to peak.

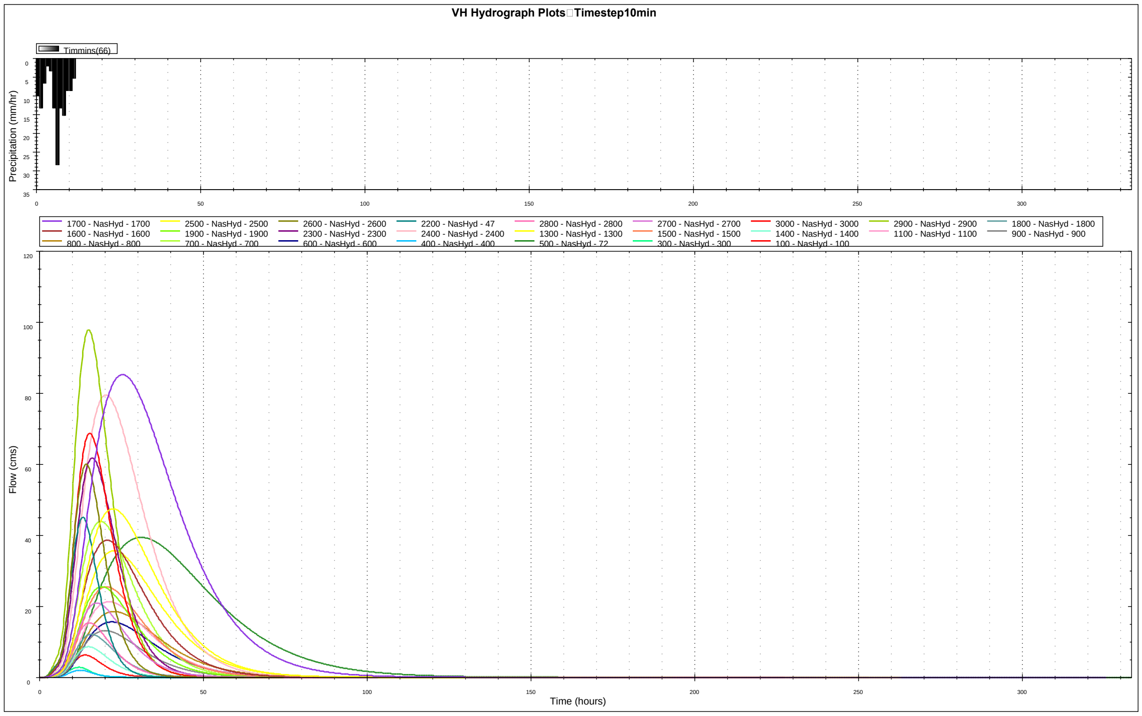


Figure 4.1. Hydrographs (10-minute time step)

Table 4.1 shows the representative peak flows to be input to the HEC-RAS model; the 2-100 year flows are derived from FFA. Detail model output flow summary can be found in **Appendix E**.

Table 4.1: Input Flows to HEC-RAS

Node/XS	Peak Storm Flows in m³/s						
	2yr	**5yr**	**10yr**	**25yr**	**50yr**	**100yr**	**Timmins**
Hillside Bridge	118.73	158.77	183.61	206.29	234.73	254.9	452.50
Burnt River Bridge	119.01	159.03	183.93	206.64	234.76	255.32	487.93
Northline Bridge	123.57	165.13	190.97	214.56	243.77	265.11	503.73
Outlet to Cameron Lake	123.97	165.66	191.58	215.25	244.55	265.96	499.77

4.2. Sensitivity Analysis

Curve Number (CN*)

Flows at the key nodes were assessed to analyze the impact of varying CN* value (+/-20 %). Increasing CN* by 20% resulted in an average increase in peak flows of 26% at key nodes during Timmins storm event. Similarly, decreasing CN* by 20% resulted in an average decrease of 29%. Because there is a significant difference in peak flows as a result of modifying the CN*, it is imperative to get an accurate value.

CN* is determined by land use and soil type. Soil type information is extracted from the digitized Victoria County soils map originally produced as a joint venture by the Federal Department of Agriculture and the Ontario Agricultural College. Land use is derived from the City of Kawartha Lakes' Secondary Plan and zoning maps as well as the 2010 Ecological Land Classification (ELC) mapping. Aerial orthophotography was reviewed to confirm land use throughout the watershed. This base data is valid, and therefore any calculated value (such as CN*) based on this data truly represents the land.

Model Time Step (DT)

The model time step of 10 minutes was modified by changing it 5 & 10 minutes at all subcatchments and channel routing. There was little to no effect on peak flows at key flow nodes during the Timmins Storm Event. Therefore, time step has no effect on the regulatory flows.

The results of sensitivity analysis are shown in **Appendix M**.

5. Hydraulic Model Input Parameters

5.1. Cross Sections

Cross-section geometric data was extracted using HEC-GeoRAS from the Base DEM to ensure geo-referencing in HEC-RAS. It was necessary to supplement these areas with surveyed data to create accurate river geometry. Bathymetric survey points were taken in-channel up to the top of bank throughout the project area. The surveyed data was fused into the cross-sections generated by HEC-GeoRAS. Data sources generated by different entities were placed into the same projection and datum for consistency in processing. Stream crossings were selected based on project orthoimagery, field reconnaissance, and information in previous reports. Full photographic records of all stream cross sections are found in **Appendix G**.

As per HEC-RAS requirements, all cross-sections are oriented looking downstream, cut from left to right. The initial cross-section is at the outlet of the creek at the pond; cross-section nomenclature reflects the distance in meters relative to the initial cross-section.

Left overbank, main channel, and right overbank downstream lengths were measured from the GIS. As per HEC-RAS recommendations, the overbank distances are measured from each overbank centroid.

5.2. Bridge River Station

There are three bridges within the study area. Northline Bridge, Burnt River Bridge and Hillside Bridge. Four cross-sections were cut at each of these bridge crossings to accurately represent channel flow: two upstream and two downstream bounding cross sections. Representative deck elevations were extracted from the Base DEM. The bridges were field-surveyed by KRCA staff to ensure accuracy. Invert elevations, height/width dimensions, piers, length, and channel bottom were surveyed with either total station or GPS. **Table 5.1** provides River Station and associated Bridge and photographs are found in **Appendix H**.

Table 5.1: HEC-RAS Structure Data

Name	River Sta.
Hillside Bridge	19482
Burnt River Bridge	15618
Northline (Mitchell's) Bridge	3820

5.3. Manning's n Values

Manning's n values for channel, left and right overbanks were based on recommended values in Table 3-1 of the *HEC-RAS River Analysis System Technical Manual*, included in **Appendix I.** The main channel n value 0.04 and the overbank n values are set to 0.045 in general. Higher Manning's roughness values were included accordingly to describe areas such as woodlots/heavily forested areas. These values were chosen based on air photo and survey notes/photos. The main channel and overbank lengths were determined by performing measurements in GIS.

5.4. Building Obstructions

Where buildings are located within or between the cross-sections, the cross-section was modified by introducing obstructions to flow. The effect of a building can occur upstream and downstream of a cross-section. A 1:1 contraction effect was used for a cross-section upstream of a building; whereby the actual building width is reduced at a 1:1 ratio from each end of the building face. For instance, if a cross-section is 5m upstream of a 30m-wide building, the obstruction representing the building in the cross-section is 20m wide. A 4:1 expansion effect was used for a cross-section downstream of a building. For instance, if a cross-section is 8m downstream of a 30m-wide building, the obstruction representing the building in the cross-section is 26m wide. A representation of the expansion/contraction effects of a building location is shown in **Figure 5.1** below.

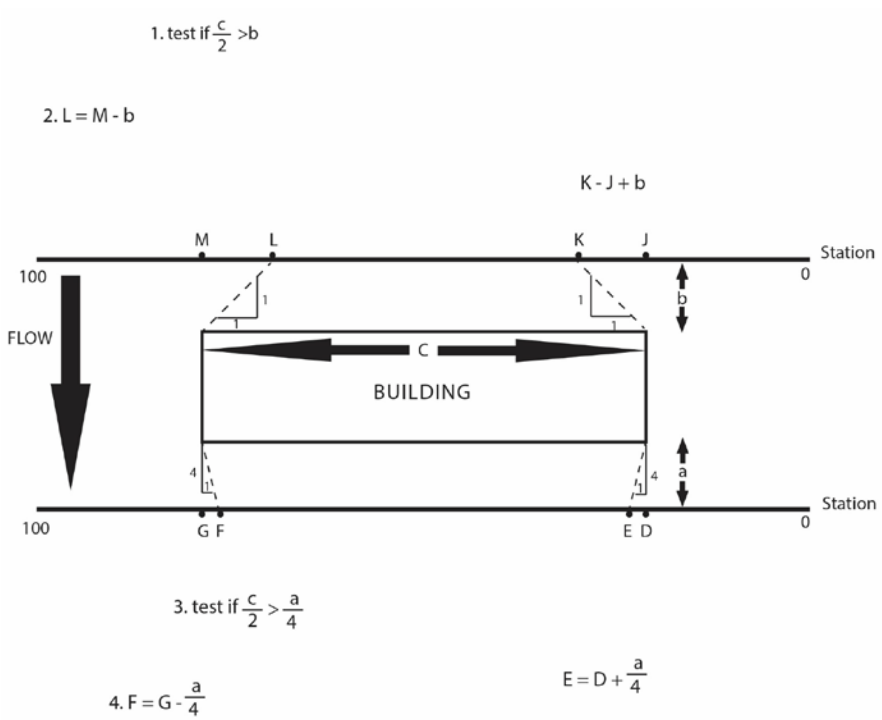


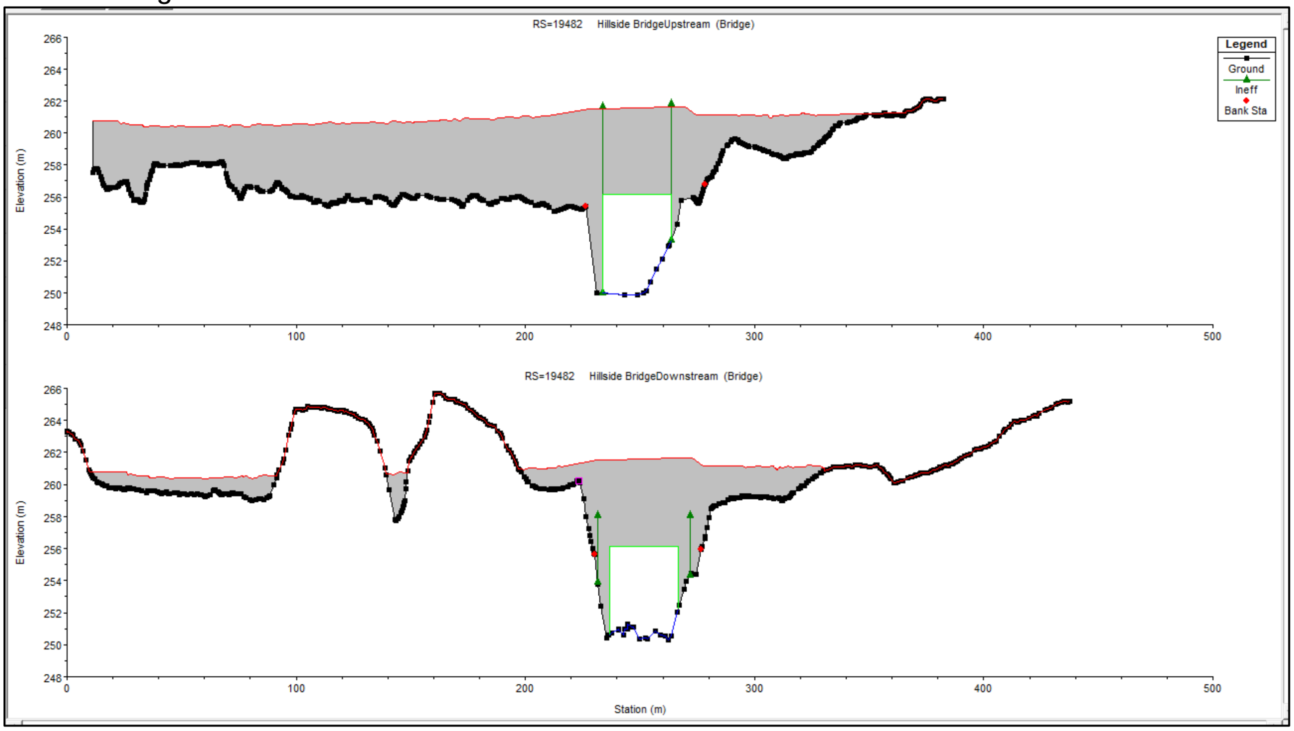
Figure 5.1: Building expansion/contraction effects

5.5. Ineffective Flow Elevations

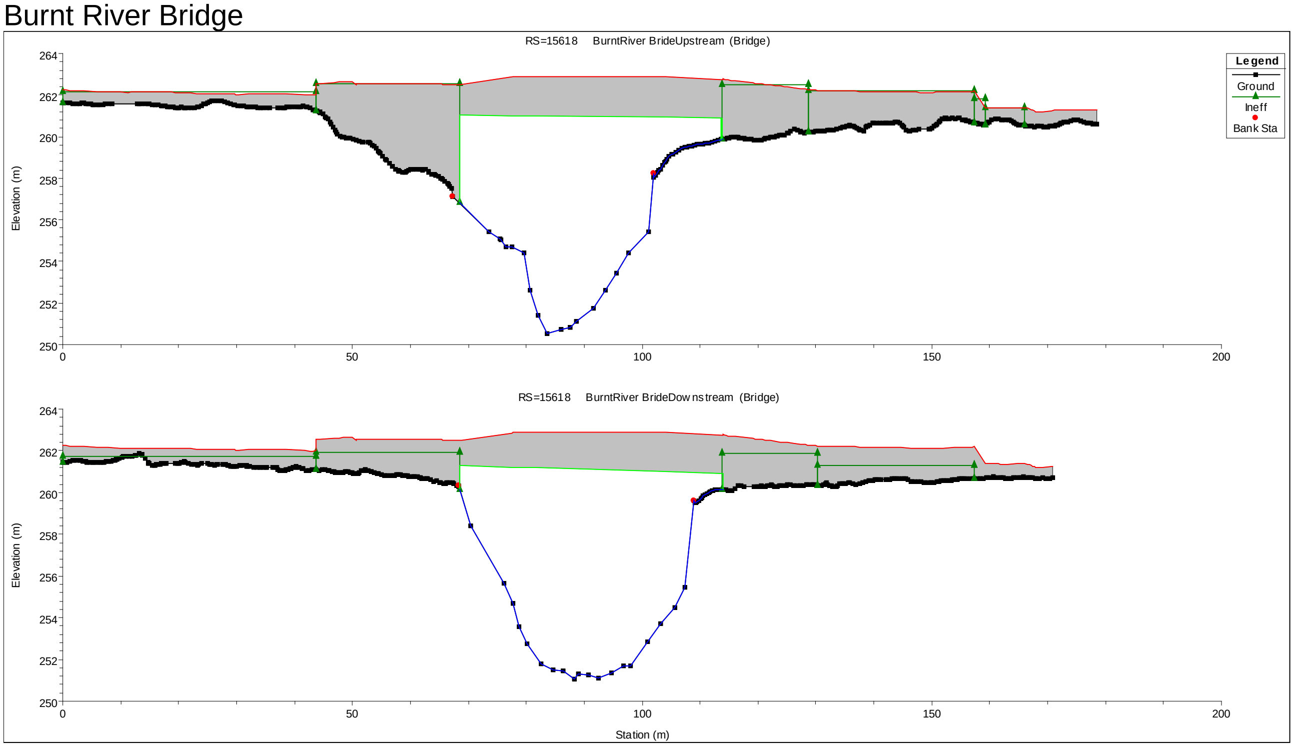
Ineffective areas are often used to describe portions of a cross section in which water will pond, and the velocity is zero with no conveyance such as certain low lying areas and oxbows. Once the water level goes above either of the established elevations, then that specific area is no longer considered ineffective.

Standard normal ineffective flow areas were introduced at the Hillside Bridge, Burnt River Bridge and Northline Bridge crossings to capture the varying guardrail elevations, as shown in **Figure 5.2** below. For the upstream bounding cross-section, ineffective flow elevations are equal to the low points of bridge deck. For the downstream bounding cross-section, the ineffective flow elevations are set at a point midway between the guardrail and the bridge obvert elevations.

Hillside Bridge



Burnt River Bridge



Northline Bridge

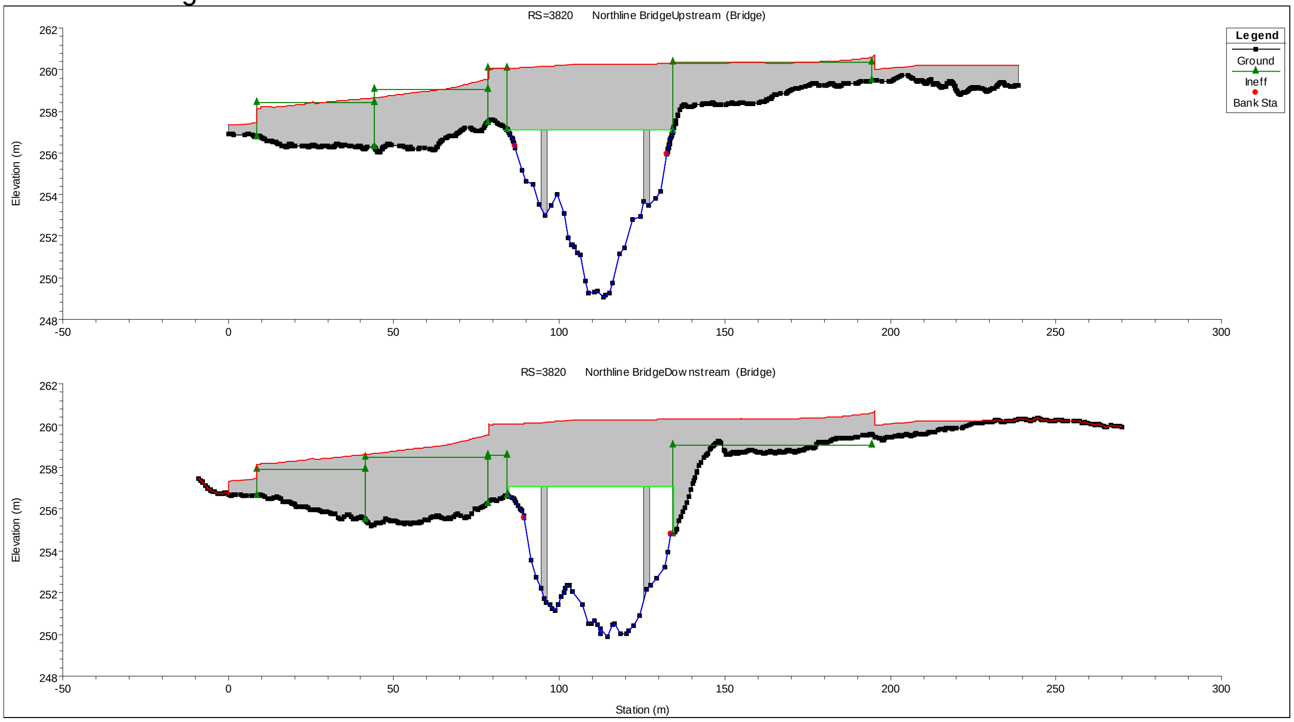


Figure 5.2: Cross-section view of ineffective flow areas

5.6. Boundary Conditions

For the flow analysis, the downstream boundary conditions are as follows:

100-yr:	255.05m
Timmins event:	255.05m

as established lake level by Parks Canada on May 16, 2019.

5.7. Expansion/Contraction Coefficients

The model uses the HEC-RAS recommendations of 0.1 and 0.3 for contraction and expansion coefficients at all normal cross sections. At the bridges, the values were increased to 0.3 and 0.5, respectively.

5.8. Schematic

The information gathered in the preceding section was used to build a HEC-RAS model of the watercourse. The geometry of the model is shown schematically in **Figure 5.3**.

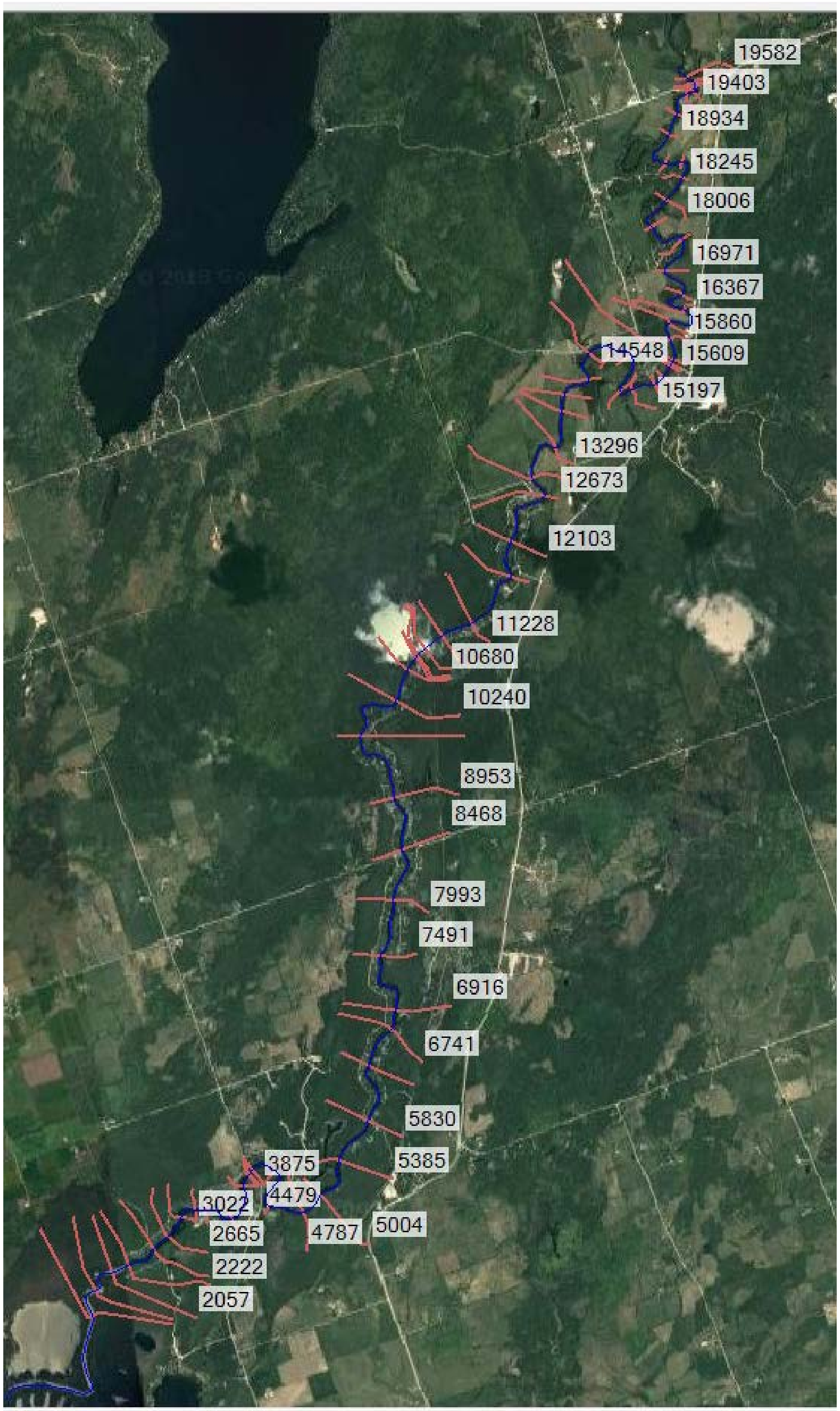


Figure 5.3: HEC-RAS Schematic

6. Hydraulic Model results

6.1. Comparison of Flood Frequency Analysis Results with Observed High Flow Survey Points

Table 6.1 shows the return period flows from the CFA model and the peak flows during the 2013 and 2016 events at the Burnt River near Burnt River gauge.

Table 6.1: Calculated and Recorded Flows

Return Period	Flow cms
2 yr	110
5 yr	147
10 yr	170
25 yr	191
2016 Event	202
2013 Event	211
50 yr	217
100 yr	236

The 2013 and 2016 peak flow events fell between the 25 year and 50 year calculated events.

Flood lines for the 25yr and 50yr events resultant from the FFA were compared to high flow data, which KRCA staff obtained during the flood events in 2013 and 2016. The difference between the generated flood lines and the actual high points is generally low and therefore is a good indicator to verify the established flood lines for the Burnt River in HEC-RAS.

7. Sensitivity Analyses

Manning's n values are varied by +/- 20 % to determine the effect on the computed water surface elevations. Results show a maximum change of depth of plus ~0.25 m for an increased roughness coefficient and a minimum change of depth of minus ~1 m for decreased Manning's n. Greatest deviations are observed in the upper reach of the Burnt River, while the downstream reach has little change in water surface elevation with varying Manning's n.

The values of flow length are varied by +/- 20 %, while other parameters remain unchanged. Results show a maximum change of depth of plus ~0.20 m for an increased flow length and a minimum change of depth of minus ~0.25 m for decreased flow lengths. Again the upper reach seems more impacted by the variation compared to the lower reach where changes in water surface elevation drop to zero.

Downstream boundary conditions were analyzed using the average lake level (255.05m) and the high level (256.22m) as established by McLaren Plansearch, 1991, while other parameters remain unchanged. This change seems to have little effect on the simulated water surface elevation upstream. The difference at the downstream end of Burnt River shows a range of higher water surface elevations from 1.17m to 0.03m.

In conclusion, simulated water surface elevations are most sensitive to changes in the roughness coefficient in the upper reach and to changes in downstream boundary conditions of the Burnt River. Results are shown in Appendix M.

A scenario was created by running 1:100 year plus 50% flows and flood levels were compared with the original flows (Appendix M). The results show difference of the levels between 1:100 yr. (vs. 1:100 yr + 50%) flows was highest (1-1.30m) at the upper reaches and then it gradually decreases to 0 at the outlet. Whereas, the difference in Timmins flows (vs. 1:100 yr + 50%) was in the range of (-0.95-0.6 m).

8. Burnt River Flood Results

The final floodplain maps are the result of the calculated Regional Storm Flood line and the 1:100 year Cameron Lake levels.

The Regulatory flood elevations in the Burnt River are listed in **Table 8.1** below, as well as the 2- through 100-year events.

Table 8.1: HEC-RAS Flood Elevations for Burnt River

Node/HEC-RiverStation	HEC-RAS Creek Flood Elevations (m)						
	Timmins	100yr	50yr	25yr	10yr	5yr	2yr
Hillside Bridge/19501	261.43	259.75	259.48	259.09	258.76	258.37	257.71
Burnt River Bridge/15631	260.51	259.11	258.89	258.55	258.27	257.93	257.36
Northline Bridge/3829	257.44	256.25	256.14	256.00	255.89	255.77	255.61
Outlet/1494	255.05	255.05	255.05	255.05	255.05	255.05	255.05

Figure 8.1 shows the Regulatory flood extents for the creek based on a starting water surface elevation of 255.05m, the normal headpond operating level at Cameron Lake.

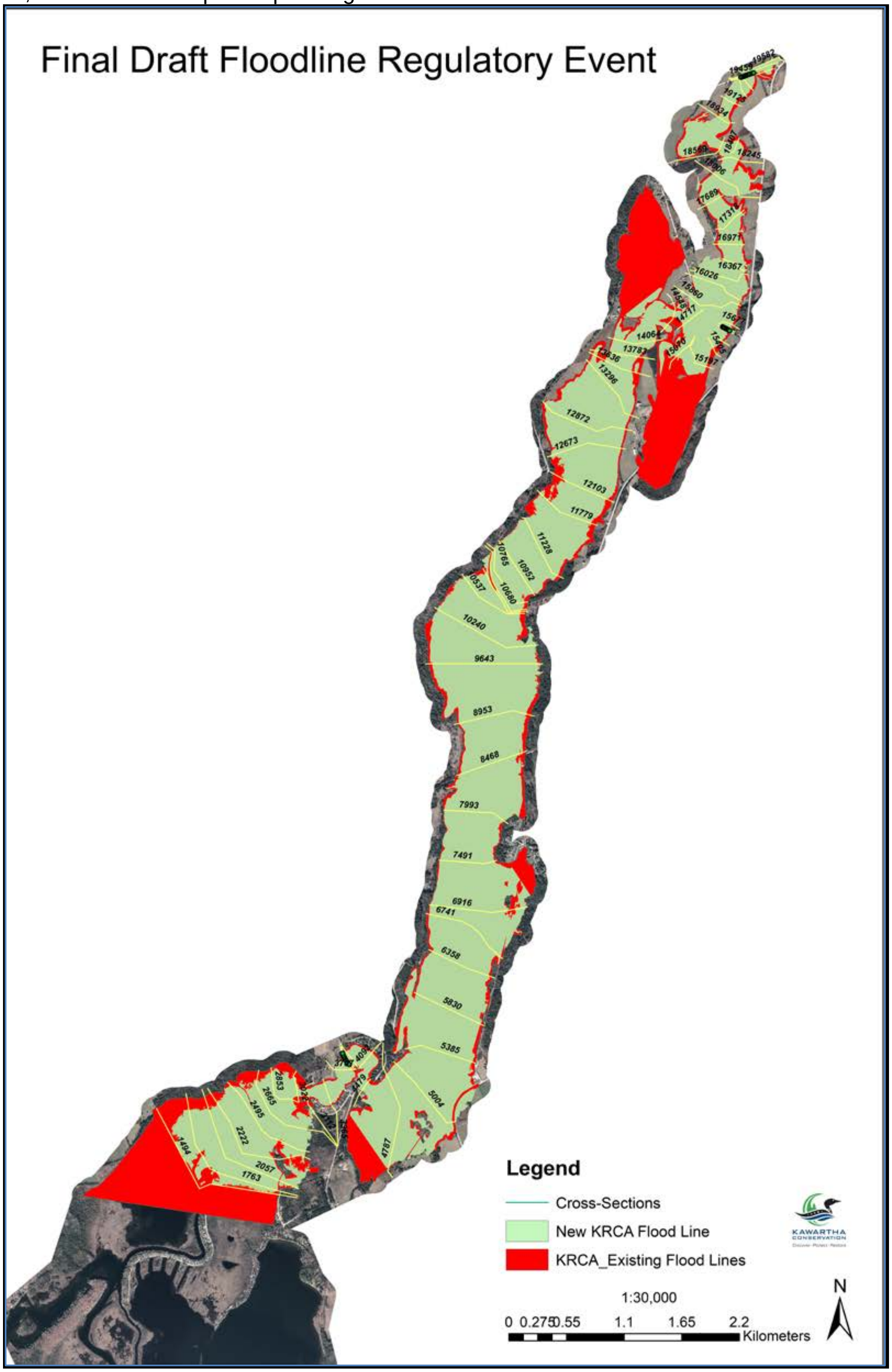


Figure 8.1: Regulatory Flood Line

9. Conclusions and Recommendations

It is recommended that the results of the HEC-RAS model for Burnt River watercourse be adopted as the flood maps. The flood maps are found at the back of this report. The results of the models are reasonable and should be used to establish new Regulatory floodlines for the watershed.

The following additional analyses are recommended:

1. Update the FFA to include peak flow experienced in 2019.
2. Confirm current dam operations and corresponding stage-storage-discharge data and update if necessary.
3. Calibrate the new hydrologic model based on more recent events and analysis (e.g. 2013, 2016 and 2019) to validate any adjustments to hydrologic parameters i.e. time to peak.

Appendices

(Bound in a separate document)

Appendix A: Modeling Parameters Selection

Appendix B: Subcatchment Data

Appendix C: Subcatchment Maps

Appendix D: VH Suite Output

Appendix E: Hydrology Model Flow Summary

Appendix F: Official & Secondary Plan Maps

Appendix G: Cross-section Photo Inventory

Appendix H: Structure Photo Inventory Record

Appendix I: Manning's n Values

Appendix J: Digital Elevation Model and Orthoimagery Data Accuracy Assessment Report

Appendix K: Excerpts of Previous Studies

Appendix L: Terms of Reference for Digital Elevation and Orthoimagery Data Quality ControlAppendix M: Hydraulic Sensitivity Analyses ....

Appendix N: Dam Reservoirs-Storage Discharge tables