KGS GROUP
CONSULTING ENGINEERS

LAKEHEAD REGION CONSERVATION AUTHORITY

PENNOCK CREEK FLOODPLAIN MAPPING UPDATE STUDY GENERAL REPORT

DRAFT REV B

KGS Group 18-3065-003
March 2020

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THIRD PARTY USE OF REPORT

This report has been prepared for the Lakehead Region Conservation Authority, to whom this report has been addressed, and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

1.0 INTRODUCTION

1.1 OBJECTIVES OF THE STUDY

This study was commissioned to KGS Group by the Lakehead Region Conservation Authority (LRCA), with the objective of updating the existing floodplain mapping of Pennock Creek and its tributaries within the City of Thunder Bay and the Municipality of Oliver Paipoonge. The study included:

- The collection and processing of topographic data using LiDAR technology and ground surveys, as well as bathymetric data for the creek and tributaries.
- The preparation of mapping base data, including the development of a digital elevation model (DEM) with the topographic data obtained.
- Hydrologic analysis and modelling to obtain flows for representative flood events along the Pennock Creek system.
- Hydraulic analysis and modelling to calculate the conditions (water levels and flow velocities) across the creek system, associated with the flows estimated for the various flood events.
- The preparation of floodplain maps depicting the flood hazard limits and the administrative fill lines along the reaches of Pennock Creek and its tributaries included in the scope of project.
- The presentation of the study results to stakeholders and to the public in an open house, which will take place in March 2020.

Separate technical reports have been submitted to describe, in detail, the data used, the methodology applied, and the results obtained during the execution of the project. These reports include:

- Pennock Creek Floodplain Mapping and Kaministiquia River Floodplain Mapping Study LiDAR Report (KGS Group, 2019a).
- Pennock Creek Floodplain Mapping Update Study, Hydrologic Report (KGS Group, 2019b).
- Pennock Creek Floodplain Mapping Update Study, Hydraulics Report (KGS Group, 2019c).

This report provides a summary of the findings of the study described in the above noted technical reports.

1.2 CRITERIA FOR FLOODPLAIN AND FILL LINE

To minimize the risk of flooding to people and property, the Province of Ontario has established policies and flood standards to restrict development within floodplains.

The Lakehead Region is located within Zone 3, as defined in the Technical Guide – River and Stream Systems: Flooding Hazard Limit (Technical Guide, OMNR, 2002)[1]. For all watersheds within this zone, the flooding hazard limit is defined as the greater of the flood resulting from:

a. the Regional Storm (which for this area is the Timmins Storm of 1961), transposed and centred over the watershed and combined with the local conditions;

b. the 100-Year flood;

c. a flood which is greater than a) or b), which was actually experienced on a particular watershed or portion thereof, for example as a result of ice jams, and which has been approved as the standard for that specific area by the Minister of Natural Resources.

No specific storm, with the characteristics indicated in item “c”, has been approved by the MNRF for the study area, so the criterion used in this study corresponds to the maximum from the conditions described in items “a” and “b”.

The definition of the fill line, for administrative purposes, was based on the “Guidelines for Developing Schedules of Regulated Areas” (2006). The criteria described in that document includes consideration of the river valley characteristics and in particular stability of the bank slopes. LRCA indicated that, for this watershed, bank slopes with a horizontal to vertical ratio of 2:1 or greater are considered stable. The criteria for definition of the fill line applied for the Pennock Creek mapping can be summarized as follows:

[1] The Ministry of Natural Resources and Forestry (MNRF) was named Ontario Ministry of Natural Resources (OMNR) aat the time of release of the guidelines, Technical Guide – River and Stream Systems: Flooding Hazard Limit.

- In areas with gradual banks at the contact of the flood line with the terrain (bank slope flatter than 2H:1V), the fill line was set 15 m from the flood hazard line.
- In areas where a defined river bank was present, and the bank slope was flatter than 2H:1V, the fill line was set 15 m from the top of the bank.
- In areas with steep banks at the contact of the flood line with the terrain (bank slope equal or steeper than 2H:1V), the fill line was set 15 m from the point where the projection, from the floodline, of a 2H:1V slope would daylight.

1.3 GENERAL DESCRIPTION OF WATERSHED AND STUDY AREA

The Pennock Creek watershed is shown in Figure 1. The creek is a major tributary of the Neebing River. It originates north of the Village of Murillo in the Municipality of Oliver Paipoonge, and runs generally in the easterly direction, to flow into the Neebing River at a location near the Thunder Bay International Airport. The main branch of the creek is approximately 17.6 km long and its channel width is typically 5 to 8 m. The drainage area of this watershed is approximately 50 km^2.

The labelling system shown in Figure 1 was also used to identify the river branches and tributaries in the hydraulic model prepared as part of this study. In Figure 1, the main branch of Pennock Creek has been labelled as “P”. The labels assigned to the tributaries of Pennock Creek include the letter “T” and a number indicating the order in which they join the creek. The ordering numbers were assigned in the direction from downstream to upstream. There are also a few second order tributaries, which are identified by the name given to the tributary that they join, followed by a dot and a consecutive number.

It must be noted that there are numerous small tributaries in the watershed that are not included in Figure 1. It was indicated by LRCA, that only the tributaries with draining areas larger than 125 ha were to be included in the hydraulic model.

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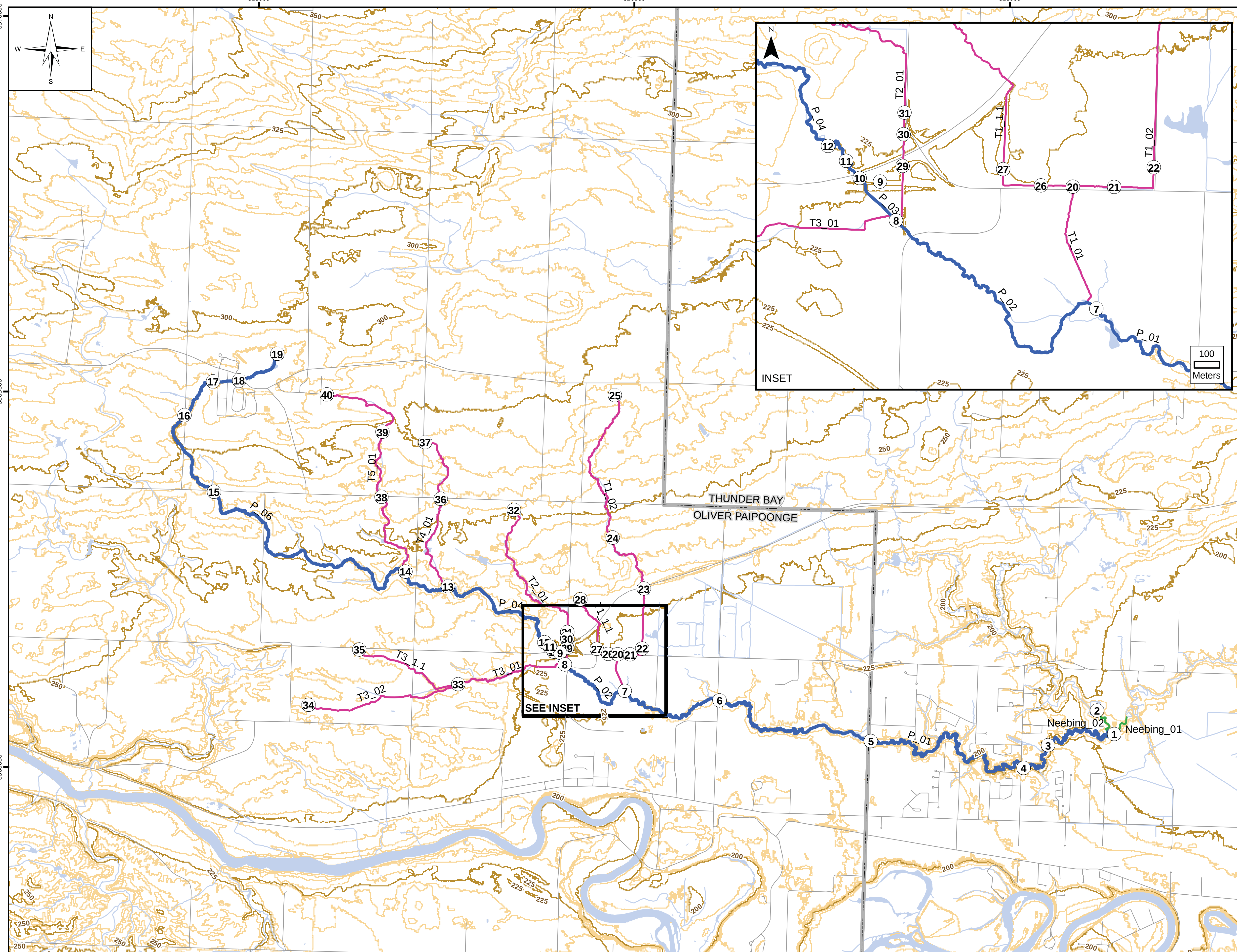

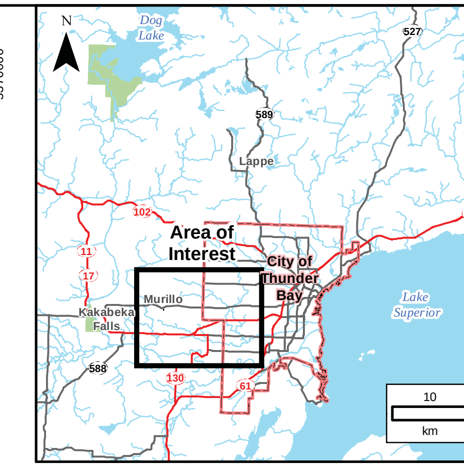

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LEGEND:

- 15 Model Flow Input Location (Reference ID in Table 4)
- Neebing River
- Pennock Creek Main Channel
- Pennock Creek Tributaries
- 25m Index Contour
- 5m Contour
- Road
- Watercourse
- Waterbody
- Municipal/Township Boundary

NOTES:
1. Topographic data was derived from the Northwestern Ontario Orthophotography Project (NWOOP) DEM obtained from Land Information Ontario (LIO).

DRAFT

0.5 0 0.5 1 1.5 2
Kilometres

SCALE: 1:50,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 16 Elevations are in metres above sea level (MSL)

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B	20/03/12	ISSUED AND RE-ISSUED AS DRAFT	FC	MSW
A	20/01/15	ISSUED WITH DRAFT REPORT	FC	MSW

REVISIONS / ISSUE

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PENNOCK CREEK FLOODPLAIN MAPPING PROJECT GENERAL REPORT

PENNOCK CREEK REACHES

MARCH 2020 | FIGURE 01 | REV: B

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11"x17" PLOT SCALE 1:1

1.4 HISTOY OF FLOODING

Hydrometric data records are not available for Pennock Creek and records or observations of historical flooding events are limited. LRCA provided photos at various locations of Pennock Creek taken during the flood events that occurred on May 28, 2012. These photos were used as references to compare with results from the hydraulic model prepared as part of this study, details were discussed in the hydraulic technical report (KGS, 2019c).

1.5 PREVIOUS STUDIES

There is a previous study for the Pennock Creek watershed, that was carried out for the purpose of floodplain mapping. It was completed in 1982 by M.M. Dillon Limited (Dillon), and included hydrologic analyses and hydraulic modelling. The peak flow obtained in that study for the Regional Storm, and used as the basis for the previous floodplain maps, was found in this study to be proportionally too large. This is further discussed in Section 3.0.

2.0 DATA USED IN THE ANALYSIS

2.1 LIDAR AND TOPOGRAPHIC DATA

The topographic data used in this study is referenced to the 6-degree Universal Transverse Mercator (UTM), North American Datum 1983 (NAD83CSRS) Zone 16 grid projection system and Canadian Geodetic Vertical Datum (CGVD28).

As part of the study, LiDAR (Light Detection and Ranging) data along Pennock Creek was obtained by KGS Group and its sub-consultant ATLIS Geomatics. LiDAR and aerial imagery acquisition were completed by ATLIS on May 17th and 18th 2019. The data capturing, processing, and quality control are reported in the Pennock Creek Floodplain Mapping and Kaministiquia River Floodplain Mapping Study LiDAR Project Report by KGS (2019a). The specifications of the LiDAR capture are summarized in Table 1.

TABLE 1
LIDAR ACQUISITION SPECIFICATIONS

LiDAR Acquisition Specifications	
Flying Height (metres AGL)	805 to 1100m
Aircraft Ground Speed (knots)	105
Pulse Rate (KHz)	482
Scan Rate (Hz)	47
Full Field of View (degrees)	40
Multi-Pulse	YES
Nominal Swath Width (Metres)	1025
Swath Overlap (percentage)	30%
Nominal Point Spacing Across Track (Metres)	0.3
Nominal Point Spacing Along Track (Metres)	0.3
Average Pulse Density (points per m^2)	8.7
Vertical Accuracy	5 cm or less RMSE
Horizontal Accuracy	25 cm or less RMSE

Topographic surveys were carried out by KGS Group in October and November of 2018 and in May, June, and July of 2019. The surveys allowed developing a control network to support LiDAR acquisition, provide baseline coverage, and perform quality control on the LiDAR data. The LiDAR data was then used to develop a Digital Elevation Model (DEM) with the program Model Builder in ArcGIS v10.4. This DEM was the basis for the derivation of the cross sections used in this study for the preparation of the hydraulic model of Pennock Creek.

Topographic and bathymetric surveys were also carried out and used to supplement the LiDAR data. This work included localized survey of riverbed elevations, focused at the crossing locations. The data collected at the crossings also included measurements of the size and elevations of the water passages, top of road elevation as well as photo documentation. A total of 108 locations were surveyed of which 54 were included in the hydraulic model[2]. The structures included in the model are six bridges, 47 culverts and one inline structure. Data sheets summarizing the data collected at all locations surveyed are provided in the hydraulic technical report (KGS, 2019c).

[2] A number of crossings that were survey corresponded to tributaries with small drainage areas (less than 125 ha). These tributaries were not included in the hydraulic model, as per the requirements specified for this study.

3.0 HYDROLOGIC ANALYSES

The drainage area of this watershed is approximately 50 km^2. It includes the main branch of Pennock Creek, as well as several smaller tributaries. The headwaters of the creek are located north of Oliver Road and are situated at approximately El. 289 m. The confluence with the Neebing River is located at approximately El. 188 m. Characteristic parameters of the Pennock Creek watershed, obtained using the MNRF's Ontario Flow Assessment Tool OFAT III[3], are listed in Table 2.

TABLE 2
HYDROLOGIC CHARACTERISTICS PENNOCK CREEK WATERSHED (FROM OFAT III)[4]

Drainage Area	49.5 km^2
Shape Factor	19.0
Mean Elevation	253.5 m
Maximum Elevation	363.3 m
Mean Slope	2.5 %
Length of Main Channel	30.7 km
Slope of Main Channel	5.5 %
Annual Mean Temperature	3.1 ^oC
Annual Precipitation	711 mm
Area of Lakes	0.143 km^2
Area of Wetlands	6.3 km^2

The existing land use in the Pennock Creek Watershed is predominantly rural, especially in Oliver Paipoonge. The watershed also includes some suburban developments and pockets of commercial, industrial and institutional land use in the villages of Murillo and Rosslyn, and in the City of Thunder Bay.

[3] The Ontario Flow Assessment Tool (OFAT), version 3, is an online spatially-based application which includes a number of tools that allow conducting hydrologic tasks. It was developed by the Ontario Ministry of Natural Resources and Forestry.
[4] The drainage area shown in Table 1 was obtained with OFAT III. It is slightly less than what was measured independently with GIS tools.

As part of this study, a hydrologic analysis of the Pennock Creek watershed was carried out by KGS Group and it was reported in the Hydrology Report KGS (2019b). It included Regional Flood Frequency Analysis and hydrologic modelling.

KGS carried out the Regional Flood Frequency Analyses (using the Index Flood Method) with the formulas developed in the McIntyre River Floodplain Mapping Study (HMM, 2015) and the McVicar Creek Floodplain Mapping Study (KGS, 2018). The two formulas provided similar results; but those obtained with the formula from the McIntyre River Study were slightly more conservative, and therefore were adopted in this study.

The Regional Flood Frequency Analysis was used to obtain peak flows for Pennock Creek, based on the single flood frequency flows obtained for the Neebing River at Water Survey Canada Station 02AB008, that had been obtained as part of the Neebing River Floodplain Mapping update (KGS, 2018). This is considered a correct approach given that Pennock Creek is a tributary of the Neebing River and the characteristics of those two watersheds are similar. The results were adopted in this study (KGS, 2019b) and are shown in Table 3.

TABLE 3
REGIONAL FREQUENCY ANALYSES OF THE PENNOCK CREEK WATERSHED

Return Period	Index Flow Method Using Flood Frequency Values for the Neebing River
2	8.2
5	14.4
10	19.0
25	24.9
50	29.5
100	34.0

The program Visual OTTHYMO Version 5.0 (VO 5) was used in this study to develop a hydrologic model of the Pennock Creek watershed. The model elements used to represent the various watershed features include sub-catchments, routing channels and reservoirs. The hydrologic model was developed based on the topographic data available as well as the characteristics of the various sub-catchments, obtained from OFAT III and from the Ontario Agricultural Information Atlas. The hydrologic model domain extended through the entire

Pennock Creek watershed, from the headwaters of its branches and tributaries to its mouth at the confluence with the Neebing River.

In the hydrologic model, the watershed was divided into 25 sub-catchments. Twenty-two sub-catchments correspond to rural areas and three, to suburban catchments. The model also includes seventeen river reaches that allow simulating the routing of runoff flows as they travel through the river system. A review of the future development plans for the watershed indicated only minor changes to land use. It was, therefore, determined that the model prepared based on existing conditions also represented anticipated future conditions.

The model was validated, using the results obtained from the Regional Flood Frequency Analysis, and was used to simulate the runoff resulting from the Regional Storm Flood as well as from recurrent storms ranging from 2 to 100 years return period. The Regional Storm for the area is the Timmins Storm. Hyetographs for this storm were prepared for the Pennock Creek watershed using an area reduction factor of 84%. This factor was based on the equivalent circular area of the watershed in adherence with the Technical Guide (MNR, 2002). For the recurrent events, synthetic storm hyetographs were developed using the most current Intensity-Duration-Frequency curves for the City of Thunder Bay.

The results of the simulation of the Regional Storm Flood were considerably lower than those reported in Dillon's 1982 study and used in the previous floodplain maps for the Pennock Creek. The 1982 value (108.6 m^3/s) is too high, considering that the peak flow obtained for the entire Neebing River watershed (which is approximately 4.5 times larger) was 128 m^3/s (KGS, 2018)[5]. The two studies used different approaches, since modern hydrologic models were not available in 1982.

The values recommended to be adopted as representative of peak flood flows for Pennock Creek at the confluence with the Neebing River are listed in Table 4.

[5] This value was adopted for the Neebing Floodplain Mapping Update because it had been used in the previous floodplain maps for the Neebing River and was only slightly greater than the value of 125 m^3/s obtained with the new model prepared by KGS Group.

TABLE 4
RECOMMENDED PENNOCK CREEK PEAK FLOWS AT THE LOCATION OF CONFLUENCE WITH NEEBING RIVER

2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional Storm
8.2	14.4	19.0	24.9	29.5	34.1	52.4

4.0 HYDRAULIC ANALYSIS

The computer program HEC-RAS, Version 5.0.7, was used in this study to prepare a hydraulic model of the Pennock Creek system. The hydraulic model was used to simulate the recurrent events with return periods ranging from 2 to 100 years, as well as the Regional Storm Flood.

The model includes all the river reaches highlighted in Figure 1. Cross sections were extracted from the DEM and the localized survey data described in Section 2.1. These cross sections were spaced at maximum intervals of 200 m, and in most cases at shorter distances, particularly at locations of crossings and where the data suggested changes in the geometry of the channel.

The downstream boundary condition for the model was the water levels at the Neebing River, for the Regional Storm Flood and recurrent flood events, obtained from the Neebing River study (KGS, 2018). Input flows were provided at the upstream section of each river branch and tributary reach, based on the results from the hydrologic analysis (Section 3.0), so that the flows at the confluence with the Neebing River matched the values indicated in Table 4. The model inflows are summarized in Table 5.

The Manning n-values used in the model to represent surface roughness were selected based on typical values obtained in the literature for rivers and floodplains with similar characteristics (surface type, vegetation coverage) to those observed in aerial imagery and the photographs collected during the ground survey for the various reaches of Pennock Creek. In the lower reaches of the creek, where the main channel is generally clean and uniform, a Manning n-value of 0.03 was adopted. In the upper Pennock Creek branches and tributaries, the channel features gravels, small cobbles and weeds on the riverbed, as well as sections of shallow flow, so a higher Manning n-value of 0.035 was adopted. For the overbanks, generally covered by grass and medium to dense brush and trees, the selected n-values ranged from 0.07 to 0.1; except at farmlands and residential lands, where the adopted Manning n-values were 0.04 and 0.05, and at road surfaces where an n-value of 0.025 was used.

The model includes the culverts, bridges and hydraulic structures surveyed in the study and described in Section 2.1.

TABLE 5
HYDRAULIC MODEL INPUT FLOWS AND LOCATIONS

Model Location		Figure 1 Reference ID	Flow (m^3/s)						
Branch	Station (km)		Regional Flood	100 Year	50 Year	25 year	10 Year	5 Year	2 Year
Neebing_01	37.464	1	109.77	80.27	67.11	55.46	40.81	29.29	14.47
Neebing_02	37.571	2	109.77	80.27	67.11	55.46	40.81	29.29	14.47
P_01	1.737	3	52.41	34.14	29.53	24.9	19.01	14.35	8.16
P_01	2.589	4	52.25	34.07	29.46	24.85	18.97	14.33	8.15
P_01	6.759	5	51.74	33.84	29.13	24.58	18.78	14.19	8.09
P_01	9.824	6	48.34	32.16	27.28	23.05	17.68	13.42	7.72
P_01	11.629	7	44.63	29.72	25.28	21.43	16.53	12.62	7.39
P_02	1.317	8	31.61	21.02	17.88	15.15	11.68	8.91	5.2
P_03	0.137	9	26.96	17.79	15.14	12.82	9.87	7.51	4.36
P_04	2.453	13	24.57	16.16	13.75	11.63	8.95	6.81	3.94
P_05	0.802	14	16.95	11.02	9.35	7.89	6.04	4.57	2.61
P_06	4.203	15	12.74	8.47	7.19	6.08	4.66	3.53	2.02
P_06	5.658	16	8.9	5.85	4.97	4.21	3.23	2.45	1.41
P_06	6.987	17	7.72	5.2	4.43	3.75	2.88	2.19	1.26
P_06	7.458	18	5.98	4.1	3.48	2.95	2.26	1.72	0.99
T1_01	0.503	19	9.66	6.56	5.61	4.79	3.72	2.88	1.73
T1_02	1.214	22	7.15	4.82	4.11	3.5	2.71	2.09	1.24
T1_02	2.303	23	6.22	4.13	3.5	2.96	2.26	1.71	0.98
T1_02	4.883	24	4.87	3.28	2.79	2.36	1.81	1.37	0.78
T1_1.1	1.174	27	2.51	1.74	1.5	1.29	1.01	0.79	0.49
T2_01	2.808	31	2.39	1.63	1.39	1.18	0.92	0.71	0.42
T3_01	1.665	32	3.67	2.38	1.99	1.65	1.23	0.91	0.5
T3_02	2.164	33	0.7	0.41	0.33	0.26	0.18	0.12	0.05
T3_1.1	1.545	34	2.12	1.42	1.21	1.02	0.78	0.59	0.34
T4_01	1.447	35	5.76	3.96	3.39	2.89	2.26	1.75	1.04
T4_01	2.527	36	3.21	2.06	1.75	1.48	1.14	0.86	0.49
T5_01	1.442	37	4.48	2.86	2.42	2.04	1.56	1.18	0.67
T5_01	2.527	38	3.21	2.06	1.75	1.48	1.14	0.86	0.49
T5_01	3.894	39	1.76	1.14	0.97	0.82	0.63	0.48	0.28

There was no data for calibration or validation of the hydraulic model. The model results for the Regional Storm Flood were compared with the photos and observations obtained from the May 28, 2012 flood event, described in Section 1.2.

Recognizing the uncertainty associated to numerical modelling, sensitivity analyses were carried out to evaluate the effect of the Neebing River levels and the adopted roughness parameters. The results showed that the model results are largely independent of the assumptions made for these two parameters, within the range of values normally acceptable for the site conditions. The values adopted for the calibrated model are considered appropriate for the analysis to define flood hazard limits.

The adopted hydraulic model was used to simulate recurrent events corresponding to 2, 5, 10, 25, 50, and 100-Year return periods and the Regional Storm Flood.

5.0 FLOOD AND FILL LINE MAPPING

The proposed flood hazard limits for the Pennock Creek system are the water levels obtained from the simulation of the Timmins Storm, which is the Regional Storm for this watershed, and were higher than those obtained for the 100-Year event. These limits were plotted in floodplain maps that were prepared using a Geographic Information System (GIS). They were reviewed for consistency and adequacy by inspection of model results and terrain levels throughout the study area. Subsequently, the fill lines were generated based on the criteria described in Section 1.2 and refined after review and discussions with LRCA.

A set of floodplain maps were produced to display the flood hazard line and the fill line. The base mapping data for preparation of these maps includes:

- Imagery supplied by LRCA as part of the North West Ontario Orthophotography Project – 2017 (NWOOP), acquired through Land Information Ontario (LIO).
- Municipal boundaries, municipal parcels, and road network supplied by LRCA.
- Tile Index followed the City of Thunder Bay 1:2000 scale maps (1 km x 1 km) non-overlapping tiles. The tile index data was provided by LRCA.
- 0.5 m and 1 m interval contours were developed from the LiDAR digital elevation model (DEM) by KGS Group.
- Cross sections, thalweg, and Regional Floodline were imported into GIS format from HEC-RAS by KGS Group.
- Fill line, prepared by KGS Group following the criteria described in Section 1.2.

The floodplain maps are included as an appendix in the Hydraulic Report (KGS Group, 2019c) and have been provided in digital copy format to LRCA. All floodplain maps are in 24x36 full size format.

6.0 STUDY RESULTS AND COMPARISON WITH PREVIOUS FLOODPLAIN MAPS

A general comparison of the results of the present study, with the previous flood lines provided by LRCA, show good agreement. In general, the present study shows less extensive flooding when compared to the previous study.

The following are locations where both the present study and the 1982 study show overbank flooding. These are described in detail in the hydraulic report (2019c).

- Upstream of the Thunder Lake Dam (Branch P_01), both the previous floodplain maps and the updated model results show spill over the private bridge off Rosslyn Road between 25th Side Rd. This area is shown in Map Sheet Number 355.
- At Hwy 130 (Branch P_01) both the previous floodplain maps and the updated model results show spill over the private bridge downstream of Hwy 130 on the main Pennock Creek channel; however, the 1982 floodplain maps show more extensive flooding upstream of Hwy 130. This area is shown in Map Sheet Number 354.
- At Cooper Road (Branch P_01) both the previous floodplain maps and the updated model results show overtopping of the private driveway off Cooper Road and another private pedestrian bridge to the west; but the 1982 floodplain maps show more extensive flooding. This area is shown in Map Sheet Number 353.
- At Vibert Road and Hwy 130 (Branch P_02, Tributary T3_01 and T2_01) both the previous floodplain maps and the updated model results show spill over Vibert Rd N and Vibert Rd, the ramp of Vibert Rd to Hwy 130 and Hwy 130. The updated model includes areas north of the Hwy 11 that had not been modeled in the previous study. This area is shown in Map Sheet Number 1960, 1961 and 1986.

The present study included major tributaries of Pennock Creek that were not included in the previous floodplain maps, and therefore it revealed locations of overtopping of banks and crossings that had not been previously identified. These are summarized below.

- North of Hwy 130 (Tributary T1_02 and T1_01), west to intersection with Cooper Rd, the updated model results indicate overtopping of one driveway and the road on the left river bank of reach T1_02. It also shows impact on two ancillary buildings in this area. This area is shown in Map Sheet Number 331 and 1961.
- Along Centre Street (Tributary T1_02), north of Pole line Rd, the updated model results show overtopping of three driveways those next to Centre Street, and also show impact on three ancillary buildings. This area is shown in Map Sheet Number 1886 and 1911.

- At Pole line Road (Tributary T4_01), east of intersection with Boulter Rd, the updated model results show overtopping of the Pole line Rd, one private crossing downstream of Pole line Road and another private crossing further downstream. This area is shown in Map Sheet Number 1909.
- At Pole line Road (Tributary T5_01), west of intersection with Fraser Rd, the results show overtopping of the Pole line Rd, and two private crossings off Pole line Road. This area is shown in Map Sheet Number 1908.
- At Wing Road (Branch P_06), the updated model results show spill over Wing Road, three private driveways off Wing Road, and a private pedestrian bridge east of Wing Road. This area is shown in Map Sheet Number 1907 and 1932.
- At Pole line Road (Branch P_06), east of Mud Lake Rd, the updated model results show overtopping of Pole line Rd and one private crossing south of it. This area is shown in Map Sheet Number 1906.
- At Mud Lake Rd (Branch P_06), north of Pole line Rd, the updated model results show spill over two crossings of Mud Lake Rd over the Pennock creek. This area is shown in Map Sheet Number 1880.
- At McLean Rd (Branch P_06), north of intersection with Baxendale Dr, the updated model results show spill over McLean Rd. This area is shown in Map Sheet Number 1856.
- At Baxendale Dr (Branch P_06), the updated model results show spill over Baxendale Dr and a driveway off Baxendale Dr. Spilling over the Baxendale Dr. also causes impact on additional four driveways south of Baxendale Dr. This area is shown in Map Sheet Number 1856.
- East of intersection of Oliver Rd ((Branch P_06) and Baxendale Dr., the updated model results indicate flooding one dwelling and eight ancillary buildings. This area is shown in Map Sheet Number 1856 and 1857.

6.1 SPILL AREAS AND FLOOD VULNERABLE LOCATIONS

Spill areas in Pennock Creek, identified in the analysis, include the areas along Vibert Rd, Vibert Rd N, Hwy 130, private road north of Hwy 130 (east of intersection with Cooper Rd), and Baxendale Dr.

The largest spill area in Pennock Creek, identified in the analysis, is around the intersection of Hwy 11, Hwy 130 (Arthur Rd) and Vibert Rd. This area is shown in in Appendix M and Map Sheet 1960 and 1961. The model results show that during the Regional Storm, the creek (Reaches P_04 and T2_01) would overtop the left river banks and spill over Vibert Rd N. These flood water would then discharge to the Tributary T1_1.1, at location north of Hwy 11.The results also show that the creek (Reach P_02) would spill over Hwy 130 in direction from south to north. Another notable overtopping in this area, identified by the model results, is that Tributary T3_01 would overtop Vibert Rd (south of Hwy 11) then discharge to reach P_02. Overtopping in this area would cause flooding of Vibert Rd, Vibert Rd N, Hwy 130 and two private crossings.

In the same area, spills were also identified in the property of the Municipality of Oliver Paipoonge, as shown in Map 331. The analysis shows that the creek (Reaches T1_1.1 and T1_02) would overtop the road west of, and spills over to, this property. A review of the model results indicates that floodwaters will surround this building, but will not impact it since the building is located at higher land. Spills also appear to overtop of the driveway, north of the interception of Cooper Rd. and Hwy 130, flows into the open areas, and eventually discharge through the culvert at Hwy 130 and flow back to the river system. It is possible the spill will continue to the east further from the Hwy 130 culvert; however, the spill extent cannot be determined by this study.

Map 309 shows another notable spill, it discharges south to the open area as mentioned above. A review of the model results indicates that this spill will flow through the above discussed Hwy 130 culvert.

The model results also show spilling over Baxendale Dr at location west of Oliver Rd during the Regional Storm Flood, causing flooding of Baxendale Dr, driveway and private lot. This is shown in Map Sheet 1856.

A full list of areas with risk of flooding, not only for the Regional Storm but also for recurrent events is provided in Appendix A. The tables in that appendix show water depths, flow velocities and depth-velocity products obtained from the hydraulic model simulations. The tables highlight those areas where there could be potential risk to people and restrictions to access or egress, based on the criteria defined by LRCA. These criteria are based on MNR (2002) and consists of:

- flow depths in excess of 0.3 m,
- flow velocities in excess of 1.7 m/s, and
- depth velocity products in excess of 0.4 m2/s.

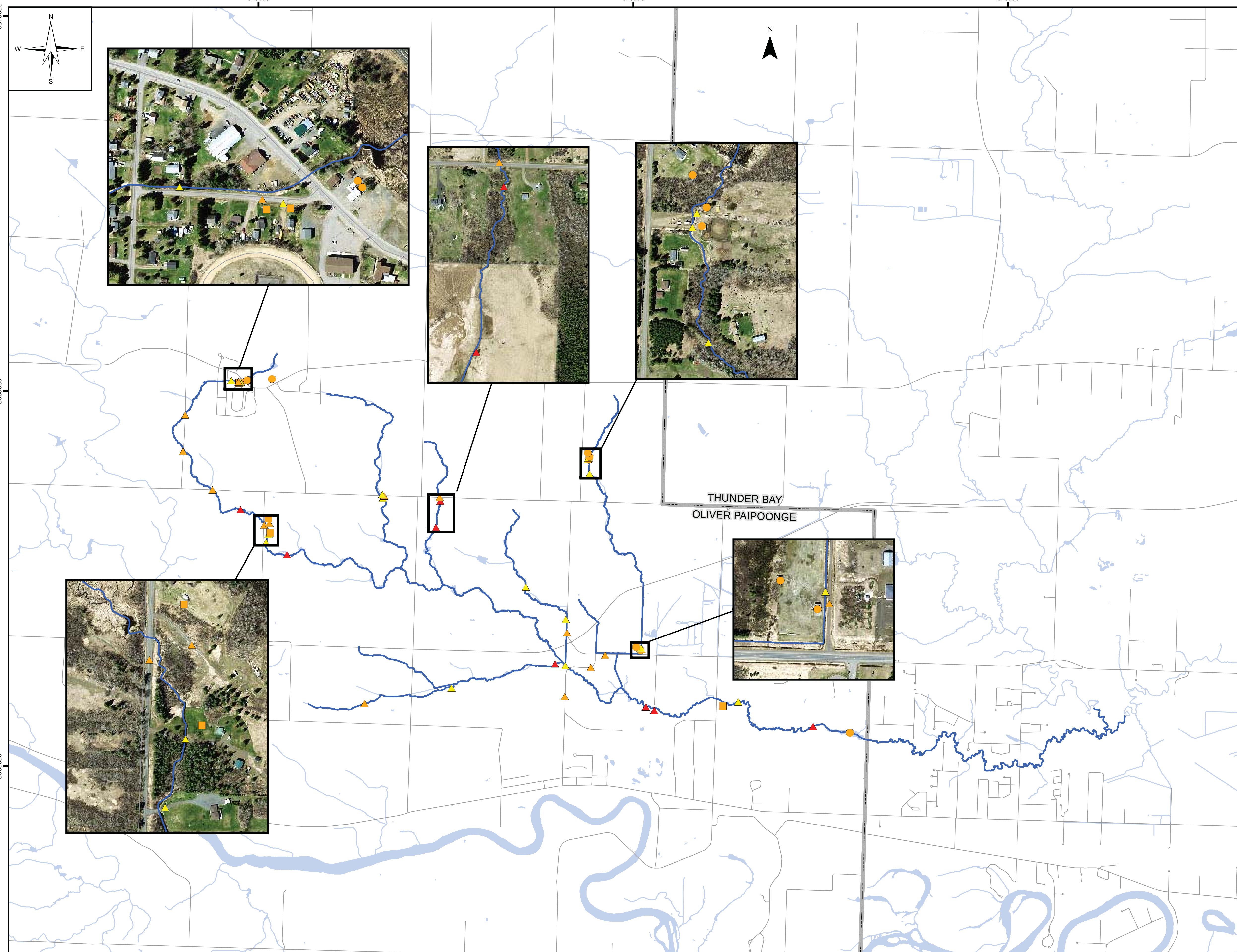
The features identified in Appendix A were classified in the following categories:

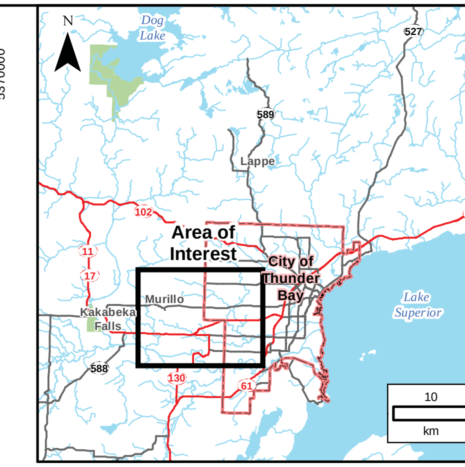
- Dwellings
- Ancillary buildings
- Lots
- Bridges/Culverts
- Roads
- Driveways

A summary of the number of affected infrastructures for all floods is provided in Table 6. The location of the features affected by the Regional Flood is summarized in Figure 2.

TABLE 6
QUANTITY OF FLOOD AFFECTED INFRASTRUCTURE FOR ALL FLOODS

		FLOOD MAGNITUDE						
		2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
QUANTITY OF AFFECTED INFRASTRUCTURE	Dwelling	0	0	0	0	0	0	0
	Ancillary Building	0	0	1	3	4	4	9
	Lot	0	1	1	1	1	2	5
	Bridge/Culvert	1	5	5	8	10	10	10
	Road	1	1	3	4	8	9	14
	Driveway	0	1	6	7	8	11	14





LEGEND:

- Dwellings
- Ancillary Building
- Bridge/Culvert
- Road
- Driveway
- Lots
- Pennock Creek & Tributaries
- Road
- Watercourse
- Waterbody
- Municipal/Township Boundary

NOTES:

1. Aerial Photography, dated 2017, was provided by Land Information Ontario (LIO) as part of the North West Ontario Orthophotography Project (NWOOP).

DRAFT

0.5 0 0.5 1 1.5 2

Kilometres

SCALE: 1:50,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 16 Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
B	20/03/12	ISSUED AND RE-ISSUED AS DRAFT	FC	MSW
A	20/01/15	ISSUED WITH DRAFT REPORT	FC	MSW

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

LAKEHEAD REGION CONSERVATION AUTHORITY

PENNOCK CREEK FLOODPLAIN MAPPING PROJECT GENERAL REPORT

AFFECTED INFRASTRUCTURE – REGIONAL STORM FLOOD

MARCH 2020 | FIGURE 02 | REV: B

FileName: P:\Projects\2018\18-3065-003\Dwg\GIS\MXDs\General_Report\RevB\18-3065-003_Fig02_RevB.mxd

11"x17" PLOT SCALE 1:1

7.0 SUMMARY AND CONCLUSIONS

7.1 PROJECT SUMMARY

KGS Group was retained by the LRCA to update the floodplain mapping for the Pennock Creek system. A summary of the project tasks and findings is provided below:

- New LiDAR, topographic and bathymetric data was obtained for the Pennock Creek watershed and used to prepare a Digital Elevation Model (DEM) of the study area, in the municipality of Oliver Paipoonge and City of Thunder Bay. This new data satisfied the criteria for accuracy and density that was established in the terms of reference for the study.
- The topographic data used in this study is referenced to the 6-degree Universal Transverse Mercator (UTM), North American Datum 1983 (NAD83CSRS) Zone 16 grid projection system and Canadian Geodetic Vertical Datum (CGVD28).
- A Regional Flood Frequency Analysis was carried out with formulas prepared in the McIntyre River and McVicar Creek Floodplain Mapping studies. Results from both formulas are similar. The slightly higher results obtained with the formulas from the McIntyre River study were adopted in this study.
- Storm hyetographs for return periods ranging from 2 to 100 years, developed using the most current IDF curves for Thunder Bay were used in this study to obtain corresponding flows from the hydrologic model. The hyetographs were prepared using a Chicago Storm distribution. The storms were developed for a 24-hour duration with a peak occurring at 1/3 of the storm duration (r = 0.33). The 2 to 100 years storms were not simulated in the 1982 study.
- The Regional Storm for the area is the Timmins Storm. Hyetographs for this storm were prepared for the Pennock Creek watershed using an area reduction factor of 84%. This factor was based on the equivalent circular area of the watershed in adherence with the Technical Guide (MNR, 2002).
- A new hydrologic model was developed and validated with Regional Flood Frequency Analysis for Pennock Creek.
- The flows obtained with the hydrologic model for the Regional (Timmins) Storm Flood, were significantly lower than those obtained in Dillon (1982) and previously used for floodplain mapping. The differences are likely attributed to the use of different hydrologic calculation approaches. The values used in this study are considered to better represent the response of the watershed, and are consistent with the peak flows obtained for the Neebing River in a previous floodplain mapping study (KGS, 2018).
- A new hydraulic model was prepared with the program HEC-RAS for the Pennock Creek system, including the tributaries in the system that drained areas larger than 125 ha.

- The hydraulic model was used to simulate the hydraulic conditions during the Regional Storm Flood and recurrent flood events with return periods ranging from 2 to 100 years.
- Recognizing the uncertainty associated to numerical modelling, sensitivity analyses were carried out to evaluate the effect of the Neebing River levels and the adopted roughness parameters. The results showed that the model results are largely independent of the assumptions made for these two parameters, within the range of values normally acceptable for the site conditions. The values adopted for the calibrated model are considered appropriate for the analysis to define flood hazard limits.
- Floodplain maps were developed for the Pennock Creek based on the model results obtained for the Regional Storm Flood.
- A review of the updated floodplain maps, using this study report, indicates that in most parts the updated results were generally consistent with those previously obtained by Dillon (1982). However, the extent of the flooding obtained in the present study was less extensive.
- A review of the hydraulic model results was carried out to evaluate flow depth, velocity and depth-velocity product at the locations of buildings and infrastructure. These were compared with the hazard criteria required by LRCA. The results are listed for each building and infrastructure located within the flood hazard limit, in Appendix A.

7.2 RECOMMENDATIONS

Based on the investigations and analyses completed for this project, KGS Group has the following recommendations:

- Adopt the updated Pennock Creek floodplain maps that show the flood hazard limits in accordance with provincial regulations and the fill lines to be used for administrative purposes.
- Evaluate the available monitoring system and program in place with respect to the need to provide timely and adequate information to agencies and the public in the event of a flood in the Pennock Creek watershed. This evaluation could include a review of the local sources, the means to obtain and process the information from developing weather and flow forecasts, the tools (models, maps, tables) to forecast flood levels associated with the expected flows by using the hydraulic model, and the system to disseminate warning and execute emergency response actions.
- The table of locations of flood vulnerable infrastructure provided in Appendix A can be used for the prioritization of potential improvements to crossings that provide limited conveyance. This can be carried out through a technical study with terms of reference that would be developed with the information obtained in this study.

8.0 REFERENCES

1. M.M. Dillon Limited, 1982, Pennock Creek Flood Plain and Fill Line Mapping.
2. USACE, 2016, Hydraulic Reference Manual.
3. OMNR, 2002, Technical Guide River & Stream Systems: Flooding Hazard Limit.
4. MTO, 1997, Drainage Management Manual
5. USDA, 1986, Urban Hydrology for Small Watersheds – Technical Release 55
6. KGS, 2018, Neebing River Floodplain Mapping Update – Final Hydrologic Report
7. KGS Group, 2019a, Pennock Creek and Kaministiquia Floodplain Mapping Update Study, LiDAR Project Report.
8. KGS Group, 2019b, Pennock Creek Floodplain Mapping Update Study, Hydrologic Report.
9. KGS Group, 2019c, Pennock Creek Floodplain Mapping Update Study, Hydraulic Report.
10. KGS Group, 2018, McVicar Creek Floodplain Mapping Update Study, Hydrologic Report.
11. Hatch Mott MacDonald, HMM, 2015, McIntyre River Floodplain Mapping Study – Final Hydrology Report

APPENDIX A

INFRASTRUCTURE LOCATED WITHIN THE FLOOD HAZARD LIMIT

Lakehead Region Conservation Authority
Pennock Creek Floodplain Mapping Update Study, 2020
Appendix A. Infrastructure Located Within the Flood Hazard Limit

Critical Flood Criteria: >0.3m, >1.7 m/s, depth × velocity > 0.4 m²/s

Shaded cells indicate infrastructure that exceeds Critical Flood Criteria (red font indicates exceeded parameter).

Flood Event	Flow at Confluence with Neebing River (m³/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m²/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
Regional Storm	52.41	Ancillary	NA	12	320090	5361571	0.68	0.02	0.02	Water through the lot, and overtop the road. An ancillary building within the flood zone.	331	T1_02_0.2811		Both
		Road	NA	13	320107	5361479	0.49	0.02	0.01	Road/Driveway is overtopped	331	T1_02_0.2811		Both
		Driveway	NA	14	320102	5360834	0.65	0.11	0.07	Culvert/Driveway is overtopped	331	T1_02_0.3441	C-029-T1_02	Both
		Ancillary	NA	15	320036	5361043	0.41	0.01	0.00	Water through the lot, part of the ancillary building is in the flood zone	331	T1_02_0.3741		Both
		Bridge/Culvert	NA	5	320276	5365119	0.73	0.35	0.26	Road/Driveway is overtopped	353	P_01_11.001	C-008-P_01	Right
		Bridge/Culvert	94 VIBERT RD	6	320165	5365116	0.66	0.55	0.37	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Bridge/Culvert	3139 ARTHUR ST	3	321394	5360855	0.72	1.37	0.99	Private Bridge/Culvert is overtopped	354	P_01_9.476	B-006-P_01	Both
		Lots	66 HIGHWAY 130	4	321194	5360800	0.25	0.00	0.00	Water through the lot, low areas are flooded, buildings are not in the flood zone	354	P_01_9.758		Both
		Ancillary	25TH SIDEROAD	1	322885	5360928	0.46	0.60	0.28	Facility/Ancillary building above the Thunder Lake is within the flood zone	355	P_01_7.018		
		Bridge/Culvert	25TH SIDEROAD	2	322393	5360529	0.58	1.13	0.66	Pedestrain bridge is overtopped	355	P_01_7.605	B-005-P_01	Both
		Road	MUD LAKE RD	42	313993	5364220	0.22	0.49	0.11	Mud Lake Rd is overtopped	1856	P_06_5.063	C-020-P_06	Both
		Driveway	15 BAXENDALE DR	45	314596	5360855	0.16	0.17	0.03	Driveway appears to be submerged by flood water	1856	P_06_6.595		Both
		Driveway	16 BAXENDALE DR	47	314635	5363215	0.32	1.55	0.49	Part of the driveway appears to be submerged by flood water	1856	P_06_6.632		Both
		Road	BAXENDALE DR	51	314733	5360800	0.04	1.90	0.07	Baxendale Dr. is overtopped	1856	P_06_6.729		Left
		Lots	3 BAXENDALE DR	52	314739	5361587	0.29	1.77	0.51	Water through the lot, buildings are not in the flood zone.	1856	P_06_6.732		Left
		Driveway	3 BAXENDALE DR	53	314758	5360529	0.11	1.38	0.16	Driveway appears to be submerged by flood water	1856	P_06_6.751		Left
		Lots	1052 BAXENDALE DR	54	314767	5360742	0.16	1.53	0.25	Water through the lot, buildings are not in the flood zone.	1856	P_06_6.751		Left
		Ancillary	4572 OLIVER RD	57	314848	5363238	0.06	0.03	0.00	Several ancillary buildings are in the flood zone	1856	P_06_6.85		Both
		Ancillary	4572 OLIVER RD	59	314853	5363111	0.06	0.00	0.00	Several ancillary buildings are in the flood zone	1856	P_06_6.85		Both
		Ancillary	4530 OLIVER RD	64	315174	5365123	0.14	0.04	0.01	An ancillary building in the flood zone	1857	P_06_7.194		Both
		Driveway	48 CENTRE ST	17	319389	5363618	0.08	0.79	0.06	Culvert/Driveway is overtopped	1886	T1_02_3.718	C-035-T1_02	Left
		Ancillary	332 DAWSON ST	18	319405	5364111	0.16	0.18	0.03	Water through the lot, part of the ancillary building is in the flood zone	1886	T1_02_3.721		Left
		Driveway	332 DAWSON ST	19	319396	5363603	0.15	0.17	0.02	Culvert/Driveway is overtopped	1886	T1_02_3.742	C-036-T1_02	Both
		Ancillary	332 DAWSON ST	20	319413	5364087	0.24	0.46	0.11	Water through the lot, the ancillary building is in the flood zone	1886	T1_02_3.746		Both
		Ancillary	68 CENTRE ST	21	319390	5363898	0.16	0.06	0.01	An ancillary building , at rear of the property lot, is in the flood zone	1886	T1_02_3.821		Right
		Bridge/Culvert	653 POLELINE RD	40	314758	5363422	0.46	1.49	0.68	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both

Flood Event	Flow at Confluence with Neebing River (m³/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m²/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
		Road	88 MUD LAKE RD	43	314019	5364699	0.29	0.34	0.10	Mud Lake Rd is overtopped	1906	P_06_5.691	C-021-P_06	Both
		Driveway	186 WING RD	35	315131	5363184	0.22	0.88	0.19	Part of the driveway appears to be submerged by flood water	1907	P_06_2.879	C-016-P_06	Both
		Lots	186 WING RD	36	315157	5365141	0.94	0.50	0.48	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Road	WING RD	37	315073	5363215	0.25	0.54	0.14	Wing Rd is overtopped	1907	P_06_3.081	C-017-P_06	Both
		Road	202 WING RD	38	315141	5363535	0.51	0.90	0.46	A side road of a private property appears to be submerged	1907	P_06_3.005		Left
		Lots	208 WING RD	39	315128	5361336	0.17	0.01	0.00	Water spill to the lot. Building is not in the flood zone	1907	P_06_3.058		Both
		Road	POLELINE RD	31	316676	5363603	0.30	0.21	0.06	Poleline Rd overtopped	1908	T5_01_1.463	C-051-T5_01	Left
		Driveway	460 POLELINE RD	32	316650	5363618	0.02	0.08	0.00	Water spills over left river bank and overtops the private driveway.	1908	T5_01_1.464		Left
		Road	POLELINE RD	41	314386	5363681	0.24	0.34	0.08	Poline Rd is overtopped	1908	P_06_4.228	C-019-P_06	Both
		Bridge/Culvert	394 FRASER RD	27	317366	5363184	0.31	0.38	0.12	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Bridge/Culvert	NA	28	317425	5363535	0.23	1.63	0.37	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Driveway	459 POLELINE RD	30	316659	5363574	0.24	0.61	0.15	Culvert/Driveway is overtopped	1909	T5_01_1.41	C-050-T5_01	Both
		Driveway	40 CENTRE ST	16	319415	5361318	0.14	0.98	0.14	Culvert/Driveway is overtopped	1911	T1_02_3.495	C-034-T1_02	Both
		Bridge/Culvert	589 POLELINE RD	33	315377	5364194	0.15	0.32	0.05	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Driveway	174 WING RD	34	315098	5363422	0.51	0.21	0.11	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	3432 11/17 HWY	24	318563	5362389	0.23	0.77	0.18	Private crossing is overtopped	1935	T2_01_1.478	C-060-T2_01	Both
		Road	NA	26	316412	5360834	0.21	0.06	0.01	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both
		Bridge/Culvert	NA	10	318951	5363681	0.20	0.02	0.00	Culvert is overtopped	1960	T3_01_0.103	C-040-T3_01	Both
		Road	VIBERT RD RAMP	7	319429	5361318	0.89	0.48	0.43	Road overtopped	1961	P_03_0.086		Left
		Driveway	NA	8	319091	5363574	0.08	0.08	0.01	Driveway is overtopped	1961	P_02_1.289		Both
		Road	HIGHWAY 130	11	319620	5361479	0.11	0.23	0.03	Road overtopped	1961	T1_01_0.498	C-027-T1_01	Both
		Road	VIBERT RD N	22	319113	5364681	0.10	0.12	0.01	Vibiert Rd N is overtopped	1961	T2_01_0.1901		Both
		Driveway	221 VIBERT RD	23	319096	5365132	0.03	0.14	0.00	Culvert/Driveway is overtopped	1961	T2_01_0.484	C-038-T2_01	Left
		Driveway	NA	25	317573	5361043	0.36	0.18	0.06	Culvert/Driveway is overtopped	1961	T3_02_0.088	C-057-T3_02	Both
		Road	POLELINE RD	29	317415	5363586	0.05	0.17	0.01	Poline Rd is overtopped	1983	T4_01_1.467	C-047-T4_01	Both
		Road	VIBERT RD	9	319085	5363586	0.22	0.08	0.02	Vibiert Rd is overtopped	1986	P_02_1.289	C-011-P_02	Both

Lakehead Region Conservation Authority
Pennock Creek Floodplain Mapping Update Study, 2020
Appendix A. Infrastructure Located Within the Flood Hazard Limit

Critical Flood Criteria: >0.3m, >1.7 m/s, depth × velocity > 0.4 m²/s

Shaded cells indicate infrastructure that exceeds Critical Flood Criteria (red font indicates exceeded parameter).

Flood Event	Flow at Confluence with Neebing River (m^3/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m^2/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
100 YR	34.14	Ancillary	NA	12	320090	5361571	0.64	0.02	0.01	Water through the lot, and overtop the road. An ancillary building within the flood zone.	331	T1_02_0.2811		Both
		Road	NA	13	320107	5361479	0.44	0.01	0.01	Road/Driveway is overtopped	331	T1_02_0.2811		Both
		Driveway	NA	14	320102	5360834	0.61	0.08	0.05	Culvert/Driveway is overtopped	331	T1_02_0.3441	C-029-T1_02	Both
		Bridge/Culvert	NA	5	320276	5365119	0.38	0.02	0.01	Road/Driveway is overtopped	353	P_01_11.001	C-008-P_01	Right
		Bridge/Culvert	94 VIBERT RD	6	320165	5365116	0.47	0.51	0.24	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Bridge/Culvert	3139 ARTHUR ST	3	321394	5360855	0.56	1.53	0.86	Private Bridge/Culvert is overtopped	354	P_01_9.476	B-006-P_01	Both
		Bridge/Culvert	25TH SIDEROAD	2	322393	5360529	0.31	0.89	0.28	Pedestrain bridge is overtopped	355	P_01_7.605	B-005-P_01	Both
		Driveway	16 BAXENDALE DR	47	314635	5363215	0.10	1.28	0.12	Part of the driveway appears to be submerged by flood water	1856	P_06_6.632		Both
		Driveway	48 CENTRE ST	17	319389	5363618	0.12	0.96	0.12	Culvert/Driveway is overtopped	1886	T1_02_3.718	C-035-T1_02	Left
		Ancillary	332 DAWSON ST	18	319405	5364111	0.05	0.11	0.01	Water through the lot, part of the ancillary building is in the flood zone	1886	T1_02_3.721		Left
		Driveway	332 DAWSON ST	19	319396	5363603	0.07	0.14	0.01	Culvert/Driveway is overtopped	1886	T1_02_3.742	C-036-T1_02	Both
		Ancillary	332 DAWSON ST	20	319413	5364087	0.17	0.35	0.06	Water through the lot, the ancillary building is in the flood zone	1886	T1_02_3.746		Both
		Ancillary	68 CENTRE ST	21	319390	5363898	0.08	0.04	0.00	An ancillary building , at rear of the property lot, is in the flood zone	1886	T1_02_3.821		Right
		Bridge/Culvert	653 POLELINE RD	40	314758	5363422	0.34	1.52	0.52	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Road	88 MUD LAKE RD	43	314019	5364699	0.14	0.37	0.05	Mud Lake Rd is overtopped	1906	P_06_5.691	C-021-P_06	Both
		Driveway	186 WING RD	35	315131	5363184	0.18	0.99	0.18	Part of the driveway appears to be submerged by flood water	1907	P_06_2.879	C-016-P_06	Both
		Lots	186 WING RD	36	315157	5365141	0.86	0.38	0.33	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Road	202 WING RD	38	315141	5363535	0.41	0.75	0.31	A side road of a private property appears to be submerged	1907	P_06_3.005		Left
		Lots	208 WING RD	39	315128	5361336	0.02	0.01	0.00	Water spill to the lot. Building is not in the flood zone	1907	P_06_3.058		Both
		Road	POLELINE RD	41	314386	5363681	0.13	0.25	0.03	Poline Rd is overtopped	1908	P_06_4.228	C-019-P_06	Both
		Bridge/Culvert	394 FRASER RD	27	317366	5363184	0.06	0.57	0.03	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Bridge/Culvert	NA	28	317425	5363535	0.17	1.51	0.26	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Driveway	459 POLELINE RD	30	316659	5363574	0.16	0.44	0.07	Culvert/Driveway is overtopped	1909	T5_01_1.41	C-050-T5_01	Both
		Driveway	40 CENTRE ST	16	319415	5361318	0.04	0.30	0.01	Culvert/Driveway is overtopped	1911	T1_02_3.495	C-034-T1_02	Both
		Bridge/Culvert	589 POLELINE RD	33	315377	5364194	0.11	0.23	0.03	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Driveway	174 WING RD	34	315098	5363422	0.35	0.14	0.05	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	3432 11/17 HWY	24	318563	5362389	0.18	0.65	0.12	Private crossing is overtopped	1935	T2_01_1.478	C-060-T2_01	Both
		Road	NA	26	316412	5360834	0.17	0.04	0.01	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both
		Bridge/Culvert	NA	10	318951	5363681	0.12	0.02	0.00	Culvert is overtopped	1960	T3_01_0.103	C-040-T3_01	Both
		Road	VIBERT RD RAMP	7	319429	5361318	0.24	0.38	0.09	Road overtopped	1961	P_03_0.086		Left
		Driveway	NA	8	319091	5363574	0.01	0.06	0.00	Driveway is overtopped	1961	P_02_1.289		Both
		Road	HIGHWAY 130	11	319620	5361479	0.07	0.17	0.01	Road overtopped	1961	T1_01_0.498	C-027-T1_01	Both
		Road	VIBERT RD N	22	319113	5364681	0.04	0.08	0.00	Vibiert Rd N is overtopped	1961	T2_01_0.1901		Both
		Driveway	221 VIBERT RD	23	319096	5365132	0.02	0.10	0.00	Culvert/Driveway is overtopped	1961	T2_01_0.484	C-038-T2_01	Left
		Driveway	NA	25	317573	5361043	0.15	0.11	0.02	Culvert/Driveway is overtopped	1961	T3_02_0.088	C-057-T3_02	Both
		Road	VIBERT RD	9	319085	5363586	0.15	0.06	0.01	Vibiert Rd is overtopped	1986	P_02_1.289	C-011-P_02	Both

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Appendix A. Infrastructure Located Within the Flood Hazard Limit

Critical Flood Criteria: >0.3m, >1.7 m/s, depth × velocity > 0.4 m²/s

Shaded cells indicate infrastructure that exceeds Critical Flood Criteria (red font indicates exceeded parameter).

Return Period	Flow at Confluence with Neebing River (m³/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m²/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
50 Year	29.53	Ancillary	NA	12	320090	5361571	0.61	0.01	0.01	Water through the lot, and overtop the road. An ancillary building within the flood zone.	331	T1_02_0.2811		Both
		Road	NA	13	320107	5361479	0.41	0.01	0.00	Road/Driveway is overtopped	331	T1_02_0.2811		Both
		Driveway	NA	14	320102	5360834	0.58	0.08	0.05	Culvert/Driveway is overtopped	331	T1_02_0.3441	C-029-T1_02	Both
		Bridge/Culvert	NA	5	320276	5365119	0.26	0.02	0.00	Road/Driveway is overtopped	353	P_01_11.001	C-008-P_01	Right
		Bridge/Culvert	94 VIBERT RD	6	320165	5365116	0.41	0.49	0.20	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Bridge/Culvert	3139 ARTHUR ST	3	321394	5360855	0.11	1.18	0.13	Private Bridge/Culvert is overtopped	354	P_01_9.476	B-006-P_01	Both
		Bridge/Culvert	25TH SIDEROAD	2	322393	5360529	0.19	0.81	0.15	Pedestrain bridge is overtopped	355	P_01_7.605	B-005-P_01	Both
		Driveway	48 CENTRE ST	17	319389	5363618	0.10	0.86	0.09	Culvert/Driveway is overtopped	1886	T1_02_3.718	C-035-T1_02	Left
		Ancillary	332 DAWSON ST	18	319405	5364111	0.02	0.10	0.00	Water through the lot, part of the ancillary building is in the flood zone	1886	T1_02_3.721		Left
		Driveway	332 DAWSON ST	19	319396	5363603	0.16	0.15	0.02	Culvert/Driveway is overtopped	1886	T1_02_3.742	C-036-T1_02	Both
		Ancillary	332 DAWSON ST	20	319413	5364087	0.16	0.30	0.05	Water through the lot, the ancillary building is in the flood zone	1886	T1_02_3.746		Both
		Ancillary	68 CENTRE ST	21	319390	5363898	0.07	0.03	0.00	An ancillary building , at rear of the property lot, is in the flood zone	1886	T1_02_3.821		Right
		Bridge/Culvert	653 POLELINE RD	40	314758	5363422	0.29	1.47	0.42	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Road	88 MUD LAKE RD	43	314019	5364699	0.04	0.38	0.02	Mud Lake Rd is overtopped	1906	P_06_5.691	C-021-P_06	Both
		Driveway	186 WING RD	35	315131	5363184	0.11	0.93	0.10	Part of the driveway appears to be submerged by flood water	1907	P_06_2.879	C-016-P_06	Both
		Lots	186 WING RD	36	315157	5365141	0.79	0.35	0.27	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Road	202 WING RD	38	315141	5363535	0.34	0.78	0.26	A side road of a private property appears to be submerged	1907	P_06_3.005		Left
		Road	POLELINE RD	41	314386	5363681	0.05	0.22	0.01	Poline Rd is overtopped	1908	P_06_4.228	C-019-P_06	Both
		Bridge/Culvert	394 FRASER RD	27	317366	5363184	0.15	0.43	0.06	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Bridge/Culvert	NA	28	317425	5363535	0.15	1.44	0.22	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Driveway	459 POLELINE RD	30	316659	5363574	0.14	0.39	0.05	Culvert/Driveway is overtopped	1909	T5_01_1.41	C-050-T5_01	Both
		Bridge/Culvert	589 POLELINE RD	33	315377	5364194	0.10	0.20	0.02	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Driveway	174 WING RD	34	315098	5363422	0.37	0.12	0.04	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	3432 11/17 HWY	24	318563	5362389	0.17	0.58	0.10	Private crossing is overtopped	1935	T2_01_1.478	C-060-T2_01	Both
		Road	NA	26	316412	5360834	0.15	0.03	0.00	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both
		Bridge/Culvert	NA	10	318951	5363681	0.10	0.02	0.00	Culvert is overtopped	1960	T3_01_0.103	C-040-T3_01	Both
		Road	VIBERT RD RAMP	7	319429	5361318	0.23	0.33	0.08	Road overtopped	1961	P_03_0.086		Both
		Road	HIGHWAY 130	11	319620	5361479	0.04	0.16	0.01	Road overtopped	1961	T1_01_0.498	C-027-T1_01	Both
		Driveway	221 VIBERT RD	23	319096	5365132	0.14	0.15	0.02	Culvert/Driveway is overtopped	1961	T2_01_0.484	C-038-T2_01	Left
		Driveway	NA	25	317573	5361043	0.08	0.13	0.01	Culvert/Driveway is overtopped	1961	T3_02_0.088	C-057-T3_02	Both
		Road	VIBERT RD	9	319085	5363586	0.13	0.05	0.01	Vibiert Rd is overtopped	1986	P_02_1.289	C-011-P_02	Both

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Appendix A. Infrastructure Located Within the Flood Hazard Limit

Critical Flood Criteria: >0.3m, >1.7 m/s, depth × velocity > 0.4 m^2/s

Shaded cells indicate infrastructure that exceeds Critical Flood Criteria (red font indicates exceeded parameter).

Return Period	Flow at Confluence with Neebing River (m^3/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m^2/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
25 Year	24.9	Driveway	NA	14	320102	5360833.5	0.47	0.00	0.00	Culvert/Driveway is overtopped	331	T1_02_0.3441	C-029-T1_02	Both
		Bridge/Culvert	94 VIBERT RD	6	320165	5365115.9	0.33	0.49	0.16	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Bridge/Culvert	NA	5	320276	5365119	0.14	0.02	0.00	Road/Driveway is overtopped	353	P_01_11.001	C-008-P_01	Right
		Bridge/Culvert	3139 ARTHUR ST	3	321394	5360854.5	0.10	1.01	0.10	Private Bridge/Culvert is overtopped	354	P_01_9.476	B-006-P_01	Both
		Bridge/Culvert	25TH SIDEROAD	2	322393	5360529.1	0.05	0.73	0.04	Pedestrain bridge is overtopped	355	P_01_7.605	B-005-P_01	Both
		Ancillary	68 CENTRE ST	21	319390	5363897.9	0.03	0.02	0.00	An ancillary building , at rear of the property lot, is in the flood zone	1886	T1_02_3.821		Right
		Ancillary	332 DAWSON ST	18	319405	5364111.1	0.05	0.08	0.00	Water through the lot, part of the ancillary building is in the flood zone	1886	T1_02_3.721		Left
		Ancillary	332 DAWSON ST	20	319413	5364087.4	0.12	0.28	0.03	Water through the lot, the ancillary building is in the flood zone	1886	T1_02_3.746		Both
		Driveway	332 DAWSON ST	19	319396	5363602.8	0.12	0.13	0.02	Culvert/Driveway is overtopped	1886	T1_02_3.742	C-036-T1_02	Both
		Driveway	48 CENTRE ST	17	319389	5363617.8	0.07	0.77	0.05	Culvert/Driveway is overtopped	1886	T1_02_3.718	C-035-T1_02	Left
		Bridge/Culvert	653 POLELINE RD	40	314758	5363421.7	0.26	1.42	0.37	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Road	202 WING RD	38	315141	5363535	0.25	0.86	0.22	A side road of a private property appears to be submerged	1907	P_06_3.005		Left
		Driveway	186 WING RD	35	315131	5363183.5	0.04	0.85	0.03	Part of the driveway appears to be submerged by flood water	1907	P_06_2.879	C-016-P_06	Both
		Lots	186 WING RD	36	315157	5365141.2	0.71	0.32	0.23	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Bridge/Culvert	NA	28	317425	5363535	0.13	1.35	0.18	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Bridge/Culvert	394 FRASER RD	27	317366	5363183.5	0.13	0.41	0.05	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Driveway	459 POLELINE RD	30	316659	5363574.1	0.12	0.33	0.04	Culvert/Driveway is overtopped	1909	T5_01_1.41	C-050-T5_01	Both
		Driveway	174 WING RD	34	315098	5363421.7	0.28	0.11	0.03	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	589 POLELINE RD	33	315377	5364193.8	0.09	0.18	0.02	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Road	NA	26	316412	5360833.5	0.13	0.05	0.01	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both
		Driveway	221 VIBERT RD	23	319096	5365132.2	0.13	0.13	0.02	Culvert/Driveway is overtopped	1961	T2_01_0.484	C-038-T2_01	Left
		Road	VIBERT RD RAMP	7	319429	5361318.1	0.21	0.30	0.06	Road overtopped	1961	P_03_0.086		Both
		Road	VIBERT RD	9	319085	5363585.7	0.11	0.02	0.00	Vibiert Rd is overtopped	1986	P_02_1.289	C-011-P_02	Both

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Return Period	Flow at Confluence with Neebing River (m³/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m²/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
10 Year	19.01	Driveway	NA	14	320102	5360834	0.10	0.12	0.01	Culvert/Driveway is overtopped	331	T1_02_0.3441	C-029-T1_02	Both
		Bridge/Culvert	94 VIBERT RD	6	320165	5365116	0.19	0.51	0.10	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Ancillary	332 DAWSON ST	20	319413	5364087	0.08	0.23	0.02	Water through the lot, the ancillary building is in the flood zone	1886	T1_02_3.746		Both
		Driveway	332 DAWSON ST	19	319396	5363603	0.09	0.33	0.03	Culvert/Driveway is overtopped	1886	T1_02_3.742	C-036-T1_02	Both
		Driveway	48 CENTRE ST	17	319389	5363618	0.02	0.65	0.01	Culvert/Driveway is overtopped	1886	T1_02_3.718	C-035-T1_02	Left
		Bridge/Culvert	653 POLELINE RD	39	314758	5363422	0.20	1.29	0.26	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Road	202 WING RD	37	315141	5363535	0.04	1.17	0.05	A side road of a private property appears to be submerged	1907	P_06_3.005		Left
		Lots	186 WING RD	35	315157	5365141	0.39	0.37	0.15	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Bridge/Culvert	NA	27	317425	5363535	0.10	1.23	0.12	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Bridge/Culvert	394 FRASER RD	26	317366	5363184	0.10	0.35	0.04	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Driveway	459 POLELINE RD	29	316659	5363574	0.05	0.28	0.01	Culvert/Driveway is overtopped	1909	T5_01_1.41	C-050-T5_01	Both
		Driveway	174 WING RD	33	315098	5363422	0.17	0.11	0.02	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	589 POLELINE RD	32	315377	5364194	0.07	0.14	0.01	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Road	NA	25	316412	5360834	0.11	0.04	0.00	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both
		Driveway	221 VIBERT RD	23	319096	5365132	0.07	0.02	0.00	Culvert/Driveway is overtopped	1961	T2_01_0.484	C-038-T2_01	Left
		Road	VIBERT RD S	9	319085	5363586	0.08	0.04	0.00	Vibiert Rd is overtopped	1986	P_02_1.289	C-011-P_02	Both

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Return Period	Confluence with Neebing River (m^3/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m^2/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
5 Year	14.35	Bridge/Culvert	94 VIBERT RD	6	320165	5365116	0.03	0.62	0.02	Culvert/Driveway is overtopped	353	P_01_11.129	B-009-P_01	Both
		Bridge/Culvert	653 POLELINE RD	39	314758	5363422	0.15	0.73	0.11	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Lots	186 WING RD	35	315157	5365141	0.08	0.53	0.04	Water through the lot, low areas are flooded, buildings are not in the flood zone	1907	P_06_2.886		Both
		Bridge/Culvert	NA	27	317425	5363535	0.07	0.45	0.03	Pedestrain bridge is overtopped	1909	T4_01_1.401	B-046-T4_01	Both
		Bridge/Culvert	394 FRASER RD	26	317366	5363184	0.07	0.40	0.03	Culvert/Driveway is overtopped	1909	T4_01_1.009	C-045-T4_01	Both
		Driveway	174 WING RD	33	315098	5363422	0.09	0.09	0.01	Driveway appears to be submerged by flood water	1932	P_06_2.751	C-015-P_06	Both
		Bridge/Culvert	589 POLELINE RD	32	315377	5364194	0.05	0.11	0.01	Culvert is overtopped	1932	P_06_2.31	C-014-P_06	Both
		Road	NA	25	316412	5360834	0.08	0.03	0.00	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both

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Critical Flood Criteria: >0.3m, >1.7 m/s, depth × velocity > 0.4 m^2/s

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Return Period	Flow at Confluence with Neebing River (m^3/s)	Structure Type	Address	Structure ID	UTM		Depth (m)	Velocity (m/s)	Depth × Velocity (m^2/s)	Comments	Map Sheet	HEC-RAS Model Station	HEC-RAS Structure ID	Bank
2 Year	8.16	Bridge/Culvert	653 POLELINE RD	39	314758	5363422	0.08	0.77	0.06	Pedestrain bridge overtopped	1906	P_06_3.534	B-018-P_06	Both
		Road	NA	25	316412	5360834	0.04	0.01	0.00	Culvert/Driveway is overtopped	1959	T3_02_1.372	C-044-T3_02	Both