Flood and Ice Damage Study:
Evaluation of 1970 and 2000 Rule Curves

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Executive Summary

The flood and ice damage project was undertaken to compare the relative flood and ice impacts associated with the 1970 and 2000 rule curves used for managing the water levels of Rainy Lake and the Namakan chain of lakes. To support the project, a geospatial database was developed that identified vulnerabilities along the Rainy Lake and Namakan chain of lakes shoreline including various building, boathouse, and dock structures as observed in various air photos and other data sources. A series of property owner site visits were undertaken in 2013 to gather input and perspectives on flood and ice damage vulnerabilities and an additional online survey was undertaken in 2014 in response to observed high water conditions. The information from both those surveys along with other shoreline photographs and elevation measurements was used to characterize the critical shoreline vulnerabilities and the expected impacts under various water level conditions. An Excel based Flood Tool was developed that calculated flood damages to lived-in and non-lived-in buildings, docks, and boathouses on an annual basis based on water level inundation. Potential ice impacts were considered using separate water level metrics.

Using the Flood Tool with simulated 1970 and 2000 rule curve water levels, results were compared for the 1950 to 2014 period. On an average annual basis, estimated high water impacts (count of structures impacted) through the study area increased by 5.5, 2.4, 2.6 and 0.7 percent for lived-in, non-lived-in, boathouse, and dock structures respectively (1.2 percent collectively) with the 2000 rule curves. Economic damages increased anywhere from 2.2 percent for docks to 5.5 percent for lived-in buildings for the system as a whole (2.7 percent collectively). The general response of a slight increase in impacts under the 2000 rule curves was consistent with the International Rainy Lake Board of Control report (1999) outlining potential changes to the 1970 rule curves.

Docks were most commonly impacted and generally represented the largest portion of the damages based on the current modelling approach which was consistent with the 2013 and 2014 property owner surveys. Non-lived-in buildings represented an important component of the number of structures impacted but a much smaller component of the economic damage estimates due to the generally low replacement costs associated with such structures. Lived-in buildings represented a relatively small proportion of the number of structures flooded within the existing simulations but were generally of high value and therefore were the second highest contributor to the overall damages on an average annual basis. The net changes of the 2000

rule curve results as a percent of the 1970 rule curve results tended to be greater for the Namakan chain of lakes, although the average annual impacts were about four times greater on Rainy Lake due to the greater number of structures that could potentially be impacted (i.e., higher amount of development).

The Flood Tool and associated input databases were developed with the anticipation that updates would be made in the future as new information becomes available. For example, alternative water management scenarios could be easily input into the database and results generated. The input database can also be readily updated as new information becomes available. If improved elevation data becomes available for portions of the Canadian shoreline, the database can be updated and the Flood Tool re-run to look at the differences.

The ice impact component of the project was less conclusive, and further work should be considered to improve that component of the analysis before there can be high confidence in the ability to compare rule curve performance regarding ice impacts.

As with all simulation tools, there were assumptions, limitations and uncertainties associated with the existing Flood Tool and analysis. Based on the current study, the following recommendations have been identified for future consideration as a means to improve the overall analysis and enhance the understanding of flood and ice vulnerability within the Rainy Lake and Namakan chain of lakes study area:

1. Acquire better elevation estimates of structures on the Canadian shoreline and update database appropriately, with focus on priority vulnerable structures as identified through the 2013 Environment Canada photos.
2. Improve understanding of the vulnerability of shoreline structures from ice under variable water level conditions.
3. Develop a complementary tool to include flood vulnerability for the Rainy River downstream of the Rainy Lake outlet.
4. Use updated elevation datum offsets to validate offsets used in the project, and make adjustments to database as necessary based on the results.
5. Review stage-damage functions used to estimate inundation damages for individual structures.
6. Incorporate a component associated with wave energy to the overall impact assessment.

7. Maintain and refine geospatial database as new information on structure vulnerability becomes available. For example, better classification of structure types as they relate to available stage-damage curves would improve the database and the application of the tool.
8. Evaluate the benefit of adding additional metrics of flood impact (e.g., flooding of roads, etc.) to the Flood Tool.

Acknowledgements: *Thanks to all individuals and teams that contributed to the completion of the project. Staff from Kenora Resource Consulting undertook the property owner surveys and Baird & Associates developed the spreadsheet Flood Tool. Boat based photographic surveys were done by staff from Environment Canada's Technical Operations group and oblique photographs were contributed by Lee Grim and the Ontario Ministry of Natural Resources and Forestry. Daniel Ferreira and David Stevenson contributed to the data analysis, as did Coop students Rachael Schulhauser, Devin Upper, and Cameron Curran. Thanks also to three anonymous reviewers on earlier aspects of the project report as well as Dr. Wayne Jenkinson (IJC) and Dr. Syed Moin (external) for their review of the final report and thoughtful suggestions.*

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1 Introduction

Rainy Lake and the Namakan chain of Lakes (i.e., Namakan Lake, Kabetogama Lake, Sand Point Lake, Little Vermilion Lake, and Crane Lake) are located along the Canada and US border in northwestern Ontario and northern Minnesota (Figure 1-1). Water levels on both lakes are managed throughout the year by the dam operators with the intent of maintaining water level conditions within a defined operational range for each lake. The International Joint Commission (IJC) provides the overall direction for the operation of the dams via orders and directives and the Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board provides operational guidance and direction to the dam operators, particularly when water level conditions are expected to be outside of the defined operational range. The water level objectives reflect seasonal variations in inflows to the system and outflow capacity resulting in targets that vary for each quarter-month of the year and in some cases, within the quarter-month. The water level objectives are also intended to support key management needs including the maintenance of important ecosystem and socio-economic outcomes within the system. Collectively, the upper and lower water level targets along with the operational guidance for specific scenarios are known as rule curves. Between 1970 and 2000, water levels were managed using the "1970" rule curves. Following a series of studies and evaluation, the updated "2000" rule curves were implemented in 2001 and remain in operation.

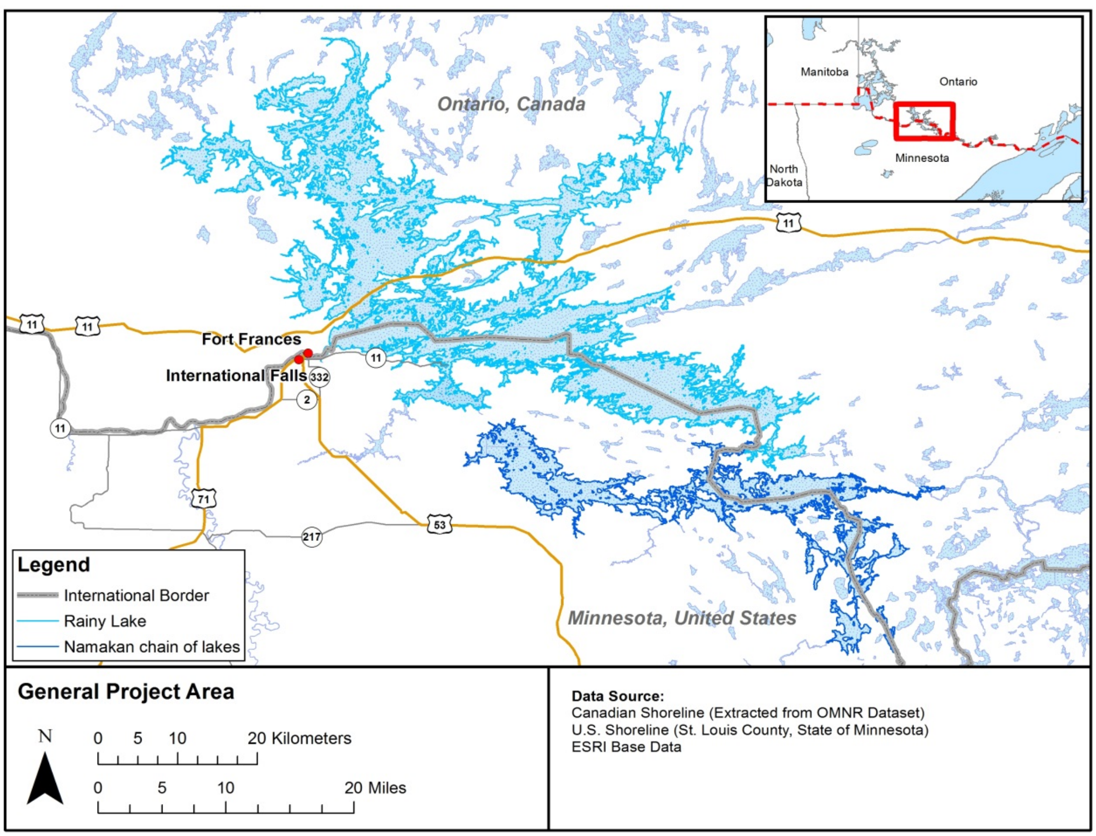


Figure 1-1: General project area including Rainy Lake and the Namakan chain of lakes

One outcome of water level management in the Rainy and Namakan system is the adaptation over time of shoreline development in response to expected water level conditions. Water levels cannot be maintained within the rule curves under all hydrologic conditions as high inflows can exceed the maximum outflow capacity of both Rainy and Namakan lakes. However, alternative water level management strategies can influence the timing and magnitude of the peak flood elevation during any given year.

Prior to the adoption of the 2000 rule curves, a series of studies were undertaken to evaluate the overall performance of the 1970 rule curves and to consider alternative management targets that could yield incremental outcome improvements for the system for a range of objectives. One such study looked at potential flood damages in the system and the impact that alternative rule curves had on associated damages (IRLBC 1999). The overall conclusion from the flood damage study was that compared to the baseline condition (the 1970 rule curves), the evaluated alternatives resulted in relatively small increases in flood levels and did not significantly increase flood risk (IRLBC 1999).

The IRLBC (1999) flooding study relied on previously developed stage-damage assessments as the economic basis for impact analysis and rule curve comparison. In anticipation of an evaluation of the performance of the 2000 rule curves to be undertaken starting in 2015, a series of studies were initiated over the past number of years to gather data and information necessary for a robust evaluation process. This study expanded on previous efforts to characterize stage-damage relationships in the region and looked at the relative performance of the 1970 and 2000 rule curves with regards to flooding damages to shoreline development, essentially damages to the built environment along the shoreline of Rainy Lake and the Namakan chain of lakes. The most recent project focused on developing information necessary to compare damages between 1970 and 2000 rule curve water levels based on historical hydrological conditions between 1950 and present. The project design emphasized the need to establish a baseline data set that could be used to compare the performance of the 1970 and 2000 rule curves while establishing a framework that would allow for updating, adjustments and the evaluation of alternative management scenarios and hydrological conditions that may become available at some point in the future. As such, the project emphasized baseline database development and the creation of a simple flood impact evaluation tool that would be available moving forward. Specifically, the project was designed to:

- Establish a geospatial database for the Rainy/Namakan Lake system with a classification of shoreline activities as they relate to flooding and ice damage vulnerabilities to allow a general estimation of overall economic impacts.

- Undertake field verification for representative focus sites to verify flooding and ice damage vulnerabilities (e.g., elevation) and update geospatial database accordingly.
- Develop stage-damage functions of potential flooding and ice impacts for the Rainy/Namakan Lake system.
- Utilize stage-damage functions to estimate potential differences in overall flooding and ice impacts between the 1970 and 2000 rule curves.
- Provide a data storage framework in the form of the attributed geospatial database that can be maintained and updated in the future to incorporate new information on vulnerabilities.

This document describes the project methods and compares flood damages under the 1970 and 2000 rule curves using the stage-damage curves and geospatial database. A brief discussion is also included regarding potential differences in ice impacts between the 1970 and 2000 rule curves. Project limitations, evaluation uncertainty, and opportunities for future modifications and improvements to the evaluation tool are also briefly outlined.

2 Project Design

The methodology for the flooding assessment was designed to address four primary areas including:

- the development of a geospatial database to establish baseline characteristics of the Rainy Lake and Namakan chain of lakes shoreline;
- field surveys of select focus areas within the study area to verify flooding and ice vulnerabilities;
- development of stage-damage functions to estimate impacts associated with various water levels; and
- evaluation of potential 1970 and 2000 rule curve impacts using a spreadsheet tool.

The unexpected high water conditions in 2014 provided an opportunity to validate the methodology developed above, and the scope of the project was expanded to include:

- collection and qualitative analysis of oblique shoreline imagery taken during the high water period; and
- an online property owner survey to identify particular types and extent of damages.

Figure 2-1 provides a general schematic of key steps in the project. Initial work included data scoping, preliminary database development, and vulnerability screening. That information was used to prepare for and undertake the 2013 field surveys. Following the field surveys, additional attribute information was added to the geospatial database. The refinement of the geospatial database was an iterative process. New data sets beyond those obtained in the 2013 field surveys were also used to update the database during this period. This included the follow-up activities to the 2014 flood event (identified in Green in Figure 2-1). The 2014 activities were outside those originally identified in the project scope but supported validation and verification of the project activities.

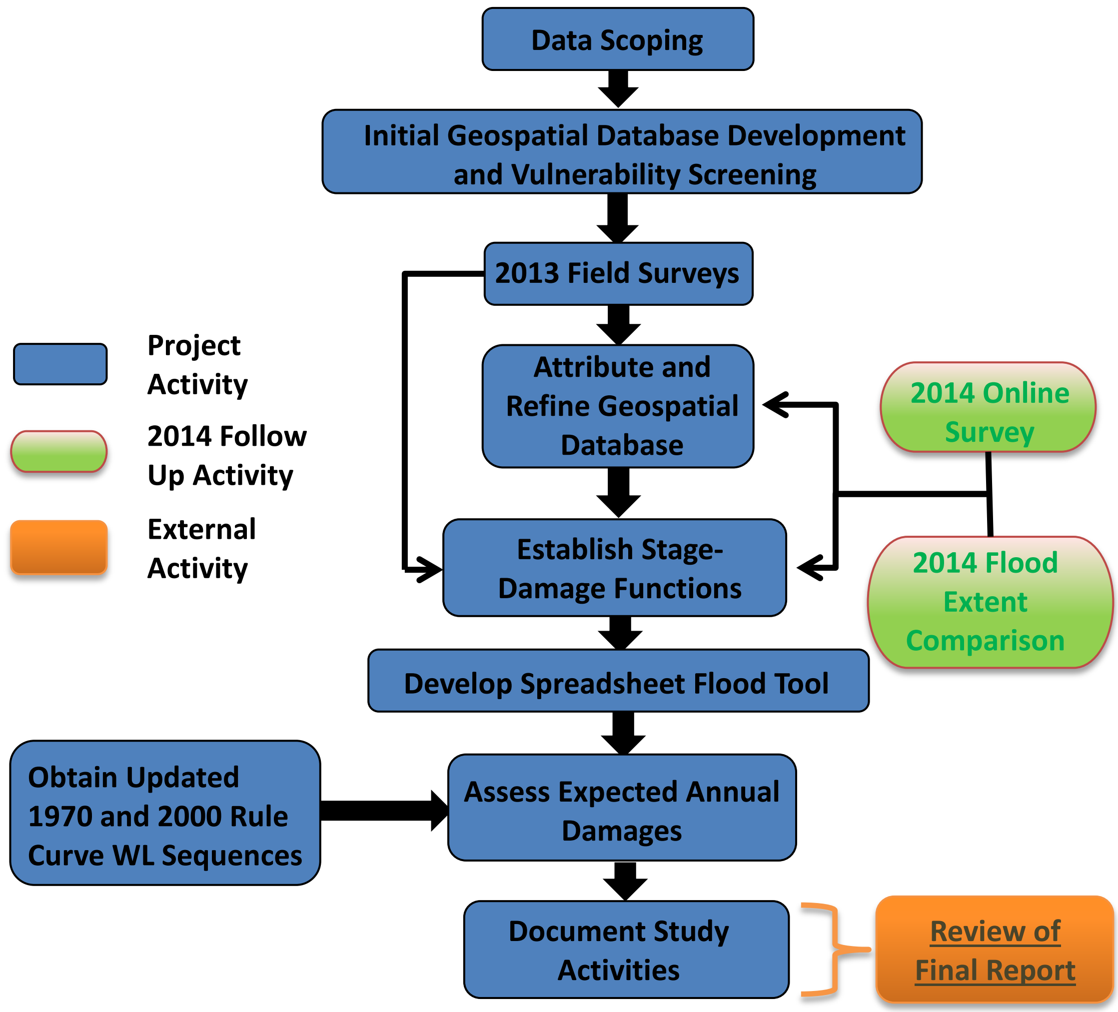


Figure 2-1: General overview schematic of key steps in the flood project

In addition to refinement of the geospatial database, the survey data was used help establish relevant stage-damage functions. The collective information was then used to develop the spreadsheet Flood Tool. The Tool along with previously modelled water level scenarios by Thompson (2014) and recently updated in January 2016 were then used to assess expected annual damages. The results of the expected annual damage analysis were reviewed by external reviewers.

The following sub-sections briefly describe the various activities undertaken to establish the baseline shoreline characteristics and obtain information necessary to develop the evaluation tool.

2.1 Data scoping

There was a high degree of variability in the availability, quality, and accuracy of geospatial data relevant to the flood damage project. Data was available from a variety of sources (local, state, federal, private) and while there was overlap in areas directly adjacent to the Canada/United States border within the study area, there were rarely data sets of interest that covered the entire study area. As a result, the initial data scoping effort largely focused on tracking down available data for critical themes relevant to the development of flood impact curves. Within each theme, attempts were made to find the "best available" data source. Since full coverage was rarely available, this generally meant identifying multiple coverage layers for each theme, such that collectively they provided coverage for as much of the study area as possible. Licensing requirements varied by dataset ranging from general user license agreements for base state and provincial datasets to specific and negotiated user license agreements for private datasets or datasets with limited distribution (e.g., parcel dataset available for St. Louis County Minnesota).

Initial themes of relevance to the flood and ice damage assessment were identified to support the data search effort. They included shoreline delineation, elevation, imagery (ortho, oblique, on-water, etc.), parcels, and footprints of shoreline development structures. Other base data layers were also considered (e.g., roads, parks, etc.). Various federal, state (Minnesota) and provincial (Ontario), and county base data holdings were identified through online interfaces with associated search engines and metadata records. In some cases the base data holdings were available for download directly from the supporting organization. For the flood and ice damage project, data of interest was generally found at the state/provincial or local level. Various data holdings were searched for datasets relevant to each theme including:

- Land Information Ontario (LIO) (http://www.mnr.gov.on.ca/en/Business/LIO/2ColumnSubPage/STEL02_167955.html)
- Minnesota Geographic Information Clearinghouse (which includes state acquired LiDAR data) (http://www.mngeo.state.mn.us/chouse/data.html)
- St. Louis County (http://www.stlouiscountymn.gov/LANDPROPERTY/Maps.aspx)

Local county and provincial management agencies working with relevant local GIS data were contacted via email including:

- Fort Frances District of the Ontario Ministry of Natural Resources (Andy Chepil)
- St. Louis County GIS (Lea Bergwall)

- Koochiching County GIS (Quinn Mccarthy)
- Minnesota Department of Natural Resources (LiDAR) (Tim Loesch)
- Koochiching County surveying (Matt Gouin)
- Voyageurs National Park (John Snyder)

In addition, efforts were made to coordinate with a few of the relevant project leads for other rule curve evaluation projects to see whether they identified or uncovered other data sources that might be relevant to the flood damage study. Primarily these were other project leads within Environment Canada and included:

- Hydrologic and Hydraulic modelling efforts (Aaron Thompson and Dave Stevenson of Environment Canada)
- Bird studies (Paul Watton of Environment Canada)
- Ecohydraulic Modelling (Jean Morin of Environment Canada)

Finally, relevant data maintained by private companies either for their own uses or under agreement with certain public agencies was reviewed. These generally required purchase and/or special data use agreements. In some cases, these data sets were originally identified for use in other projects (e.g., the hydrologic modelling) and were subsequently considered for use in the flood damage study. These included:

- Lake Master – Johnson Outdoors (bathymetric contours) – originally acquired to support the hydrologic and hydraulic modelling efforts
- Ontario parcel outlines – Teranet – purchased using flood damage project funds
- Ontario assessment information (Municipal Property Assessment Corporation (MPAC))

2.2 Initial geospatial database development and vulnerability screening

Following the data scoping, work focused on the development of a geospatial database for shoreline development on Rainy Lake and the Namakan chain of lakes shoreline upstream of the dam at Fort Frances/International Falls on the Rainy River. Figure 2-2 illustrates the general study area. Primary interest was identifying shoreline structures that might be sensitive to high water conditions including low elevation buildings, docks, and boathouses (collectively referred to as structures throughout this document). Due to variations in the timing of the availability of individual datasets, there was overlap in some of these stages and the database development was an iterative process. The following sub-section outlines the initial database development, which included structure presence/absence and did not consider specific characteristics such as elevation or value.

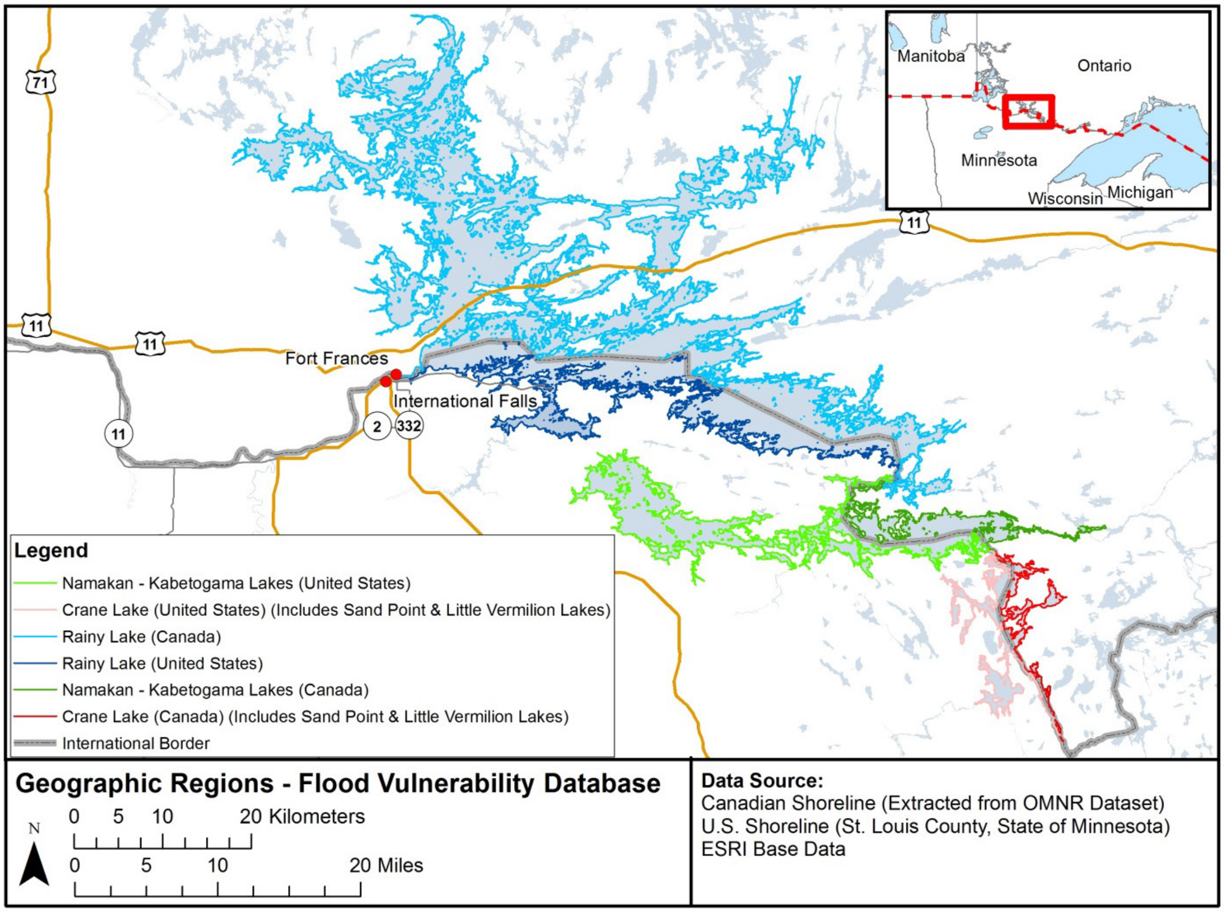


Figure 2-2: Coverage area of study showing Canadian and US portions of 1) Rainy Lake, 2) Namakan and Kabetogama Lakes, and 3) Crane, Sand Point, and Little Vermilion Lakes

2.2.1 Structure digitization

The geospatial database was created using "heads-up" digitizing, a manual digitization process for capturing on-screen structures of interest, based on available air photo and elevation data. The process involved using air photo imagery as a base layer, visually identifying structures from the imagery and then manually creating polygon structure outlines for the structure footprint. Figure 2-3 illustrates an example of structure identification and digitization for the Kabetogama Lake shoreline.

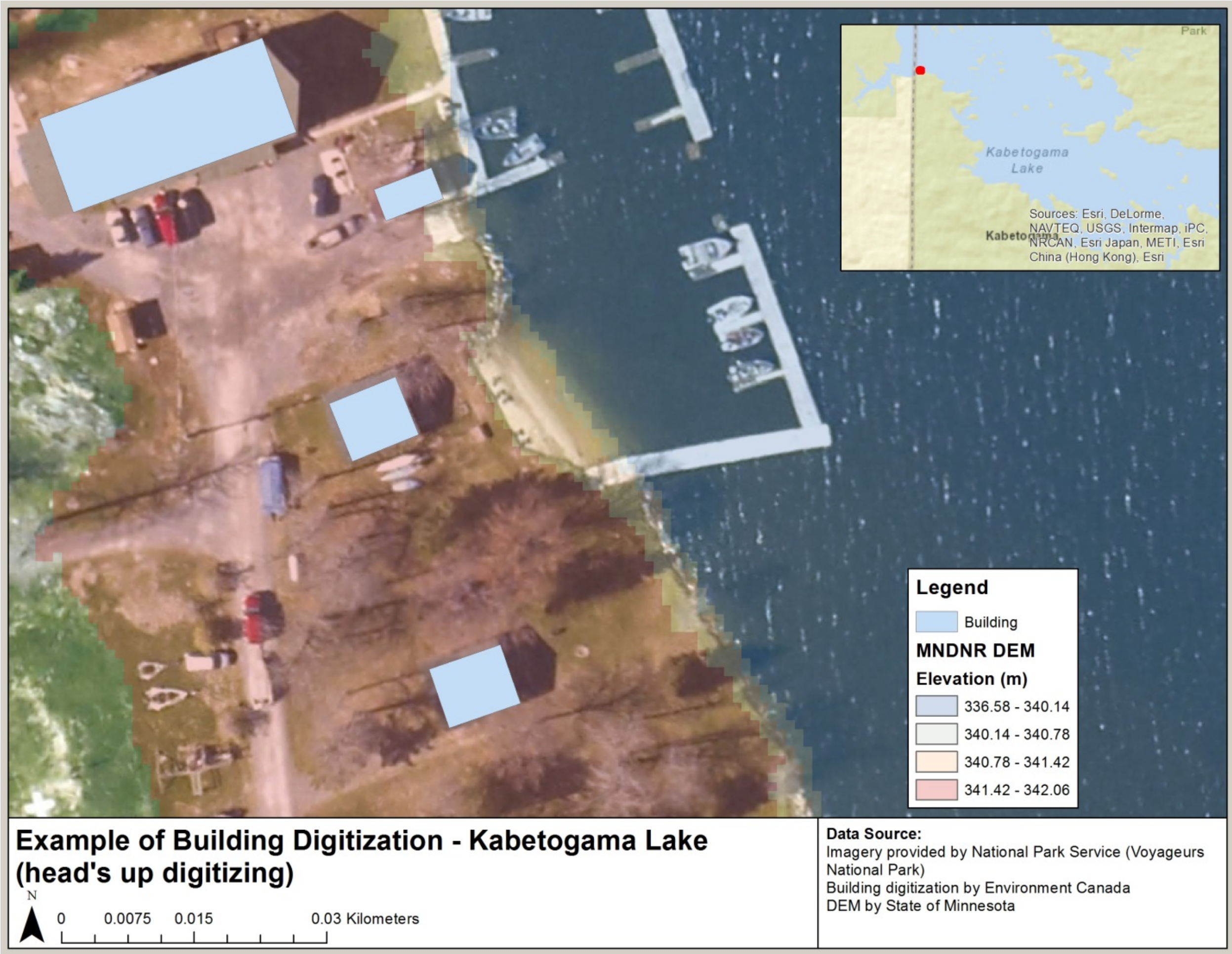


Figure 2-3: Example of base air photo and building structure footprint outline for a portion of the Kabetogama Lake shoreline

The availability and quality of the air photo and elevation data used in the digitization process varied widely across the study area which in turn impacted the database characteristics. On the US shoreline, much of the study area had good quality (i.e., high resolution) air photos and Light Detection and Ranging (LiDAR) derived Digital Elevation Models (DEMs). On the Canadian shoreline, small portions of the study area close to the US border benefited from similar datasets. Figure 2-4 illustrates the coverage area for the high resolution elevation datasets. There were four primary DEM sources including RedRiver, Arrowhead, Central, and NPS. The RedRiver, Arrowhead, and Central DEMs were all made available through the State of Minnesota LiDAR distribution website. The names represent the different acquisition campaigns and it is important to distinguish them as the data collection and processing methods varied slightly between the campaigns. As well, each campaign was undertaken during different years (see DEM metadata available on the State of the Minnesota website for specific details (http://www.mngeo.state.mn.us/chouse/elevation/lidar.html)). The NPS DEM was provided through the US National Park Service and covers a portion of Kabetogama Lake within the study area. Table 2-1 summarizes some of the critical characteristics for the LiDAR datasets. Note that the US National Park Service dataset for Kabetogama Lake was only available for use in the project in 2013. As a result, the geospatial database structures were initially digitized using the State of Minnesota datasets. Areas covered by the US National Park Service dataset were later updated when that elevation and imagery data became available.

Where the LiDAR elevation data was available, it was utilized to screen potentially vulnerable areas and focus the digitization effort. In general, the peak 1950 water level elevations on each lake were identified from the dataset developed by Thompson (2014) and utilized as the minimum upper screening bound. The elevations were 339.21 m USC&GS 1912 on Rainy Lake and 342.19 m USC&GS 1912 on the Namakan chain of lakes. On the Canadian shoreline where LiDAR data was not available, the older contour dataset and elevation contour of 340 m GSC was used as a broad screening elevation, recognizing that the horizontal precision is +/- 10 m and the vertical reliability is +/- 5 m (see metadata link: https://www.javacoeapp.lrc.gov.on.ca/geonetwork/srv/en/pdf?id=655).

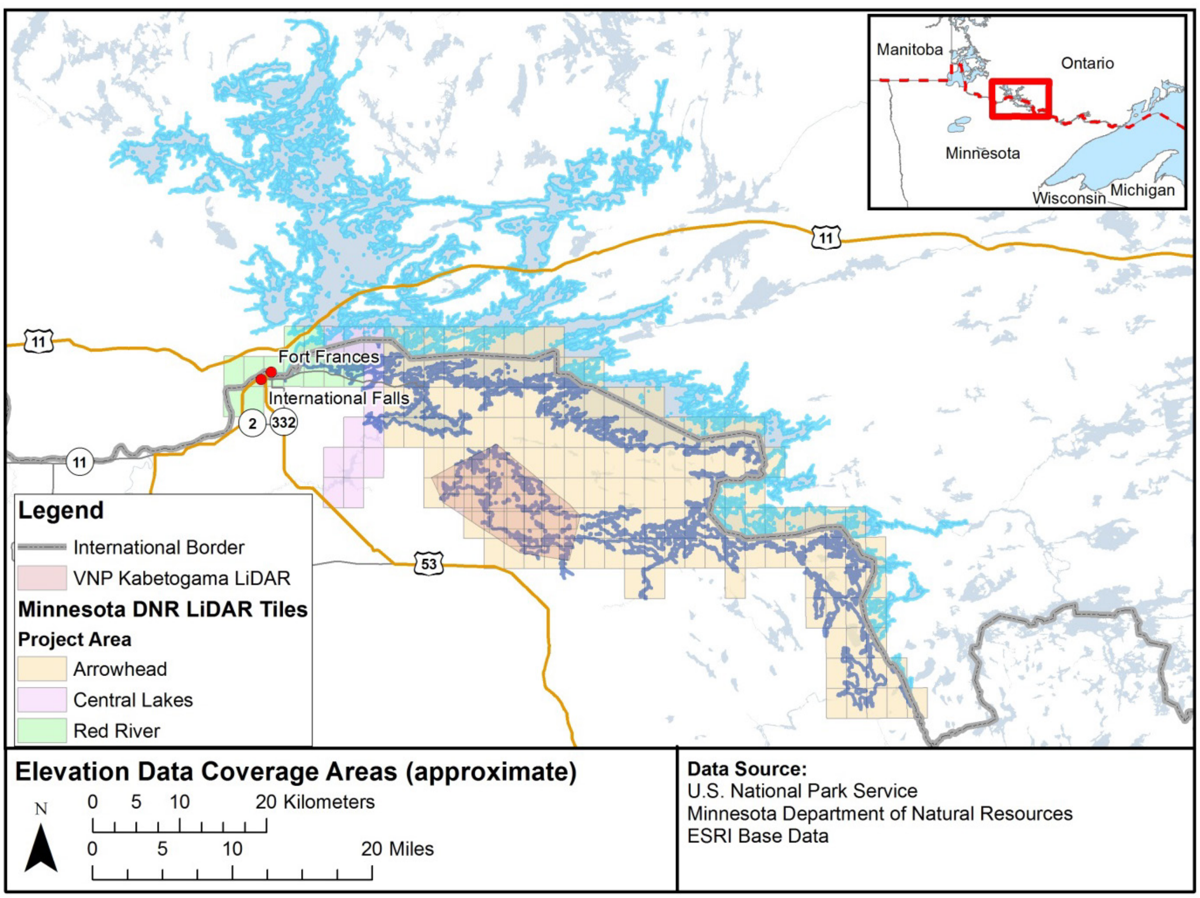


Figure 2-4: Coverage areas for various LiDAR elevation data used in the project

Name	Source	Description	RMSE – Vertical Accuracy	Flight Dates
VNP Kabetogama LiDAR	US National Park Service	The US National Park Service contracted WSI to acquire topographic and bathymetric LiDAR data for a portion of Kabetogama Lake	0.019 m	October 27 and 28, 2012
Arrowhead	State of Minnesota	Data was acquired by Woolpert, Inc. for the State of Minnesota for the Minnesota Elevation Mapping Project	Between 0.05 and 0.15 m	May 24-26, 2011
Central Lakes	State of Minnesota	Data was acquired by Woolpert, Inc. for the State of Minnesota for the Minnesota Elevation Mapping Project	Between 0.05 and 0.11 m	April 2012
Red River	State of Minnesota	LiDAR data was collected by the International Water Institute and processed by the State of Minnesota.	0.15 m	May 17-30, 2009

Table 2-1: Summary information regarding various LiDAR data used in the project

Coverage areas for the orthoimagery data are outlined in Figure 2-5 and associated details are summarized in Table 2-2. Structure identification varied greatly between the different imagery datasets due to image resolution, quality, and the timing of the acquisition (e.g., leaf-on vs. leaf-off timing and the ability to see structures). For the purposes of the structure digitization, the 2008 VNP dataset was found to be the most easily interpreted. As a result, that was the priority dataset where it existed. The secondary dataset was the Minnesota dataset and it was utilized where the 2008 VNP did not have coverage (particularly the area close to Ranier and International Falls on the US shoreline). Where neither of those imagery datasets had coverage, the FRI dataset was utilized. As with the elevation data, the US National Park Service dataset for Kabetogama Lake acquired in 2012 and available in 2013 was not available for the initial database development. Areas covered by that imagery dataset were then updated prior to the finalization of the database and creation of the flood damage tool. Where subsequent data such as on-the-ground photographs became available after the initial digitization effort, the structures were updated with the newer and higher resolution data prior to the finalization of the database.

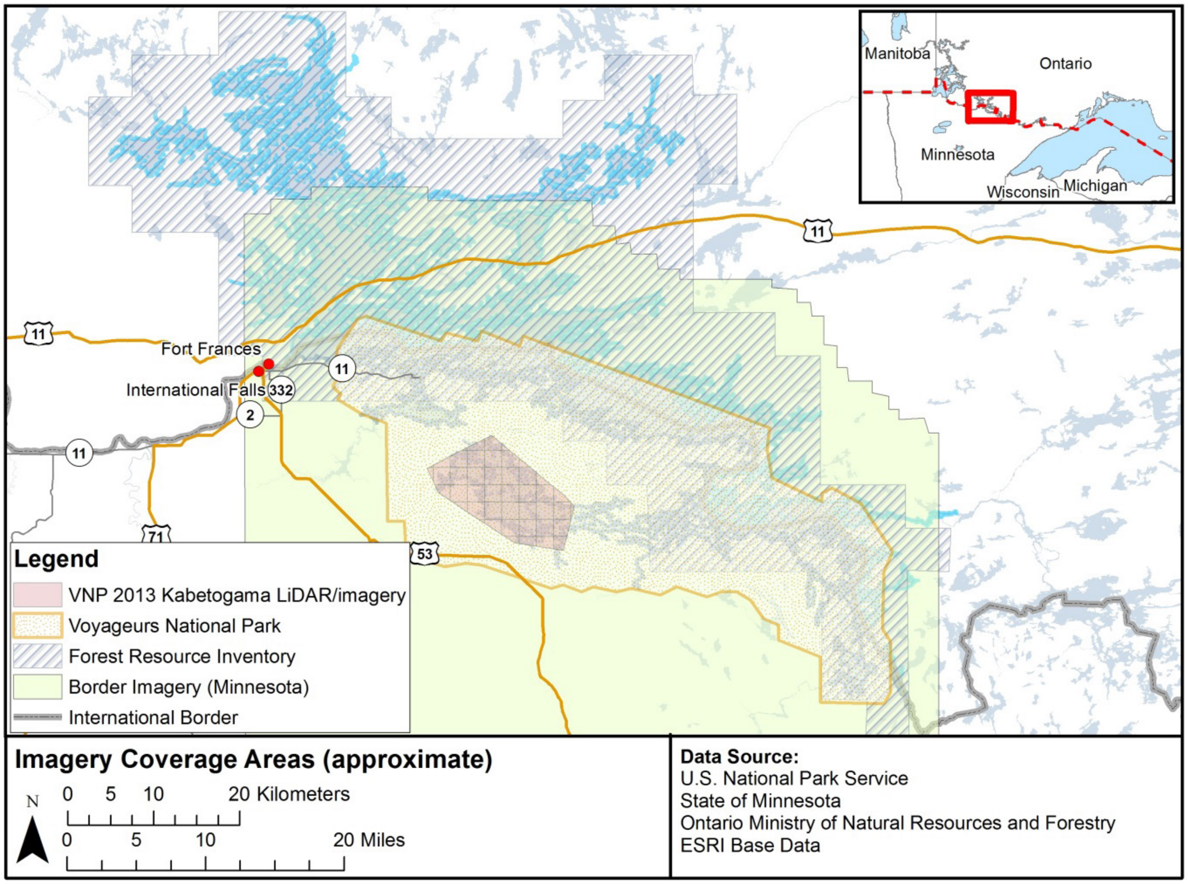


Figure 2-5: Coverage areas for various imagery data used in the project

Source	Description	Horizontal Resolution	Date Obtained	Scale for Digitizing
Forest Resource Inventory (FRI)	Infrared imagery taken during leaf-on period	Horizontal: Precise +/- 1 metre X,Y and Vertical: Precise +/- 1 metre Z	Full provincial FRI dataset obtained June to September in 2006 to 2010	1:750
Border Area Imagery	Leaf-on true colour imagery covering all US shoreline and portion of Canadian shoreline	0.3 m pixel resolution with design accuracy estimated not to exceed 6 m horizontal RMSE for locations within the US	data collected in 2009/4/14	1:500
NPS – Voyageurs	true colour	0.15 meter pixel	Spring 2008	1:500

National Park	imagery covering the National Park	RGB (true color) imagery flown at 6,000' AGL.		
NPS – 2013 Kabetogama imagery	Imagery (RBG) acquired during LiDAR campaign	0.30 m RMSE	October 27 and 28, 2012	1:500

Table 2-2: Summary information regarding various imagery data used in the project

2.3 2013 Field survey – flooding and ice damage

2.3.1 Field surveys

A series of field data acquisition activities were undertaken as part of the project to gather further information on the nature and extent of flood vulnerability within the study area and to further refine the geospatial database. The primary initial data collection activity was a series of site visits with shoreline property owners within the study area in August to October 2013. Due to limitations in available resources relative to the size of the study area, an initial screening was undertaken using dock density along the shoreline to help identify priority areas that should be investigated during the field visits with areas of high dock density indicating more intensive shoreline development. Dock density was identified separately for the US and Canadian shoreline by dividing the shoreline into 5 km intervals with a point feature generated at those locations within ArcGIS. For each point feature, a 2 km buffer was created around the location and all the identified (digitized) docks from that side of the shoreline (i.e., Canadian docks for Canadian shoreline and US docks for US shoreline) were counted within each buffer area. The density of dock structures was categorized as high (>57), medium (19-56), or low (<18) density using the “Natural Breaks” data classification method in ArcGIS 10.1 and mapped for both the Canadian and US shoreline. While the analysis was done separately for both Canadian and US shoreline, the results are shown collectively in (Figure 2-6). From this process, a series of priority areas were identified for further data collection and site visits.

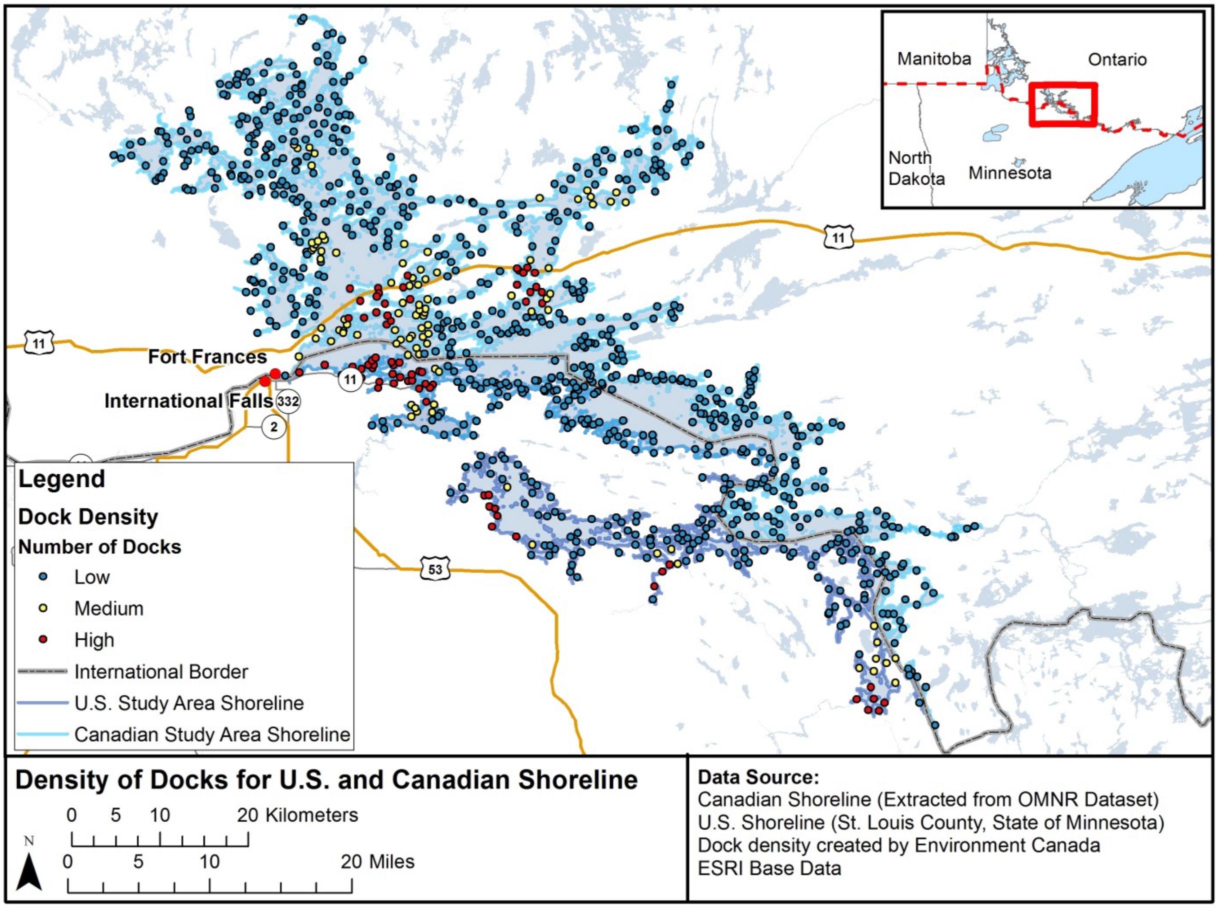


Figure 2-6: Dock density for Canadian and US shoreline of study area

Kenora Resource Consultants (KRC) was retained to plan and carry out the field surveys in each of the priority areas. In total, 131 field surveys were completed in the various priority areas (Figure 2-7). The choice of actual properties visited in each of the priority areas was limited by availability of residents during the time of the survey. Road access was the primary means of access in all areas. In the Bear Pass, the Ash River, and Crane Lake areas, a few properties were also accessed by boat.

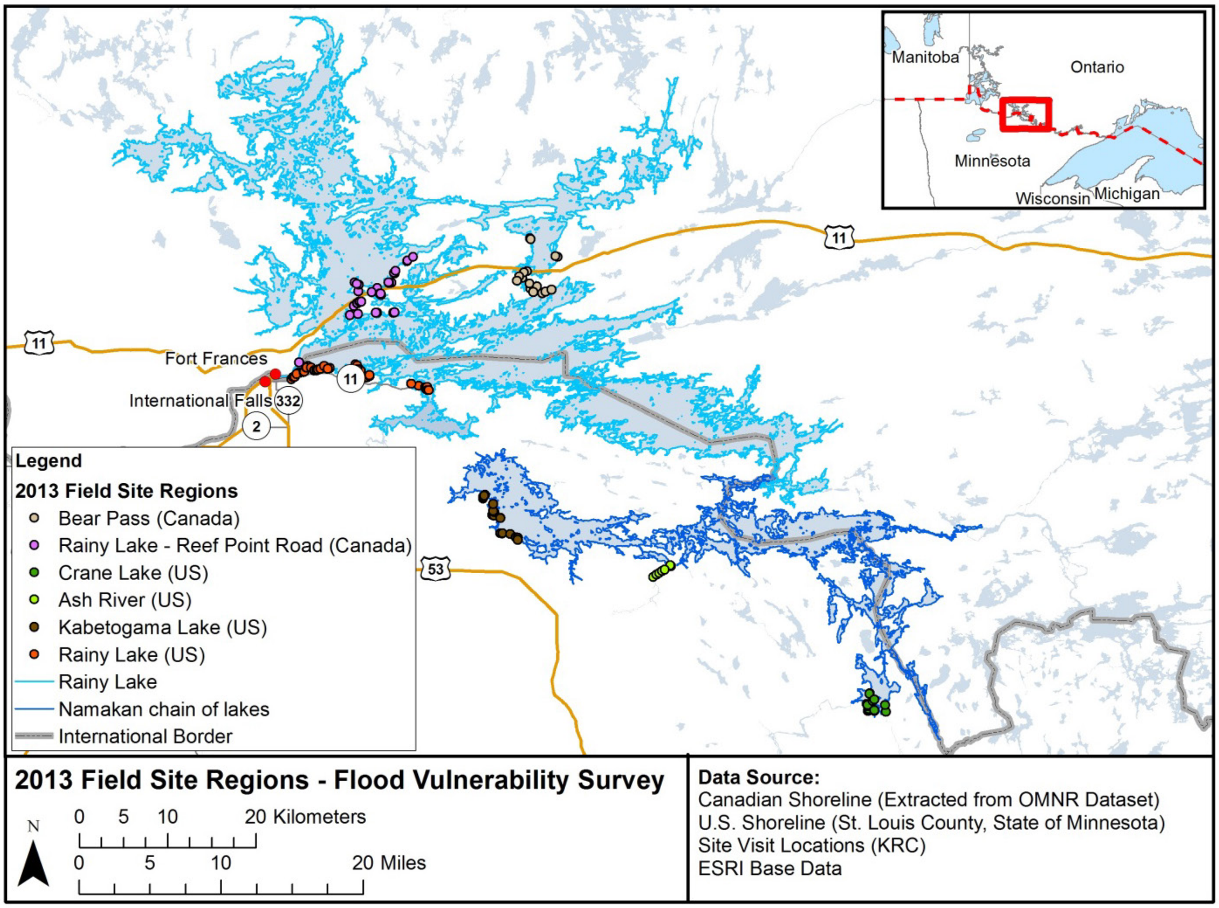


Figure 2-7: Location of 2013 site visits, by priority region

There were two components to the field surveys. The first was to obtain structure specific elevation values for docks, boathouses, and other buildings at each of the sites for use in verifying elevation information within the geospatial database. The second component was to seek information and feedback from shoreline property owners on their perspectives related to high water and ice conditions and the potential impacts for their properties such as the types of impacts and the associated costs to build into the development of the flood evaluation model.

2.3.1.1Elevation measurements

For the elevation component, KRC applied two different sets of GPS equipment. KRC initially visited 17 properties during a preliminary four day methodology testing period. The GPS equipment utilized for the field test was a GNSS enabled Trimble ProXRT receiver, with an Omnistar G2 subscription, and Zypher 2 antenna. Real-time vertical accuracy was measured using Trimble's TerraSync software. The GPS equipment used for the preliminary field test did not meet the study standards in terms of vertical accuracy for use in the flood study. Further testing indicated that the GPS value was on average 36 cm less than the water level offset method with a standard deviation of 18 cm. As well, the equipment took much too long to obtain a signal and the measurements were not consistent with the hand measurements of the dock surface. For the remainder of the site visits, a Trimble RTK system comprised of a base station, antennae booster, and rover setup was used to improve both the response time and the vertical and horizontal accuracy of the measurements. The changes were made to improve the overall study results. While it was recognized that these changes would result in some inconsistencies between the results from the preliminary field testing and the remainder of the survey results, it was considered important to make the changes to improve the overall confidence in the observations.

Local benchmarks were utilized each day to determine a unit offset on that particular day. The KRC report (included as Appendix A in this document) outlined the benchmarks used each day and the field site IDs that applied to those different benchmarks. However, the KRC report did not specify the vertical datum for each benchmark. For the most part, the Canadian MTO benchmarks were reported in CGVD 1928 while the US benchmarks were generally in NAVD88. In addition, the KRC document compared GPS based elevations to the water level elevations on those days which would have been reported in USC&GS 1912. The result is that the comments section of the KRC report did not adequately distinguish the relationship between the three vertical datum utilized. Table 2-3 distinguishes between the various measurement dates and the associated reference datum and provides the offset used to convert the GPS elevation to USC&GS 1912. Datum conversions were based on those discussed by Stevenson and Thompson (2013).

Date	Sites	Geodetic Monument	Reference Datum	Offset to USC&GS 1912
Oct. 2	CDN01 to CDN16	MTO BM 738351	CGVD 1928	Add 25.4 cm to the field GPS measurements (effectively converting CGVD 1928 to USC&GS 1912)
Oct. 3	CDN 17 to CDN28	None	Effectively calibrated to water level (USC&GS 1912)	No offset applied – KRC had effectively calibrated the unit to the USC&GS 1912 datum for measurements taken that day
Oct. 4	CL01 to CL10	GSID # 28366 GREG MNDT	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 5	CL11 to CL14	GSID # 28366	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting

		GREG MNDT		NAVD88 to USC&GS 1912)
Oct. 5	AR01 to AR07	GSID # 27739 ART MN137	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 6	KL01 to KL17	GSID # 27780 B 208	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 7	KL18 to KL22	GSID # 27780 B 208	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 8	US01 to US21	GSID # 94615 REINAR and RANIER	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 9	US22 to 25 and US 27 to 33	TBIRD	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 9	US26, US 34 to 41	KENOS	NAV88	Subtract 16.6 cm from the field GPS measurements (effectively converting NAVD88 to USC&GS 1912)
Oct. 10	CDNNWO	MTO BM 738351	CGVD 1928	Add 25.4 cm to the field GPS measurements (effectively converting CGVD 1928 to USC&GS 1912)
Oct. 10	CDNRV	MTO BM 738351	CGVD 1928	Add 25.4 cm to the field GPS measurements (effectively converting CGVD 1928 to USC&GS 1912)

Table 2-3: Summary of KRC field survey GPS reference points and conversions used in flood damage study

KRC attempted to gather GPS elevation data for all sites visited. They were largely successful in their efforts and were able to acquire elevation data at 128 of 131 sites. The missing sites could not be completed due to a lack of dock structure and/or difficulty with the GPS unit acquiring satellite signal due to dense forest canopy cover. In addition to the GPS measurements, KRC staff also used a water level offset technique for some structures. The water level offset approach used hand measurements with a tape measure relative to the water surface to determine an elevation. The water level elevation was determined by using the reported average lake level for the measurement day as provided on the Lake of the Woods Control Board data website and adding the measured offset from the water surface. This approach represented an easy and reasonably reliable means of acquiring elevation estimates for docks and structures near the shoreline. However, it was difficult to determine the approximate water surface when there was wave activity. As wave activity increased, so did the uncertainty around the offset estimates. Strong winds and associated wave activity could also lead to a small amount of wind setup on certain portions of the lake depending on the wind direction leading to potential differences between the mean daily lake level used for estimating the overall elevation and the lake surface elevation at the point and time of measurement. In the case of the KRC field surveys, hand measurements were not undertaken when conditions were deemed too wavy to make a reasonable measurement. The uncertainty in the hand measurement approach was not quantified but assumed to be a few cm or less under most observation conditions. There may also have been a few cm difference between the average lake surface elevation and the water surface elevation at the time and location of the hand measurement. Generally, the measurements were taken for dock structures but some secondary buildings (e.g., sauna's, sheds, boathouses, etc.) were situated such that their offset from the water surface was also obtained.

For areas where both site-specific GPS and water level offset measurements were taken during the field survey, comparisons were made to estimate how closely the two approaches aligned. The comparisons are provided in Figure 2-8 to Figure 2-10. The results generally show good agreement between the two measurement approaches (following conversions to common datum). For the US sites, the GPS measurements were generally referenced to NAV88 benchmarks. As such, a 16.6 cm offset was subtracted from the GPS measurement to convert the elevations to USC&GS 1912 (see Stevenson and Thompson, 2013). On the Canadian side (excluding Bear Pass), a portion of the GPS measurements were referenced to the CVGD 1928 datum and 25.4 cm had to be added to those values to convert to USG&GS 1912 (Stevenson and Thompson, 2013). The remaining sites were essentially referenced to the lake level on the day of the survey and were effectively reported as USC&GS 1912 by KRC. As a result, no offset was required for those sites. It should be noted that there was a concurrent study looking at updating the offset factors between the various datums in the study area. Both the flood damage and elevation projects concluded at roughly the same time and any updates to the offsets used within the flood study will need to take place as a new project.

For Rainy Lake (Figure 2-8), there were good relationships between the GPS measurements (KRC1) and the water level offset approaches with R^2 values of 0.950 and 0.907 for the US and Canadian sites respectively. Note that the Bear Pass GPS results were not included in the chart due to the equipment problems as discussed earlier in this section. On the U.S side, the water level offset values were on average 0.05 m higher than the respective GPS based measurement and the standard deviation of the differences was 0.04 m. On the Canadian side, the water level offset values were on average 0.10 m higher than the respective GPS based measurements and the standard deviation of the differences was 0.07 m. The differences between the two approaches may have been associated with uncertainty in the individual measurement methods (e.g., GPS and water level offset), the conversions between the GPS datum and USC&GS 1912, or some combination. In the context of the flood study, the two independent approaches provided adequate and consistent results and were considered a reliable baseline to support flood damage assessments and to ground truth elevation extraction approaches from LiDAR and DEM data.

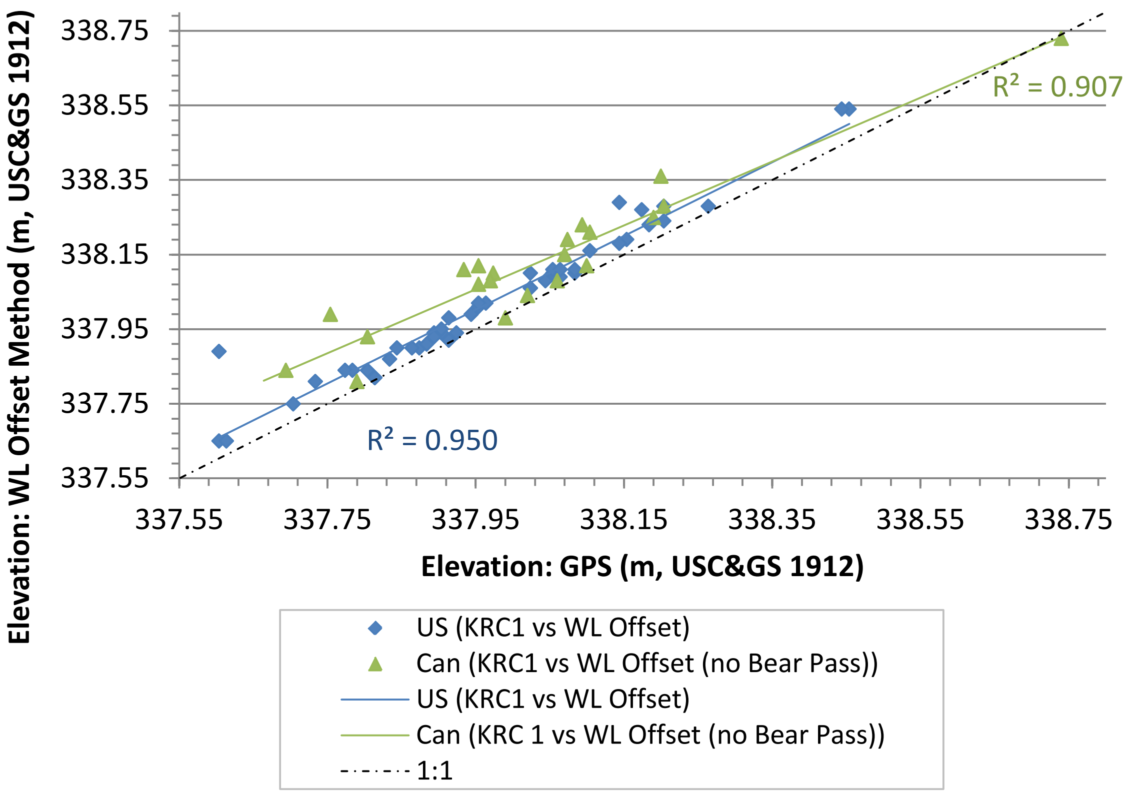


Figure 2-8: Comparison of KRC GPS elevation measurements and water level offset measurements for docks on Rainy Lake

For the Kabetogama Lake measurements (Figure 2-9), there was also a good relationship between the GPS measurements and the water level offset approaches with R^2 values of 0.9335. The water level offset values were on average 0.07 m higher than the respective GPS based measurement and the standard deviation of the differences was 0.05 m. As with the Rainy Lake results, the differences between the two approaches may have been associated with uncertainty in the individual measurement methods (e.g., GPS and water level offset), the conversions between the GPS datum and USC&GS 1912, or some combination. In the context of the flood study, the two independent approaches provided adequate and consistent results and were considered a reliable baseline to support flood damage assessments and to ground truth elevation extraction approaches from LiDAR and DEM data.

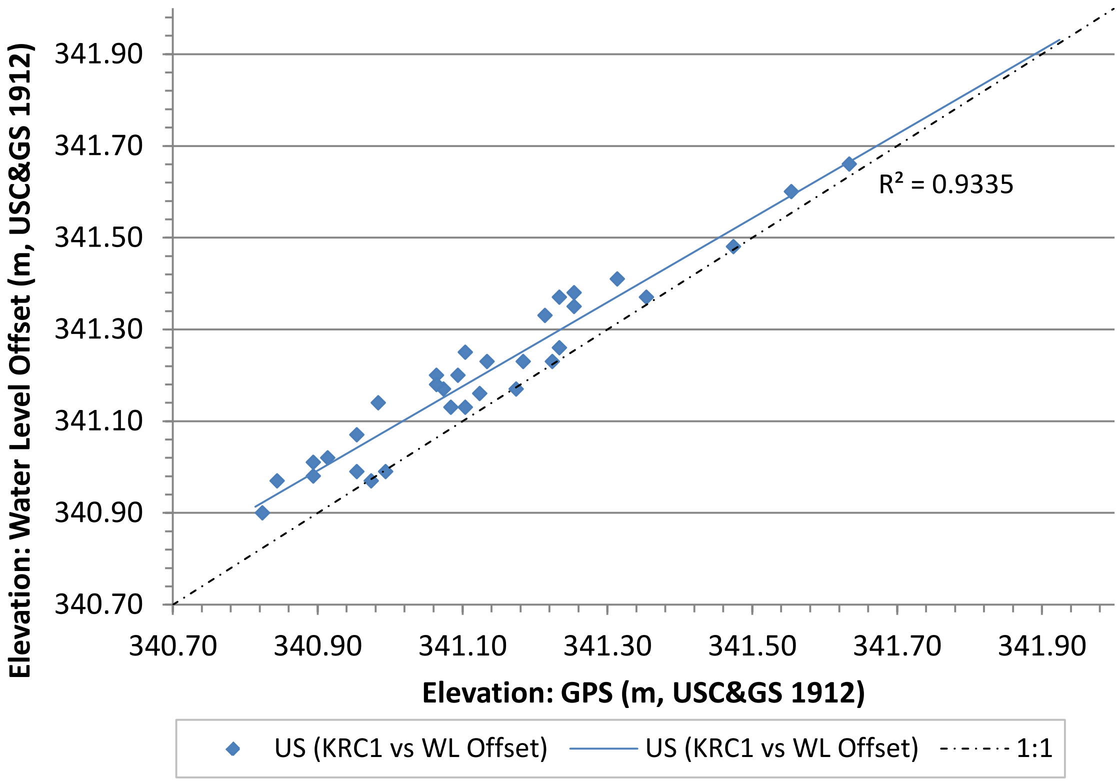


Figure 2-9: Comparison of KRC GPS elevation measurements and water level offset measurements for docks on Kabetogama Lake

There was also a good relationship between the GPS measurements and the water level offset approaches on Crane Lake (Figure 2-10). Comparisons were made between the individual GPS points obtained by KRC (KRC1) and the water level offset values. A comparison was also made using average values (KRC average) if multiple GPS points were obtained for a single dock. In both cases, r^2 values were high (0.9933 and 0.9577 respectively). The water level offset values were on average 0.08 m higher than the respective GPS based measurement. When using the single KRC GPS points, the standard deviation was 0.04 m and when using the average of multiple GPS values, the standard deviation of the differences was 0.02 m. As with the Rainy Lake results, the differences between the two approaches may have been associated with uncertainty in the individual measurement methods (e.g., GPS and water level offset), the conversions between the GPS datum and USC&GS 1912, or some combination. In the context of the flood study, the two independent approaches provided adequate and consistent results and were considered a reliable baseline to support flood damage assessments and to ground truth elevation extraction approaches from LiDAR and DEM data.

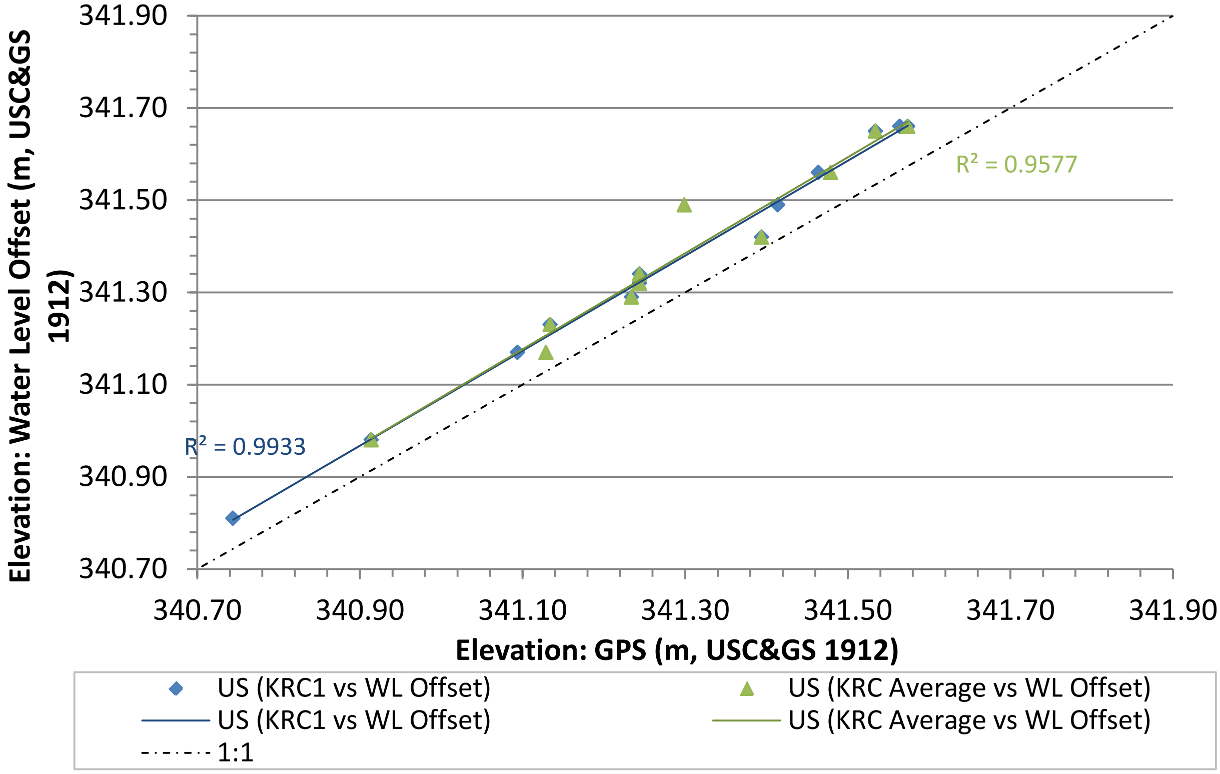


Figure 2-10: Comparison of KRC GPS elevation measurements and water level offset measurements for docks on Crane Lake

Comparisons of the water level offset elevations and the GPS elevations (after conversions and where both exist) indicate the GPS measurements were on average 7 cm lower than the water level offset method (standard deviation of 6 cm). The differences between the two approaches seem reasonable in the context of the study and given that FEMA requirements from a floodplain mapping perspective may be as large as 1 to 2 foot contours in some situations (National Research Council of The National Academies, 2007).

2.3.1.2 Questionnaire

To support the property owner surveys, KRC prepared a draft questionnaire based on input from Environment Canada staff (Mike Shantz). A primary resource in developing the questionnaire was a previous property owner survey undertaken by Acres Engineering in 1993. The KRC questionnaire was designed to support field data collection on a number of related topics including the use of individual properties as well as the perceptions and experience of individual property owners with flood damages on their shoreline property. The questionnaire was not distributed to the property owners directly but was used as a form by KRC staff (Ryan Haines) when meeting with property owners and discussing their flooding experiences. KRC undertook a preliminary field test of the questionnaire between August 29th and September

2nd, 2013 in the Bear Pass area of Rainy Lake on the Canadian shoreline. For this field test, KRC staff attempted to visit properties by boat. Sites were identified based on the likely presence of the property owners at that time. This approach was highly influenced by weather conditions. On days with good weather, it was much easier to determine whether property owners were on site. On poor weather days, it was difficult to identify occupied properties, adding considerable time and effort to the work.

Based on the observations from the preliminary field testing, changes were made to the methodology to improve the interview and elevation collection process. The questionnaire was modified by:

- Adding extra space to separate the lake (waterbody) and site information;
- Re-organizing questions to specifically ask about 2001 and 2002 damages earlier in the questionnaire;
- Adding a specific question on ice related damages;
- Adding a specific item for further clarification on flood proofing costs;
- Identifying primary property access (Boat vs. Road).

A copy of the adjusted questionnaire is included as part of the KRC summary report in Appendix A. The changes were made to improve the overall study results. While it was recognized that these changes would result in some inconsistencies between the results from the preliminary field testing and the remainder of the survey results, it was considered important to make the changes to improve the overall confidence in the observations. KRC provided a brief supplementary report of their field survey activities including information on scheduling, methodology (including site access, equipment, and data collection), as well as lesson's learned and the interviews themselves (Appendix A).

In general, KRC staff received a positive response to their requests for information with only one property owner approached about the survey not wanting to participate although a few additional property owners did not have time to participate while the contractors were in the area. Shoreline property owners were keen to discuss their concerns associated with high water levels and the potential impacts on their properties. For reference, further details on the property owner survey and question-by-question results regarding property owner perspectives on shoreline vulnerabilities and implications for the flood damage modelling are provided in Appendix B.

One of the primary reasons for undertaking the property owner survey was to understand critical shoreline vulnerabilities as viewed by property owners and consider whether there were opportunities to reflect those issues within the flood damage modelling effort. As well, further information was sought on the scale of the impacts that needed to be considered within the development of the flood damage model. The questionnaire was structured to reflect the expected shoreline vulnerabilities as captured in the geospatial database that was developed as part of the flood damage study. In particular, information was sought on vulnerability of main (lived-in) buildings, outbuildings (non-lived-in), and docks as those were the main damage categories (along with boathouses) in the geospatial database. However, the survey also provided the opportunity for respondents to report on other types of flood vulnerability. A few general observations from the property owner responses, as interpreted by the project lead, were used to frame some of the model structure and develop stage-damage functions outlined in Section 2.6.

Observation 1: Respondents were Aware of Fluctuating Water Levels and Survey Provides Reasonable Representation of Potential Impacts

The survey respondents on Rainy Lake had been at their properties on average 24.2 years and for the Namakan chain respondents, that value was 22.5 years. The majority of survey respondents had been present at their property long enough to have experienced past high water conditions, particularly in 2001 and 2002. Due to the overall number of residents in the study area, particularly on Rainy Lake, it was not possible to undertake a full population survey. However, the site visits that were undertaken were considered to give a good indication of the types of flood vulnerabilities that exist within the Rainy-Namakan basin.

Observation 2: A High Percentage of Respondents Reported Flooding Damages in 2001 and 2002, With Flood Damage to Main (lived-in) Buildings and Outbuildings (non-lived-in) Representing a Relatively Small Component of Reported Damages

Over 43 percent of Rainy and 41 percent of Namakan chain of lakes respondents indicated they experienced some sort of flood damage during the 2001 and/or 2002 high water periods. This represented a high number of respondents even though the flood levels were well below the 1950 flood of record. As expected, a higher percentage of respondents reported flooding of docks (25 percent) when compared with main (lived-in) buildings (5 percent) or outbuildings (non-lived-in) (6 percent). In fact, building damage represented a fairly small component of the overall number of reported damages when looking at the number of damage reports. Of the damages that were reported for buildings, main (lived-in) building damages represented a small component of the overall value of the buildings. In other words, the respondents that experienced flood damage to main (lived-in) buildings in 2001 and/or 2002 were negatively impacted by the flood conditions but in no example did the flood conditions completely destroy the building being impacted. For secondary (non-lived-in) buildings, the flood impacts were generally greater as a percentage of the building replacement value. However, the percent of impacted properties was still relatively low at ~6 percent of respondents.

In terms of flood response, the vast majority of respondents identified that they invested time and effort into some sort of flood response. In many cases, this involved securing possessions or working to keep docks and other secondary (non-lived-in) buildings from floating away. However, only 6 of the 114 respondents (5.3 percent) indicated a dollar amount in terms of flood response. There were almost certainly situations where individuals chose not to provide an economic damage estimate or one was not known, however the results also suggested that many of respondents were directly inconvenienced by past flood conditions but that was not directly reflected as an economic damage where investments were required to repair damaged infrastructure.

The investment of time and effort could be considered for use within a flood damage estimate, even in a qualitative way, since it represented such a high percentage of responses. Overall, the average time invested per event (e.g., person hours) was in the range of 5.3 to 9.4 person hours per event which were the average values with the most extreme example removed.

Observation 3: Dock Flooding Was the Most Commonly Reported Flooding Damage in 2001 and/or 2002, Although Not All Docks Sustained Damages

25 percent of respondents identified dock damage due to high water conditions in either 2001 and/or 2002. This was the highest percentage for any single damage category and was expected based on the fact that docks are generally close to the water to facilitate ease of use. Despite the relatively high percentage of reported damages, there remained a considerable number of respondents that have docks but that did not report damage. In some cases, residents did experience flooding and were required to undertake some sort of flood response effort (e.g., putting barrels on docks). In fact, 59.6 percent of respondents undertook some sort of time investment in flood response. However, given the high number of fixed and/or combination docks in the system, not all docks sustained permanent damages as a result of high water levels in 2001 and/or 2002. This represented a complicating factor when trying to model impacts as not all docks that were inundated would be permanently damaged. Other factors such as the age and construction of the dock, the length of inundation, and the exposure to wave conditions also impacted the vulnerability of specific docks and are more difficult to model using an inundation approach.

Observation 4: Shoreline Property Owners Reported Other Flooding Damages Beyond Damages to Main (Lived-In) Buildings, Outbuildings (Non-Lived-In), and Docks, Although Modelling Many of Those Damage Categories Can Be Challenging

15 percent of respondents indicated “other” types of flood problems beyond main (lived-in) building, outbuilding (non-lived-in), and dock specifically addressed in the questionnaire. These “other” flooding damages captured a range of issues including shoreline erosion, lawn

inundation, access road flooding, and other similar issues. These types of flood problems were difficult to capture through inundation modelling either because they required specific types of information to understand vulnerability (e.g., for shoreline erosion) or they were difficult to quantify in an economic context (e.g., damages associated with lawn inundation). In some cases, the reported damages actually had no significant direct economic consequence but they directly impacted the ability of property owners to use and enjoy their property for a period of time and may have had some secondary economic impacts. In the context of the flood damage assessment, it was not possible to incorporate all these issues as direct economic consequences of high water conditions although it was important to acknowledge their impact on property owners.

Observation 5: Ice Damages Were Common Along the Study Shoreline But Were Not Strictly A Function of Water Levels and Therefore May Be Difficult To Incorporate Into the Flood Damage Model At This Point

Nearly 43 percent of survey respondents reported some sort of ice damage in the past. However, few of the reported ice damages were strictly a function of water levels. In many cases, the ice damages were more commonly caused by the movement of ice along the shoreline due to wind conditions. On Kabetogama Lake, a few respondents did make it clear that higher winter water levels (during ice period) with the 2000 rule curves did create greater risks for their docks compared with the 1970 rule curves. The 1970 rule curves used to keep the water level so low in winter that their docks were out of the water and not at risk of ice movement but that was not the case now. In general, Kabetogama respondents still preferred the 2000 rule curves because it afforded better late season and early season boating due to the higher water levels and this seemed to offset any potential ice risk in the winter.

Despite the high number of respondents with ice damages, very few undertook significant adaptive responses to address those issues. In particular, fixed docks and combination docks (both fixed and floating) were common on both Rainy Lake and the Namakan chain of lakes. Only 1.5 percent of respondents had a removable docking system which would have eliminated potential ice damage issues.

In the context of the damage modelling, the primary factor that could be included in the Excel model was a comparison of water level fluctuations between ice-on and ice-out on each of the different lakes under the different rule curves. Based on a few of the responses, a greater amount of fluctuation once ice has formed on the lakes can cause greater problems for existing infrastructure. A relative comparison of the rate of change of water levels could be undertaken by looking at how much water levels change over the winter period.

Observation 6: Although Septic Systems Were Common (Except on Portions of the US Shore of Rainy Lake), A Relatively Low Percentage Were Considered At Flood Risk

Over 54 percent of the properties surveyed had a septic system. The main exception was the portion of the US Shoreline of Rainy Lake where sewer and water service is being extended eastward from International Falls. As well, the Crane Lake community has a sewer system. Generally speaking, the US Rainy properties that did have a septic system were the locations further east towards the park (further from International Falls). Despite the high number of property owners reporting the use of a septic system, a relatively small number (11.3 percent) of those systems were considered at flood risk. Because the location of septic beds was not often readily apparent from air photos, site visits would be required in order to locate the septic beds and that was not feasible for the full population within the context of this study. As a result, it was not practical to incorporate flooded septic beds in the flood damage tool, although it was certainly a factor that could be qualitatively considered in the reporting of flood damages.

Observation 7: The Sample Size is Small for the Estimates of Building Values for At-Risk Buildings

The sample size for the estimated building values of main buildings and outbuildings was small with only 20 main (lived-in) buildings and 32 outbuildings (non-lived-in). As well, the survey did not directly link the building size to the estimated value. As such, there is a high degree of variability in the estimated values making it difficult to extrapolate generic values for the broader geospatial database from this dataset alone.

Observation 8: Outbuildings (Non-Lived-In) Were More Commonly Reported As Being At-Risk When Compared With Main (Lived-In) Buildings and Their Values Were Considerably Less

Overall, 24.4 percent of the respondents identified an outbuilding (non-lived-in) at potential flood risk while only 15.3 percent of respondents identified main (lived-in) buildings at flood risk. These general patterns were reflected in the overall geospatial database with more outbuilding (non-lived-in) being at lower elevation relative to main (lived-in) buildings. From a value perspective, the average value for the at-risk outbuildings (non-lived-in) was ~$23,000 while the value was much higher (~$320,000) for main (lived-in) buildings. Although the sample size was small, that represented a 14 times greater value for the main (lived-in) buildings when compared with the outbuildings (non-lived-in).

Observation 9: For the At-Risk Main (Lived-In) Buildings Identified, Some had a Basement or Crawl Space. For Outbuildings (Non-Lived-In), None Had Basements.

Foundation type plays a role in flood vulnerability of buildings. In the context of main buildings, the presence of a basement and/or crawl space can impact the elevation at which flooding starts and the overall extent of damage. Typical stage-damage functions utilized by FEMA or the USACE often differentiate buildings with or without basements when estimating impacts. For the at-risk buildings identified in the field survey, the basement type was quite varied and included full basements, crawl spaces, no basements (concrete slab), and some combination. This variability in basement type was an important factor in looking at flood vulnerability. Unfortunately, air photo interpretation was not a good way to differentiate basement types. A secondary data source such as oblique imagery would also be required to support general characterization and that information was not available throughout the study site. As a result, foundation type was not a characteristic that could be incorporated into the flood damage model but given the variability in basement type observed in the survey, it is something that could be considered in the future. As a short-term approximation, it was important to build in a main floor offset as most of the observed main (lived-in) buildings did have some offset. This was not the case for outbuildings (non-lived-in) as they tended to be at-grade. As such, no offset should be included in the flood damage calculations for the outbuildings (non-lived-in).

2.3.1.3 Shoreline photos

In addition to the 2013 field surveys undertaken by KRC, staff from Environment Canada undertook a photo inventory of two portions of the Canadian shoreline where there was high development density. These photographs were critical for helping to identify structures (buildings, docks, boathouses, etc.) along the shoreline and include them in the database. The focus on the Canadian shoreline for this effort was primarily due to the relative lack of detailed elevation information relative to the US shoreline. As a result, the shoreline photographs were considered a time and cost effective approach to help characterize the shoreline. Figure 2-11 shows the coverage areas for the shoreline photographs. In all cases, the photos fall outside the coverage area for the high resolution elevation data.

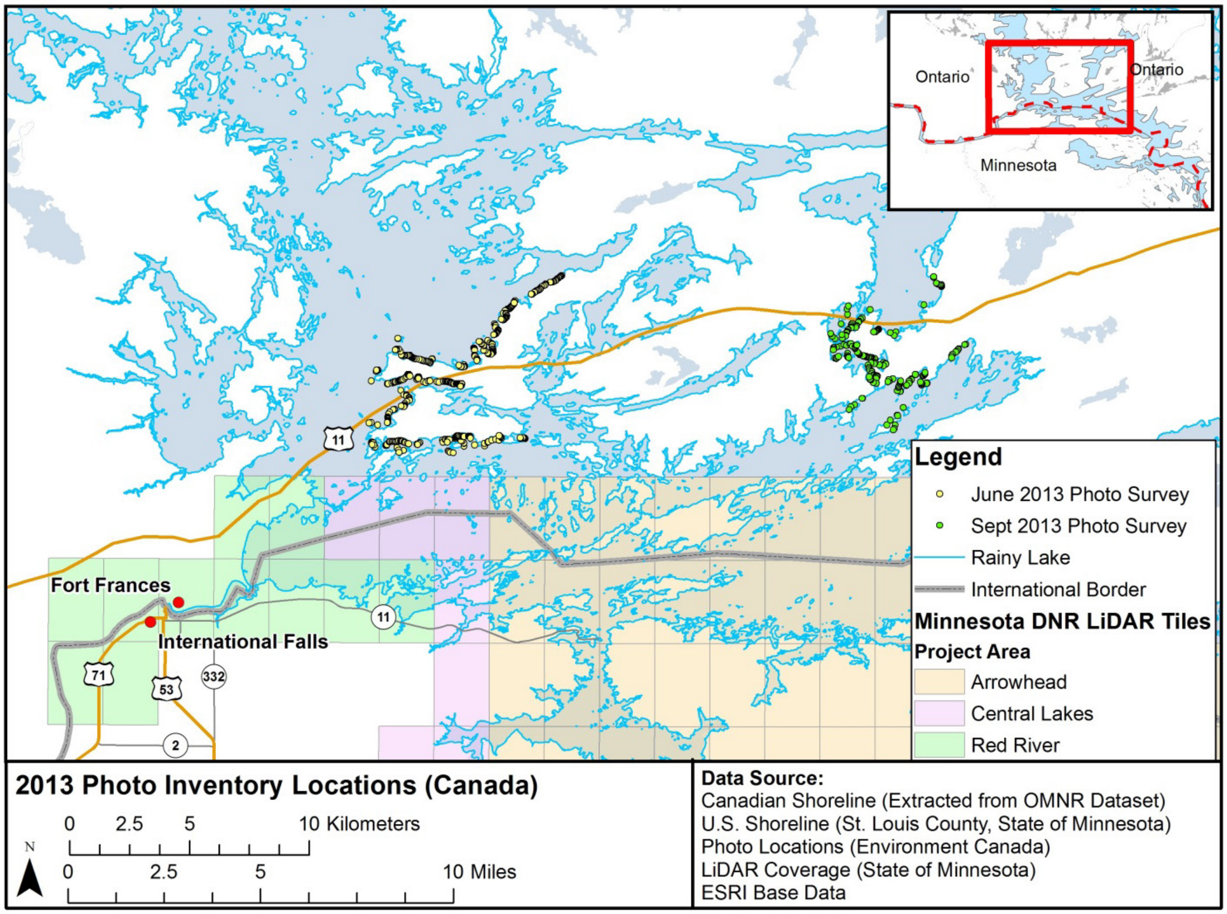


Figure 2-11: Coverage area for 2013 shoreline photographs on the Canadian portion of Rainy Lake

Where field surveys by KRC or photographs from Environment Canada were obtained, the geospatial database was refined to ensure necessary structures were captured. This was particularly important for the Canadian shoreline where the air photo imagery resolution and timing meant some structures were missed during the initial geospatial database development.

2.4 Attributing and refining geospatial database

The information gathered through the 2013 field surveys provided critical information to allow for the attribution of elevation and structure characteristics within the project geospatial database of shoreline development conditions in the study area. Within a geospatial database, **features** generically reference individual representations of items of interest. In the Rainy flood project, these database features represent individual structures along the shoreline (buildings, boathouses, docks). In Section 2.4, the term “feature” is used generically in reference to an individual polygon in the database representing a single building, boathouse, or dock (a structure). Collectively, similar structure types (e.g., docks) are represented in the geospatial database by a **feature class** with similar attributes. The structures within each feature class are attributed with similar information. For example, the same attribute categories were used to characterize each dock in the database. The primary fields used for reporting purposes are listed in Table 2-4. It should be noted that not all fields were necessarily used for all structure types (e.g., buildings, docks, boathouses), although most were used for all structure types and within each structure type, all individual structure classes were arranged the same (e.g., Docks_Rainy_US had a similar arrangement as Docks_Rainy_Can).

Field Name	Description
ObjectID*	An automatically created ID by ArcGIS during the feature creation process
FeatureID	A unique ID within the geospatial database for each individual feature (structure)
Shape_Length*	The perimeter (length) of the feature polygon in m
Shape_Area*	The area of the feature polygon in m^2
DEMSource (buildings) or LIDARSource (docks)	Source of the elevation data for extraction elevation estimates
LakeorRiver	Distinguishes whether the feature is on the lake shoreline or a river (e.g., Rainy River between dam and lake or Ash River)
KRC_Site_ID	A unique ID for features visited during the KRC field surveys
StructureCode	A 3 digit code providing information on the characteristics of the digitized feature
ReachID	Specifies the geographic zone on each lake. Particularly relevant to differentiate Crane and Sand Point lakes due to water level impacts of pinch points
Elev_Source	An identifier on Namakan and Kabetogama Lake to differentiate where NPS or Minnesota LiDAR was used. For Boathouse feature classes, an identifier as to whether elevation was based on LiDAR or DEM.
Elev_Est	The elevation estimate for the feature. For buildings, this is generally the lowest corner(s) of the building. For docks, it is based on the fixed (non-moving) part of the dock surface. Details for this portion are described in the next section.

Table 2-4: Feature class fields for the various building, dock, and boathouse datasets within the geospatial database

The **ObjectID** was a number ID automatically created by ArcGIS during the feature creation process. Because of the organization of the geospatial database (multiple feature classes within each feature dataset), the ObjectID was not a unique number for all features or even for all features of the same type (e.g., docks). Therefore, a unique ID was created (**FeatureID**) that uniquely identified each feature in the database. The FeatureID was a unique decimal formatted number with five digits before the decimal and four digits after. The first five digits identified the general lake area, the country, and the feature. The first number represented the general lake area (1 = Rainy, 2 = Namakan and Kabetogama, 3 = Crane, Sand Point, and Little Vermilion), the next two numbers represented the country (01 = US, 02 = Canada), and the last two digits represented the feature (01 = buildings, 02 = docks, 03 = boathouses). The four digits after the decimal point represented a number unique to the specific feature class. For example, FeatureID 10203.0015 represented boathouse feature number fifteen on the Canadian shoreline of Rainy Lake.

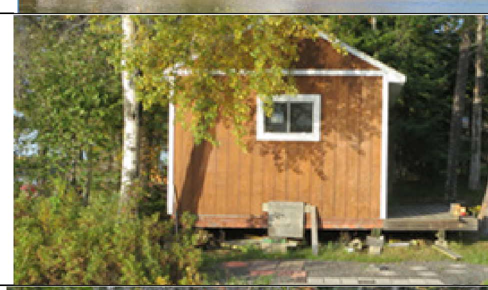
The **Shape_Length** and **Shape_Area** fields represented the perimeter (length in m) and area (area in m^2) of the specific polygon feature. These values were automatically generated by ArcGIS during the polygon creation process based on the map units.

The **DEMSource** field was used for building and boathouse feature classes. The field represented the DEM source used to generate the elevation estimate for the feature. The DEM coverage varied within the study area as the accompanying LiDAR elevation data was acquired on different dates. There were four primary DEM sources including RedRiver, Arrowhead, Central, and NPS as discussed in Section 2.2.1. Within the geospatial database, features outside the coverage areas have an entry of “none” or a blank or null value. The **LiDARSource** field was used for the dock features as the actual LiDAR data was used to generate elevation estimates (as opposed to the DEM). The possible entries for the LiDARSource field were the same as for the DEMSource.

The **LakeorRiver** field was used to distinguish whether the feature was adjacent to the shoreline of the lake or of a river. Features adjacent to a lake shoreline had a value of zero while features adjacent to a river shoreline had a value of one. Almost all the features in the geospatial database had a value of 0 for this field. The only exceptions were features adjacent to the Rainy River between the dam and the Rainy Lake outlet at the international railway bridge and features adjacent to the Ash River. It should be noted that features adjacent to tributaries other than the Rainy River and Ash River were not included within the geospatial database as they were not relevant to the work of this project.

The **KRC_Site_ID** was a unique ID for each of the GPS measurement locations and/or features visited by KRC during the fall 2013 field surveys. The KRC_Site_ID value allowed additional attributes from the field survey to be linked to the digitized feature. This included site photographs, elevation measurements, etc. The KRC_Site_ID values started with a lake identifier and a site number along with a descriptor of the feature that was being measured (e.g., boathouse). For example, rl-us21dock was the 21st site visited by KRC on the US shoreline of Rainy Lake and was a dock feature at that site.

The **StructureCode** field used a three digit number to help further characterize the feature. The StructureCode field was primarily added to help establish replacement values for the individual features. For example, it was considered important that attempts be made to distinguish lived-in buildings (e.g., homes, cottages, etc.) from non-lived-in buildings (e.g., sheds, saunas, etc.) and fixed docks from floating docks as they would respond differently under flooding conditions and would potentially have different replacement costs as well. The StructureCode entries varied based on whether they were for the buildings, dock, or boathouse feature classes. The first digit always represented the type of feature, the second digit was always zero, and the third digit represented a qualitative assessment of the confidence in the characterization (1 = very confident, observed through on-the-ground or oblique photography, 2 = confident based on air photo imagery interpretation, and 3 = low confidence). The categories for the types of features were determined based on the results and observations from the KRC surveys along with assessments of the aerial imagery regarding the extent and confidence to which different features could be distinguished. An example structure code within the building feature dataset was 101 meaning the structure was a lived-in structure and there was high confidence in the assessment based on either on-the-ground or oblique imagery. The specific values for the various types of features (the 1st digit in the characterization) are found in Table 2-5.

Feature Dataset	Type of Features	Example Photographs
Building	1 = lived-in structures	
	2 = non-lived-in structures	
	3 = gazebo	

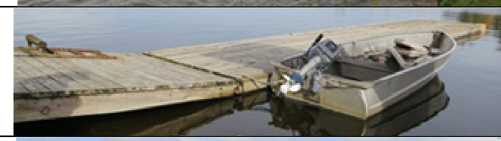
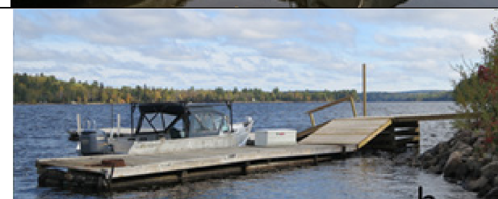
Dock	1 = fixed and/or crib dock	
	2 = floating dock	
	3 = combo (combination fixed and floating)	
Boathouse	5 = full boathouse structure	
	6 = canopy type structure (e.g., canvas or fabric cover open on all sides)	

Table 2-5: StructureCode values within the geospatial database for building, dock, and boathouse structures

Elev_Source was an identifier on Namakan and Kabetogama Lake to differentiate between the NPS LiDAR (2) and the State of Minnesota LiDAR (1) as a data source. For Boathouse feature classes, **Elev_Source** differentiated between the options for identifying the elevation. A value of one meant that the elevation was estimated from using the DEM extraction method, zero was for an elevation of an adjacent dock (using LiDAR data), three was for no elevation estimate, and four was if a field measured elevation estimate was used.

Finally, the **ReachID** was added as a way to further subdivide the geographic areas within the individual lakes. The ReachID was a three digit code that extended both the general lake area from the FeatureID and the LakeorRiver identifiers and was particularly relevant for the Crane Lake datasets as it allowed the differentiation between pinch point areas that restrict flow between smaller lakes in the chain (Crane, Sand Point, Little Vermilion) and Namakan Lake where water levels were measured (see Stevenson and Thompson, 2013). During high inflow periods, levels on upstream lakes such as Crane Lake can be higher than the levels of Namakan Lake. Identifying properties in the various upstream zones allowed for the Namakan Lake water level time series to be adjusted for the damage calculations on those lakes to account for the possible higher levels. The first digit differentiated the broad lake zone just like in the FeatureID field (1=Rainy, 2 = Namakan/Kabetogama, and 3 = Lakes upstream of Namakan including Sand Point, Crane, Little Vermilion). The second digit identified United States (1) or Canada (2). The third digit was unique based on the lake zone identified in the first digit. Table 2-6 lists the ReachID values used in the geospatial database.

Lake Zone	Shoreline Section	US Code	Canadian Code
Rainy Lake	Lake shoreline	110	120
Rainy Lake	Rainy River between dam and lake outlet	111	121
Namakan/Kabetogama	Kabetogama Lake	210	220
Namakan/Kabetogama	Ash River	211	221
Namakan/Kabetogama	Namakan Lake	212	222
Crane Lake	Crane Lake above King William Narrows	310	320
Crane Lake	Little Vermilion above Little Vermilion narrows	311	321
Crane Lake	Sand Point Lake above Harrison Narrows	312	322
Crane Lake	Sand Point Lake above Namakan Narrows	313	323

Table 2-6: Reach definitions within the geospatial database

The elevation attribute (**Elev_Est**) represented a fundamental requirement for developing stage-damage estimates in the study area. For each individual structure, elevation estimates were determined based on one of three possible approaches. These included the use of field based measurements from KRC (GPS and/or water level offset approaches), the extraction of elevation values from available DEMs, and the extraction of elevation values from the LiDAR point data. The KRC measurements covered the fewest number of structures as 131 sites were visited with approximately 368 GPS measurements and 204 overlapping water level offset measurements taken but benefited from covering portions of the Canadian shoreline where there were no other elevation datasets of adequate resolution to support the development of stage-damage estimates. The DEM and LiDAR datasets covered the full US shoreline of the study area and small portions of the Canadian shoreline allowing for elevation attribution for a large number of structures but with some level of uncertainty. Figure 2-4 in Section 2.2.1 shows the general coverage areas for the various high resolution elevation datasets. Feature specific elevation estimates were not determined for database features outside the LiDAR coverage area. Further details on how features without elevation estimates were used in the Flood Tool are described as part of the Flood Tool documentation in Section 3.2.

DEM based elevation estimates were determined for the building feature class and a subset of the boathouse feature class where the feature overlapped with DEM coverage. The DEM extraction approach was only used for features on land as the DEMs did not cover the open water surface. The coverage area for the various DEMs was illustrated in Figure 2-4. The methodology required extracting elevation estimates from the DEM for all vertices of the feature polygon and then using a combination of the lower elevation estimates to attribute the feature (LowVert1 representing the lowest point, LowVert2 representing the second lowest point, etc.). The actual combination varied by lake and type of feature being attributed. Attempts were made to compare the KRC based measurements with the DEM extraction approach on each lake. The KRC measurements were based on the lowest opening and in some cases this meant that they did not measure from the ground surface but instead from some offset level (for example to account for a shed on blocks). The KRC dataset was adjusted to account for the offsets before undertaking the comparison with the DEM extracted value if any offsets were described in the field notes. The comparison yielded positive results for each lake. Figure 2-12 to Figure 2-15 illustrate the relationships between the KRC GPS values and the DEM extracted values. R^2 values exceeded 0.75 for all lakes and trendlines closely paralleled the 1:1 line. However, in most cases, offsetting the DEM derived value by a few cm was required to achieve the best overlap of the 1:1 line. Based on the comparison, a preferred (and adjusted) DEM extracted value was determined for the full lake dataset. The DEM derived value was often the lowest or second lowest vertices elevation or a combination of both. Table 2-7 describes the DEM elevation estimate used for each lake portion.

Lake Area	Adjustment for DEM derived elevation estimate
Rainy Lake	Use LowVert2 estimate and add 0.12 m
Kabetogama and Namakan	Use LowVert2 estimate
Crane, Sand Point, and Little Vermilion	Use average of LowVert1 and LowVert2 estimates

Table 2-7: Adjustment factor for DEM derived elevation estimates of buildings

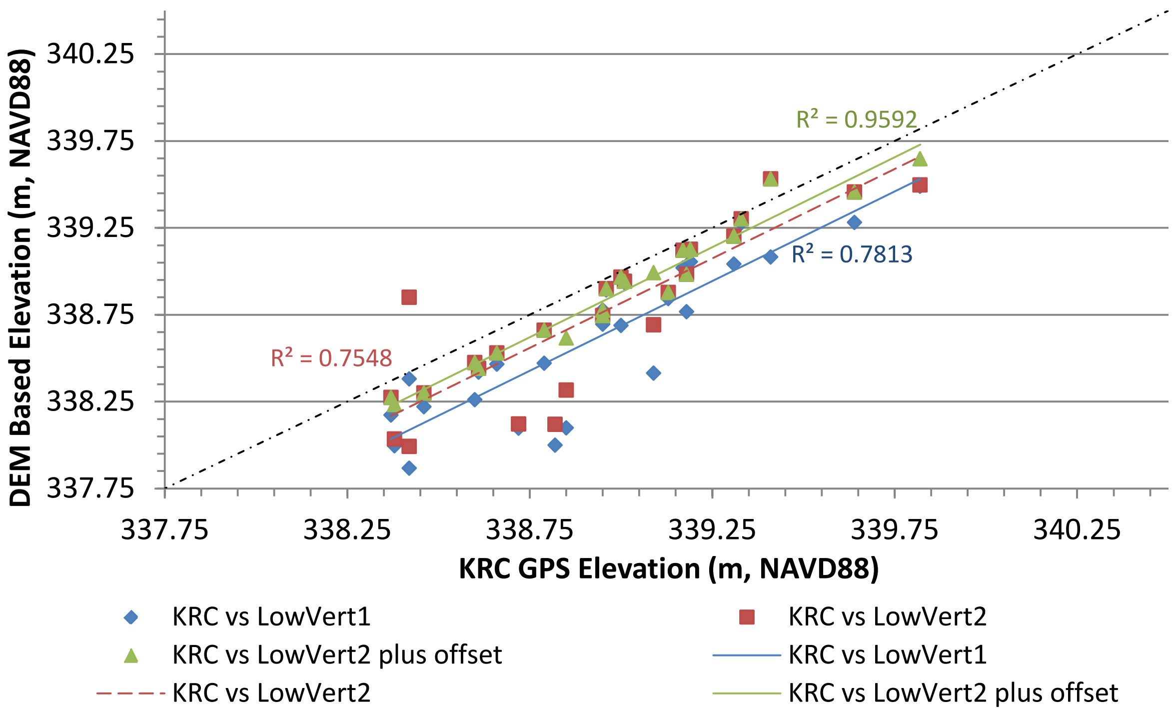


Figure 2-12: Comparison of KRC elevation measurements and DEM based estimates for buildings on Rainy Lake (US) shoreline

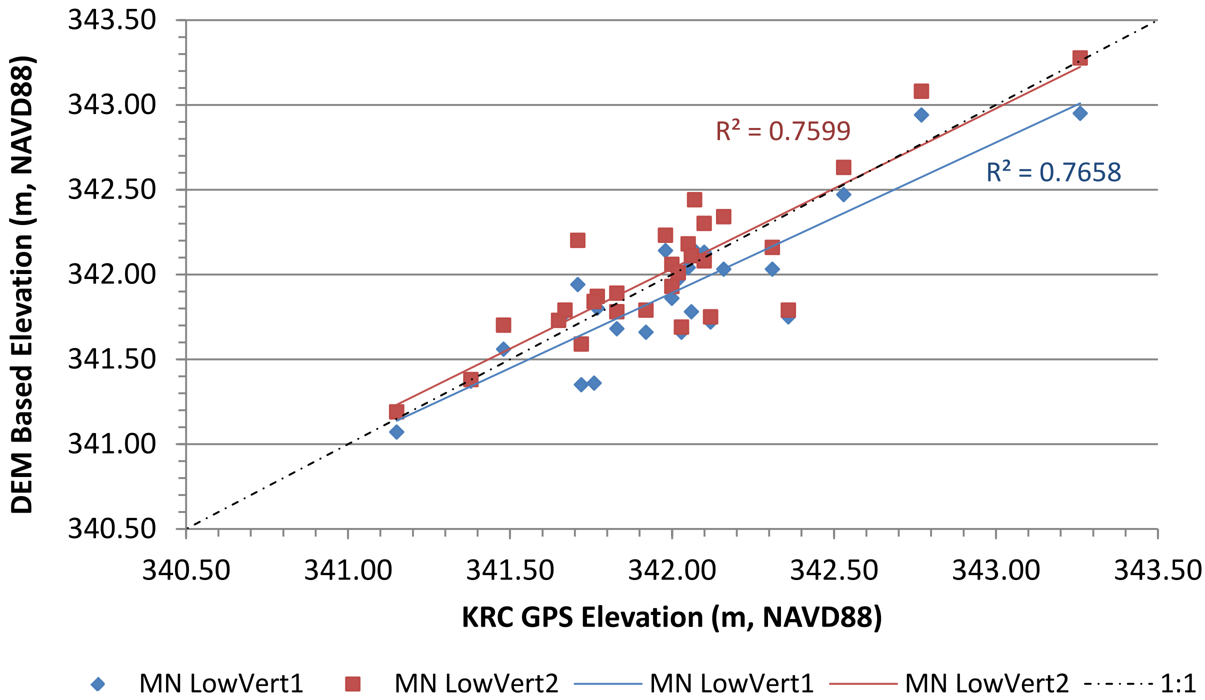


Figure 2-13: Comparison of KRC elevation measurements and Minnesota (MN) DEM based estimates for buildings on Kabetogama Lake (US) shoreline

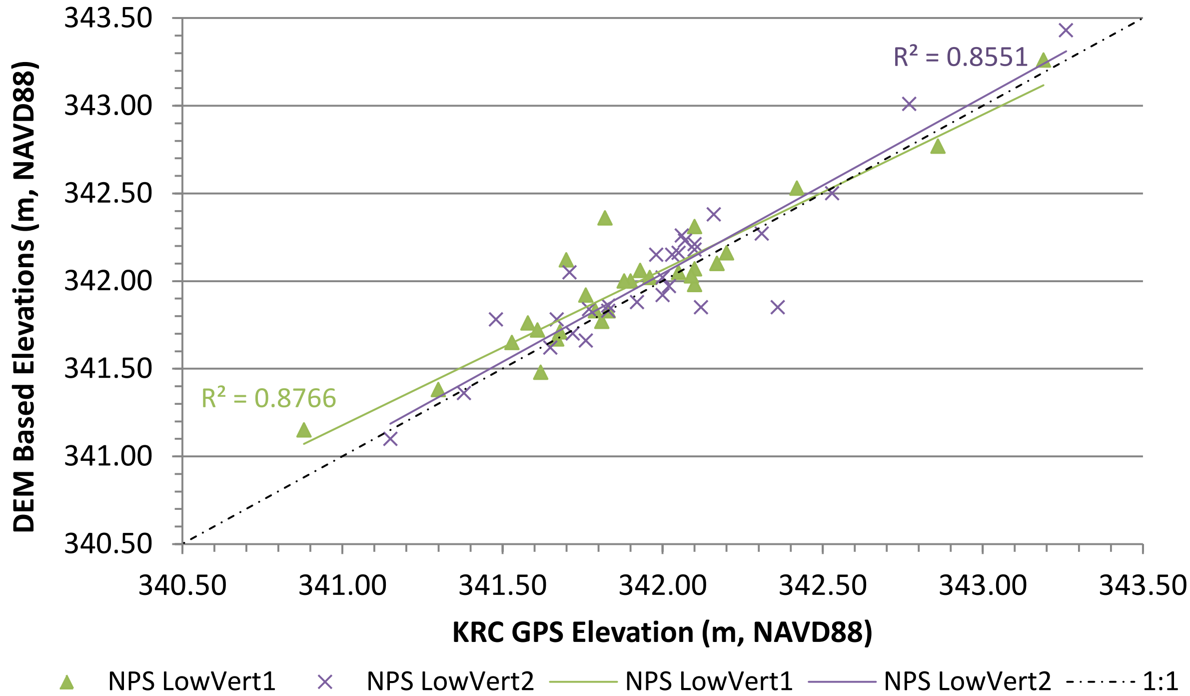


Figure 2-14: Comparison of KRC elevation measurements and National Park Service (NPS) DEM based estimates for buildings on Kabetogama Lake (US) shoreline

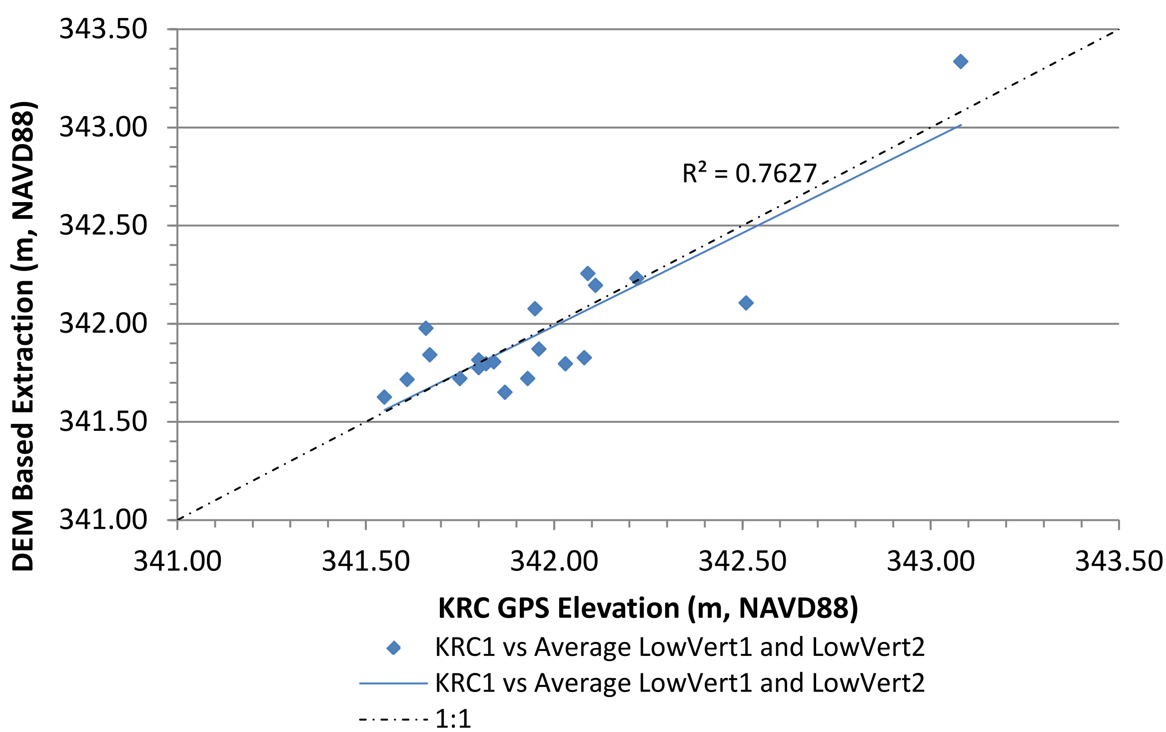


Figure 2-15: Comparison of KRC elevation measurements and DEM based estimates for buildings on Crane Lake (US) shoreline

LiDAR based elevation estimates were utilized for estimating dock elevations. All LiDAR points contained within each dock polygon classified as either fixed or combo (the fixed portion) were identified and used to determine an average and standard deviation elevation value. Each dock was reviewed based on the base aerial imagery and distribution of the associated LiDAR points to identify outlier points and to determine whether there were particular portions of the distribution that appeared to better reflect the dock surface. A subset LiDAR point dataset was created and used to create the final elevation estimates including average, standard deviation, minimum, maximum, and median values in the distribution. Appendix C describes the methodology in greater detail and illustrates examples of how the screening took place.

As with the DEM based approach, the LiDAR based elevation estimates were compared with the KRC field survey values. The relationship between the LiDAR based elevation estimates for the docks and the associated KRC values was not as strong in comparison to the land based DEM values and the KRC values discussed previously. The R^2 values ranged from 0.575 to 0.8396 for the various lakes. Figure 2-16 to Figure 2-18 illustrates the comparison between the different datasets. There were a number of factors that could be contributing to the differences between the LiDAR extracted values and the KRC values including the uncertainty in knowing whether the LiDAR points being used in the elevation determination were actually a reflection of the digitized structure. The imagery used in the digitization was not necessarily taken at the same time as the LiDAR data collection (the exception being the NPS dataset) so there were possible discrepancies between the structures on the ground being digitized and the associated elevation. As well, the docks could have a number of other items on them that would impact the determined elevation at the time of the data collection (for example an overturned canoe being stored on the dock surface). Those items could not always be determined from the air imagery and were impossible to determine from the LiDAR data itself. Despite the variability in the elevation determination, the LiDAR based elevation estimates were considered useful in helping to characterize the overall distribution of dock elevations in the study area. Table 2-8 describes the LiDAR elevation estimate used for each lake portion.

Lake Area	Adjustment for LiDAR derived elevation estimate
Rainy Lake	The mean value for the LiDAR point subset (screened)
Kabetogama and Namakan	The mean value for the LiDAR point subset (screened) minus 1 standard deviation minus 0.10 m
Crane, Sand Point, and Little Vermilion	The mean value for the LiDAR point subset (screened) minus 0.13 m

Table 2-8: Adjustment Factor for LiDAR Based Elevation Estimates of Docks

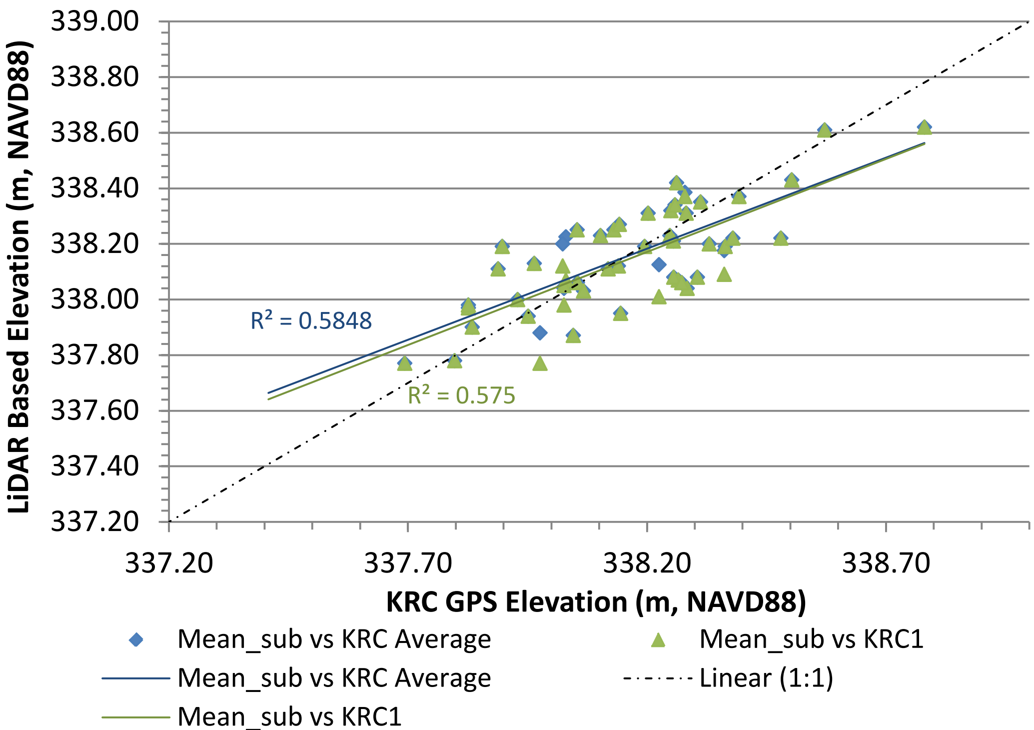


Figure 2-16: Comparison of GPS and LiDAR Based Dock Elevation Estimates - Rainy Lake

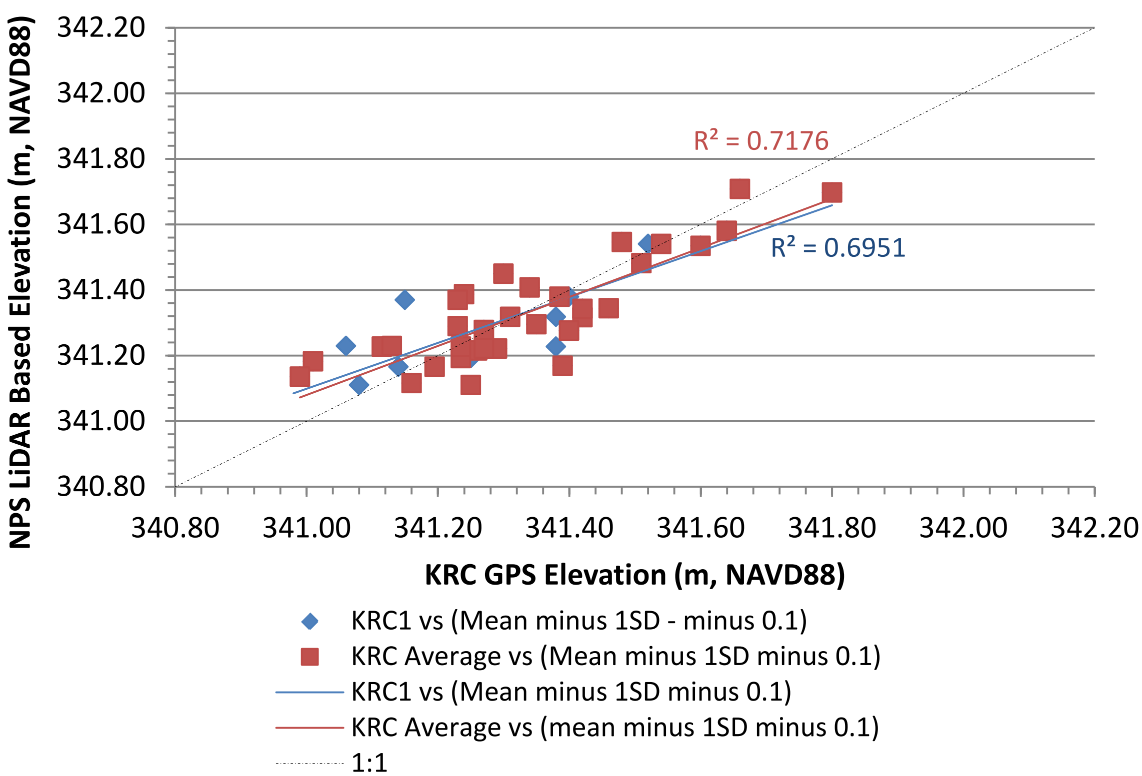


Figure 2-17: Comparison of GPS and National Park Service (NPS) LiDAR Based Dock Elevation Estimates - Kabetogama Lake

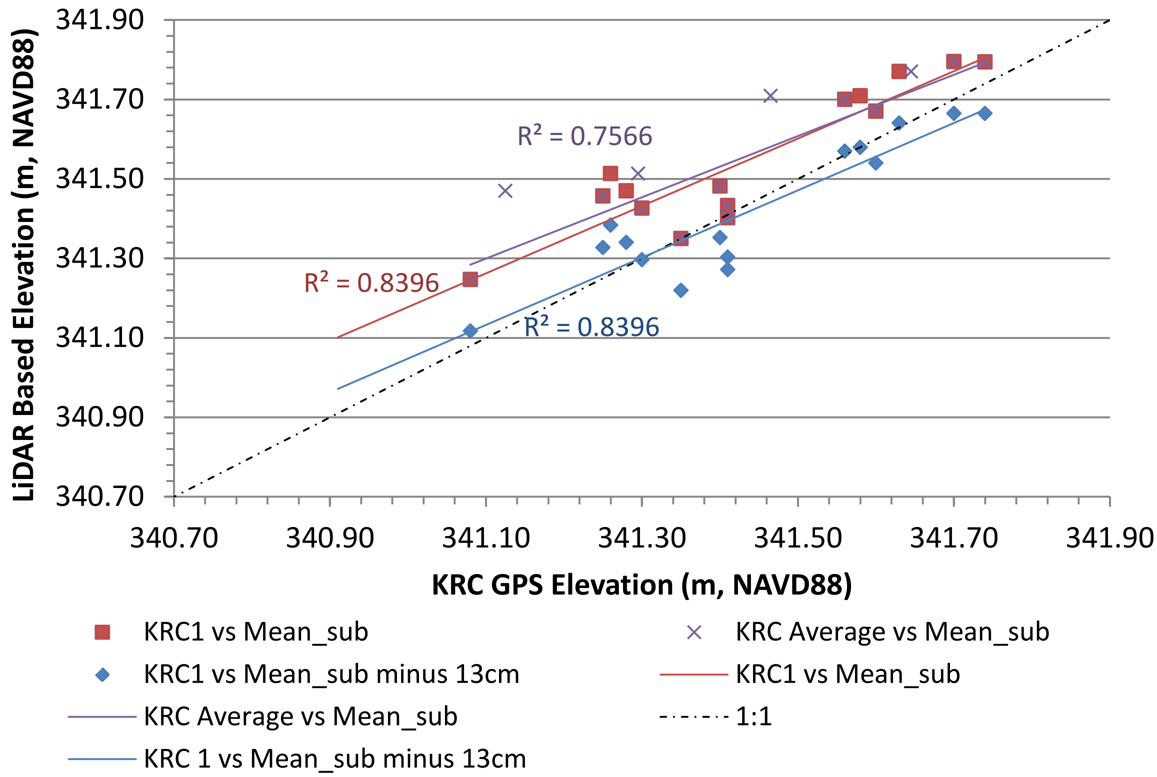


Figure 2-18: Comparison of GPS and LiDAR Based Dock Elevation Estimates – Crane Lake

Elevation estimates for Boathouses were determined based on a combination of techniques due to the relatively small datasets and the fact that some boathouses were fully over water while others were partially over water. Where boathouses were adjacent to a combo dock where a LiDAR based elevation estimate was determined, the boathouse elevation (i.e., the deck of the boathouse) was considered to be equivalent to the dock elevation. In cases where the boathouse was predominantly on land, the DEM elevation estimate was used. If the boathouse was over water but no dock structure was adjacent, no elevation estimate was determined for that boathouse in the geospatial database.

Despite the strong relationships identified between the KRC measurement approaches and the geospatial elevation data extraction techniques, there were still a number of areas of uncertainty that impacted the confidence in the results. The raw LiDAR data used in the analysis was acquired with RMSE of between 15 cm and 1.9 cm depending on acquisition year and campaign and additional smoothing and interpolation was undertaken in the conversion to the DEM. There was also horizontal uncertainty in creating the geospatial database polygons and associated vertices based on the available aerial imagery such that the extracted elevation point may not have precisely represented the expected on-the-ground position. The imagery used in the digitization was not necessarily taken at the same time as the LiDAR data collection (the exception being the NPS dataset) so there were possible discrepancies between the structures on the ground being digitized and the associated elevation. This was of particular concern for the docks as there was evidence of a number of changes to specific docks over the course of the years between when the LiDAR and imagery used for digitization was acquired. Finally, there were some situations where the dock surface was highly variable resulting in a large amount of variation in the elevation estimates for the dock surface. The KRC measurements were often taken at a low point on the dock while the LiDAR extraction was looking at a mean value to reflect the variability in dock surface elevation as well as to account for the possibility that the lowest LiDAR based elevation values for individual docks may be from points that were not actually representing the dock surface.

The completed geospatial database contained over 6,200 individual structures. The database was organized by country, geographic region, and structure type. Table 2-9 outlines the number of structures in the database for each structure type (docks, buildings, boathouses) for the various regions along with the percentage of structures with elevation estimates. All structures were classified based on the category. For example, a building typically used as a residence was considered a “lived-in” building while a non-residential building was classified as “non-lived-in”. A qualitative classification of the confidence in the assessment was also made. For example, some structures had photographs from the KRC site visits, the 2013 photographic inventory on the Canadian shoreline, or other oblique photography. In those cases, the confidence in the structure category was usually quite high. In other cases, the category was determined from lower quality air photos or other means and there was more uncertainty in the classification. There were considerably fewer structures with elevation data on the Canadian shoreline of Rainy Lake when compared to the US shoreline due to the lack of high resolution DEMs. A visual comparison was made between the elevation distributions of the Canadian and US sites visited by KRC as part of the 2013 field survey. As well, the 2013 Canadian shoreline photos were screened to identify structures with particularly low elevations. The general results did not suggest particular differences between the Canadian and US data, at least for establishing lower flood damage thresholds.

Database Feature Class	Geographic Area	Canada		United States	
		Structure Count	Percent of Count with Elevation Estimates	Structure Count	Percent of Count with Elevation Estimates
Docks	Rainy Lake (Lake Only)	1265	7.9	987	77.1
	Namakan and Kabetogama Lakes, Ash River	48	41.7	446	71.7
	Crane, Sand Point, and Little Vermilion Lakes	67	61.2	318	70.1
Buildings	Rainy Lake (Lake Only)	1162	4.5	860	95.0
	Namakan and Kabetogama Lakes, Ash River	41	31.7	500	100
	Crane, Sand Point, and Little Vermilion Lakes	50	78.0	270	97.0
Boathouses	Rainy Lake (Lake Only)	62	4.8	85	84.7
	Namakan and Kabetogama Lakes, Ash River	1	0	56	83.9
	Crane, Sand Point, and Little Vermilion Lakes	2	100	27	48.1

Table 2-9: Summary of structures within the database by geographic area based on count and percent count with elevation estimates

2.5 2014 high water impacts

High water conditions were observed within the study area in June and July of 2014 and flooding impacts were observed along the shoreline. This was an unanticipated event that provided the potential for further improvements to, and validation of, the database and flood assessment methodology. Two particular follow up activities were undertaken to support the development of a flood damage assessment tool. The first was the acquisition of oblique shoreline photography from a number of different partner agencies. These photographs were taken during the high water period to support on-the-ground management efforts by individual agencies but were also very useful in refining the shoreline structure classification within the geospatial database. Figure 2-19 illustrates the location of the various photographs obtained during the 2014 flood event that were available within the study area and Figure 2-20 provides an example photograph for Kabetogama Lake.

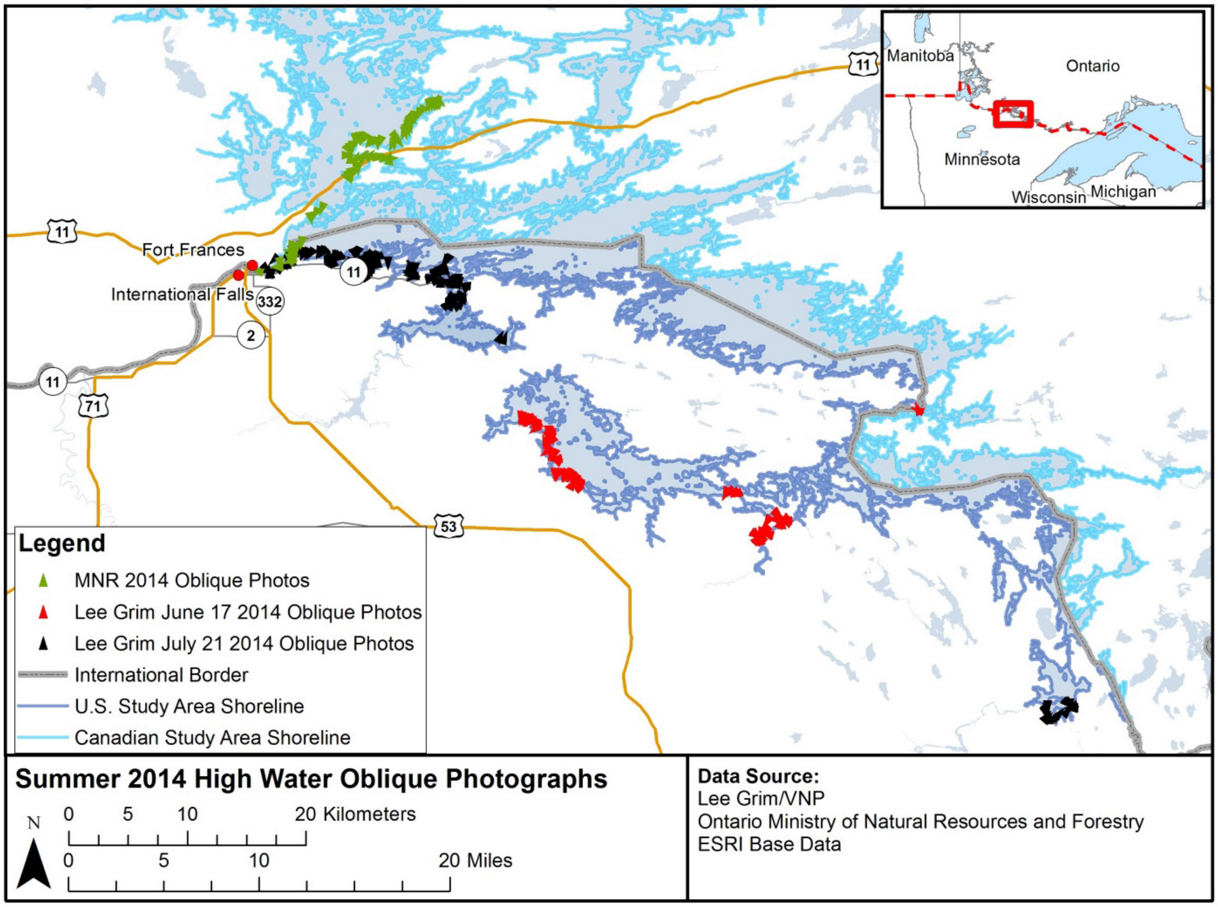


Figure 2-19: Coverage area for oblique shoreline photos taken during the 2014 high water period

Figure 2-20: Example oblique photograph from June 2014 on Kabetogama Lake (photograph by Lee Grim)

In addition to helping with the structure classification, the oblique photographs were also used to qualitatively identify shoreline structures that were either inundated or under imminent threat of inundation so that the results could be used to validate some of the elevation estimates within the geospatial database. Figure 2-21 provides an example map comparing the photo interpretation and the information from the geospatial database. The results are mapped in three categories:

Predicted Risk (Green dots) are identified where the database matched the photo interpretation. They represent either lived-in or non-lived-in buildings where:

- there is oblique photograph coverage;
- where a building appeared to be inundated in one of the oblique photographs; and,
- where that same building would be expected to be inundated for similar water levels based on the elevation estimate within the geospatial database.

Overestimated Risk (Red dots) are identified where the database overestimated flood risk, i.e., where a lived-in or non-lived-in building in the database would:

- be expected to be flooded under the same water level conditions but,
- where the oblique imagery did not provide similar evidence that inundation was occurring.

Underestimated Risk (Yellow dots) are identified where the database underestimated flood risk, i.e., lived-in or non-lived-in buildings that:

- appear to be impacted by high water conditions in the photographs but,
- where that same building was not considered impacted based on similar water level conditions in the database.

Overall, the comparison of qualitative oblique photography evaluation under high water conditions and the geospatial database yielded complementary results with the majority of the comparison showing agreement between the two methods (i.e., database and photo interpretation). For buildings, 74 percent of flooded buildings identified from the photographs would have also been flooded based on the database estimates. That comparison increases to 98 percent for docks and 100 percent for boathouses. There are uncertainties in both approaches so there are expected to be some differences but the results did not suggest that one method was particularly over or underestimating vulnerability relative to the other method.

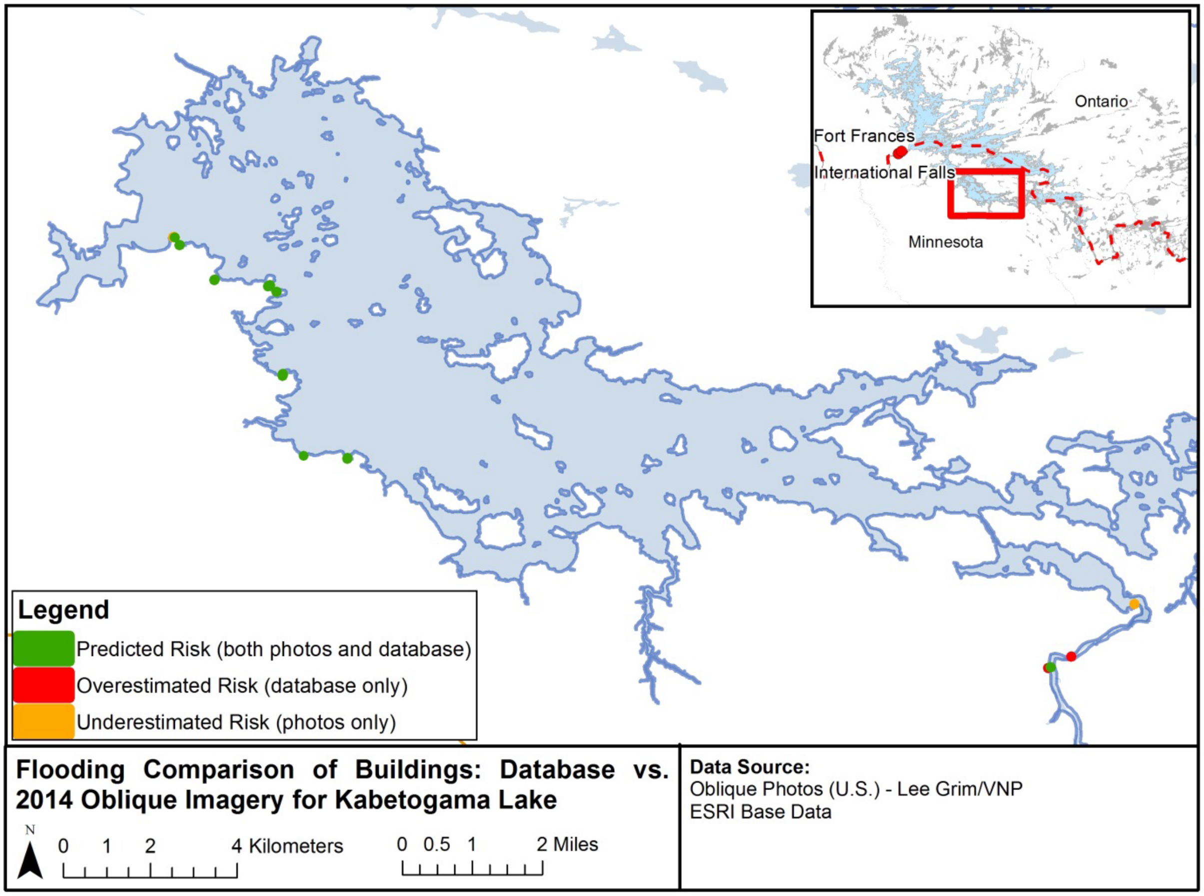


Figure 2-21: Comparison of expected flooded buildings based on DEM Extraction (database) and review of 2014 oblique imagery for Namakan and Kabetogama Lakes

The oblique imagery also supported a qualitative comparison to the DEM in the study area. Because the oblique photographs were not geo-referenced, the comparison could only be done qualitatively based on observation of inundated features and/or the extent of surface water ponding. Even so, the comparison proved useful in further validating the use of the DEMs as a way to look at potential flood vulnerability under different water levels. For illustration, Figure 2-22 shows an image with elevation data (DEM) and an accompanying oblique image for a portion of Kabegotama Lake on June 17th, 2014. The inundation extent is illustrated by the darker (grey) DEM colours on the map. Four general areas are identified between the map and the oblique image to illustrate similarities. For area A, the two benches are observed in both images with the water approaching but not quite reaching the location. In area B, the inundated area from the DEM is shown to extend inland a small amount just past the driveway and this can also be seen in the oblique image. Area C shows the water pooling inland from the trail but not including the driveway. Finally in Area D, a small path area is evident in both images with the water reaching the feature but not overtopping it. The DEM does a good job of representing the general inundation pattern in the area.

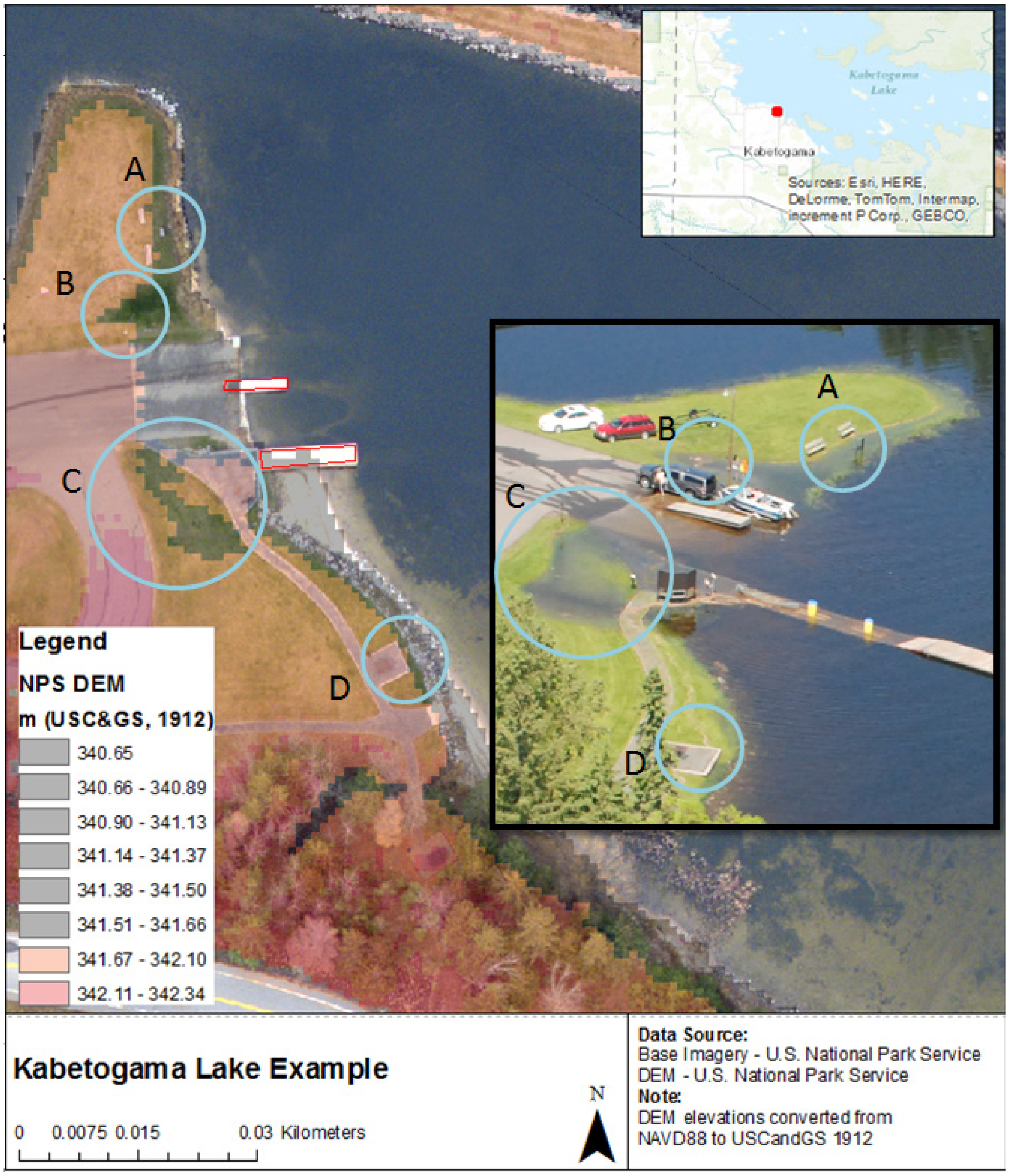


Figure 2-22: Example of oblique photography and DEM data for a portion of the Kabetogama Lake shoreline

A range of shoreline impacts was observed during the 2014 high water period. An online survey was prepared in conjunction with staff from the International Joint Commission and members of the International Rainy-Lake of the Woods Watershed Board to obtain property owner reports on the types and extent of high water impacts observed on their properties. The surveys were anonymous and responses could only be linked to a specific lake within the study area and not to a specific structure within the database. However, the results of the online survey complemented the previous face-to-face property owner surveys undertaken in 2013 by KRC. In the context of the development of a flood impact assessment tool, the goal of the online survey was to determine the extent of damages being reported by individuals, along with the nature of the high water impacts. A copy of the survey is provided in Appendix D. There were 205 usable survey submissions within the study area with over 96 percent of those submissions from the shoreline of Rainy Lake on the Canadian and US shoreline, although only about 70 percent of the database structures are associated with Rainy Lake. Surveys were considered unusable if they were submitted with no responses to any questions, they were identified as "test" responses prior to the survey going live, there was an incomplete survey submitted adjacent to a completed survey from the same IP address, or the survey response was for an area outside the project geographic boundary. Table 2-10 summarizes the results by category.

	Lived-In	Non-Lived-In	Docks
Number of Damage Reports	21	94	172

Table 2-10: Number of survey responses with damage, by structure category, for the 2014 property owner survey

Based on the survey results, there were 172 responses with dock damages, 94 responses with non-lived-in building damage, and 21 responses with lived-in building damage. The responses were not mutually exclusive. There were situations when respondents reported damages in more than one category. As well, survey respondents could report damages to more than one non-lived-in building (e.g., damages to both a shed and a gazebo). As a result, there were more than 94 non-lived-in buildings identified in the surveys. There were 15 survey submissions where no damages were reported in any of these three categories. The information from the survey related to damages to docks and buildings was used in the development of the flood damage evaluation tool to estimate the extent of damages to different shoreline structures based the type and extent of inundation.

In addition to the three damage categories identified above, a number of property owners reported damages in other categories. There were a range of alternative impacts reported although they could be broadly categorized as damages to shoreline property (e.g., landscaping, vegetation, etc.) and impacts associated with loss of use (e.g., lack of access to an island property, etc.). Based on the survey results, it was clear that these alternative impacts represented an important perspective on challenges observed by property owners during the 2014 high water conditions. Unfortunately, some of the identified impacts were also difficult to quantify in a flood damage estimation effort based on the extent of information that was available (e.g., estimating the extent of flooding to landscaped property and in turn, the associated replacement costs). In the current project, the quantitative assessment of the 1970 and 2000 rule curves was limited to the building, dock, and boathouse categories established within the database with the additional information from the 2014 online survey used to provide a qualitative description of additional associated impacts that were likely to occur. The current indicators generally associated higher water levels with higher damages and were considered adequate to support a relative comparison of the 1970 and 2000 rule curves. Other indicators could be added in the future if they represent a significant damage category, are quantifiable, or respond differently to water level changes than the current suite of indicators.

2.6 Establishing stage-damage functions for individual structures

2.6.1 Estimation of cost metrics for structure types

The US Army Corps of Engineers (2013) document on the flood risk management illustrates the challenges in establishing appropriate values for assets that may be lost in flood conditions. Specifically, the document notes that the appropriate value for an asset should be the owners willingness to pay to replace it. The critical point is that the estimation of damages should not inherently include a betterment as part of the damage estimate. If a dock that is old and has not been well maintained is destroyed by a flood and needs to be replaced. The flood damage estimate should not be the cost to put up a brand new dock with the same (or more) attributes as the old one because that represents an improvement on the structure that was impacted by the flood. Instead, the flood damage estimate should be based on the owners willingness to pay for the dock that was lost which would generally be less than the new replacement cost due to depreciation of the structure over time. For building values, the US Army Corps of Engineers (2013) recommend the use of the depreciated replacement value. As the document notes, “a brand new version of a given product is not valued at an amount equal to what the old one was worth” (USACE, 2013, 30).

Unfortunately, it is difficult to determine “representative” values for use in a flood damage assessment. Due to the size of the Rainy Lake and Namakan chain of lakes database (>6200 structures), it was not possible to undertake site visits to assess a specific value for each structure that incorporates characteristics like the age of the structure and the level of maintenance and these attributes could not be included in the geospatial database to get a full understanding of depreciation impacts. Instead, attempts were made to determine ***reasonable*** estimates of value based on the size of the structure and its expected use. Clearly, such an approach is limited in accounting for structure specific characteristics such as age, degree of maintenance, etc. and does not strictly account for the willingness to pay value of each specific structure. However, the approach allows for a baseline to compare flood damage estimates. Further sensitivity testing of the structure values is also possible within the flood damage model.

A variety of reference sources were used to support the valuation including the results from the 2013 property owner survey by Kenora Resource Consulting (KRC) and the online flood damage survey from 2014. The following descriptions outline various value estimates for docks and various buildings within the geospatial database. The value estimates represent a $\$/m^2$

multiplier that were used with the structure footprint area as represented in the database by the Shape_Area value for each individual structure to estimate a total value.

2.6.1.1 Value of docks:

The primary means of estimating the $/m² dock value was based on the responses to the 2014 public survey on observed flood damages. Respondents were asked to estimate the extent of flooding damage to their dock, both as an absolute damage and as a percent of the overall dock value. From this information, an estimate was made of the overall dock value. Figure 2-23 illustrates the distribution of estimated dock values based on 142 responses (mainly Rainy Lake but a few from the Namakan chain of lakes as well). The average dock value was $25,000 and the median value was $12,500. The standard deviation value was $29,000 and was influenced by a small number of expensive docks with the maximum estimated value of greater than $100,000.

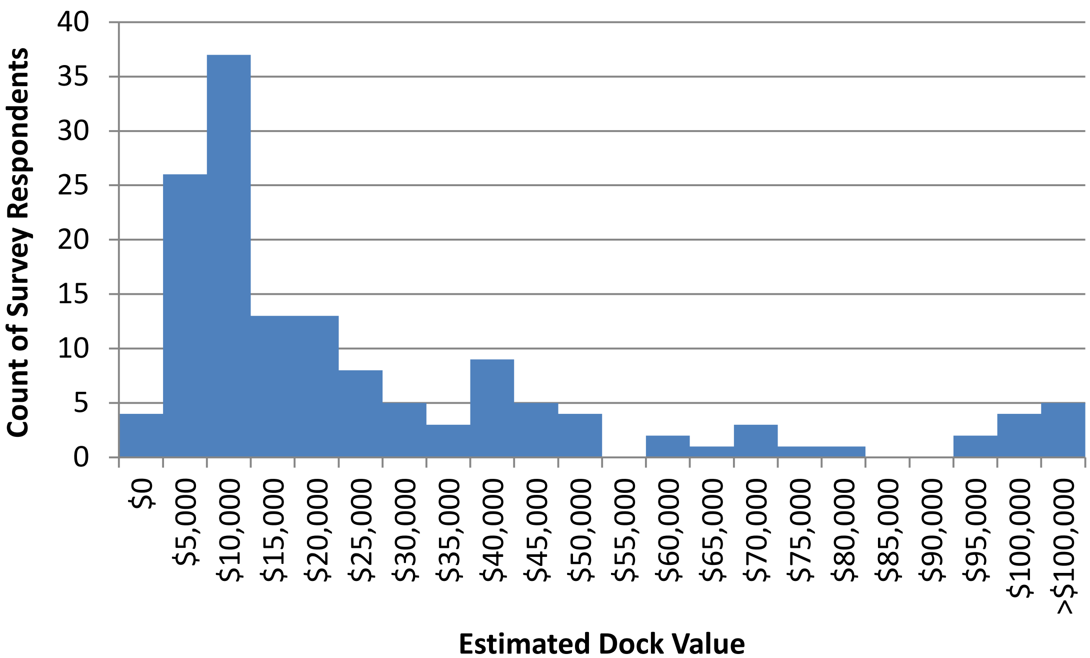


Figure 2-23: Estimated dock value based on 2014 flood damage survey responses

Using the geospatial database, all docks from the US side of Rainy Lake were categorized into 10 m² bins based on their dock area to look at the overall distribution (Figure 2-24). Based on 987 docks in the database for Rainy Lake, the average dock area was 47.16 m² and the median dock area was 32.95 m². Table 2-11 shows the average and median dock area (from database) and values (from 2014 survey). The intent was to identify a cost per m² ($xxx/m²) estimate that would scale the median (or average) dock areas with the median (or average) dock values. Estimates of cost per m² were obtained by dividing the dock value by the dock area. For average dock value divided by average dock area, the estimate was \$530/m^2 while for the median values, the estimate was \$379/m^2. Using the median values to scale the dock area for the 987 Rainy Lake (US) docks returns an average dock value of \$17,872 and a median value of \$12,489. If the average dock area and average dock value were used to scale the dock areas in the database (\$530/m^2), the average and median dock values would be higher at \$24,992 and \$17,466 respectively. Figure 2-25 shows the distribution of dock values using the median estimate of \$379/m^2.

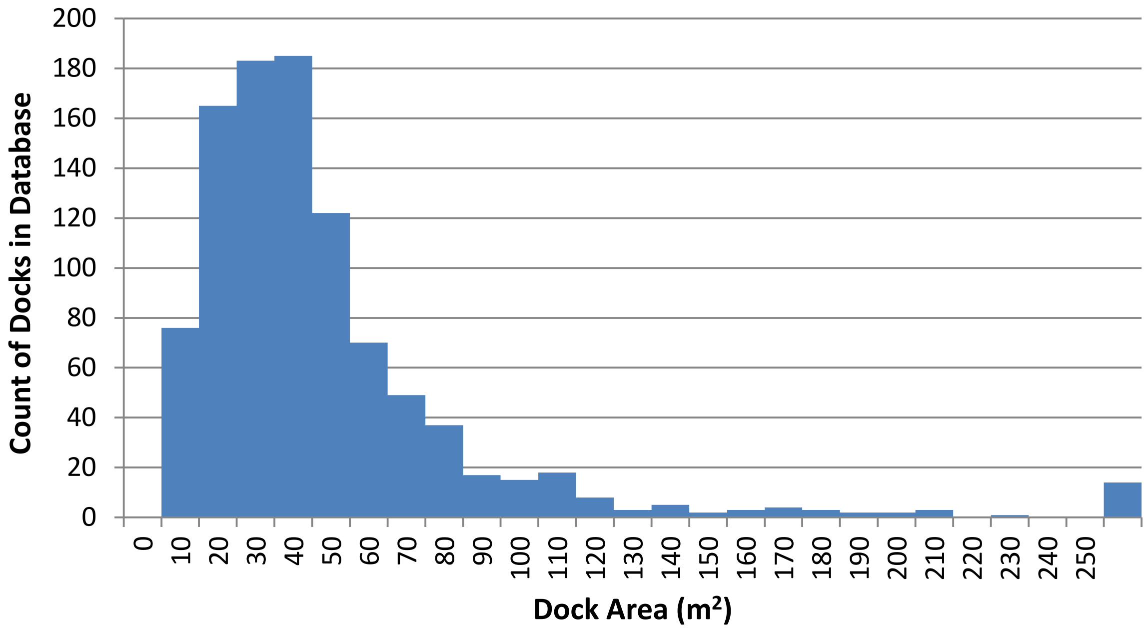


Figure 2-24: Distribution of dock area for docks on Rainy Lake (US) within the geospatial database

	Dock Area	Dock Value	\$/m^2
Average	47.16	\$25,000	\$530
Median	32.95	\$12,500	\$379

Table 2-11: Average and median dock area, value, and \$/m^2 estimate

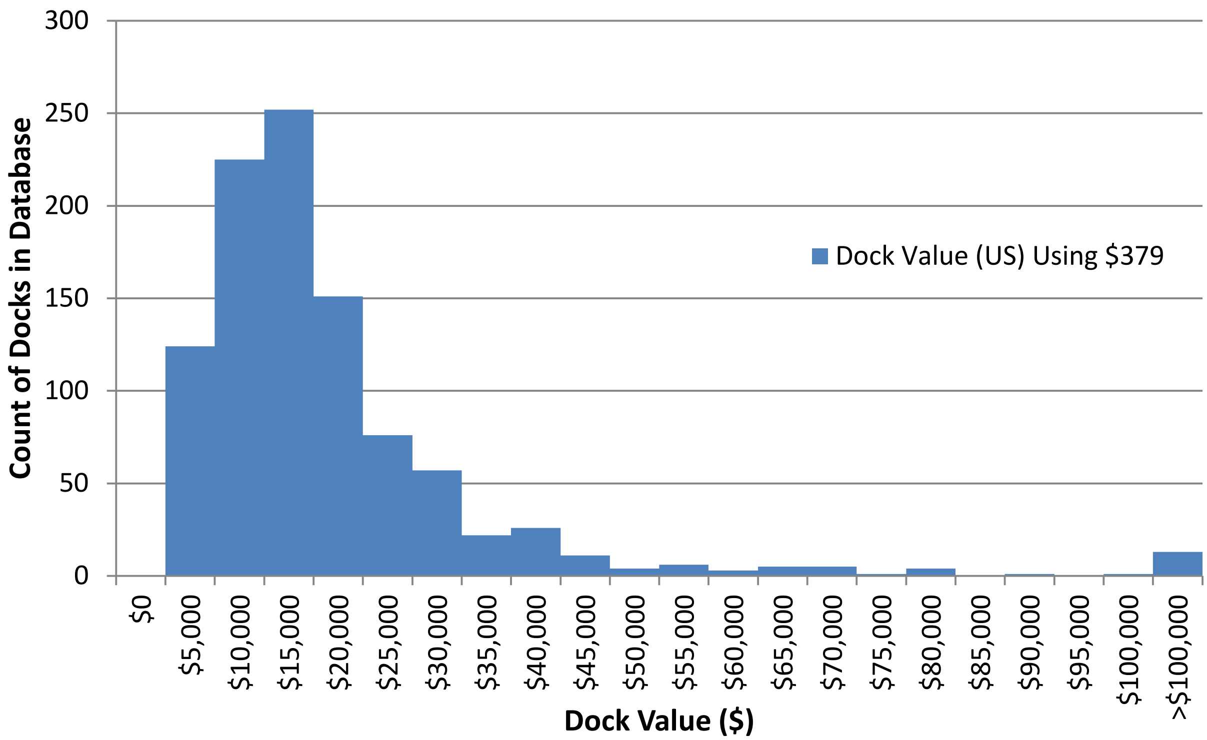


Figure 2-25: Rainy Lake (US) dock value using $379/m^2 estimate

Baird & Associates also undertook a review of possible structure costs by looking at the cost to purchase _new_ docks. The information was generally obtained by reviewing unit costs for new dock building by various dock construction companies. Further information is available in Baird's 2015 model summary report (Appendix E). Based on their work, estimated costs for new docks (pipe or floating) were between $287/m^2 and $700/m^2.

For the current assessment, it was decided to try and match the median dock values with the Rainy Lake docks so the lower value of **$379**/m^2 was utilized as the baseline scaling factor for all docks in the study area (Rainy Lake and the Namakan chain of lakes). No attempt was made to adjust the dock scaling factor to other areas of the system (e.g., Kabetogama Lake).

2.6.1.2Value of non-lived-in buildings:

Estimating building values for non-lived-in structures was challenging because such buildings have a wide range of uses and possible designs (e.g., sheds, saunas, garages, boathouses, etc.) and construction techniques (e.g., different footing and foundation types). In some cases, such buildings are small and do not require a building permit so the level of construction and the materials used can vary considerably. Although not unique to non-lived-in structures, the ages can also vary widely leading to different levels of depreciation that are difficult to account for as part of a regional estimate. Table 2-5 in Section 2.4 above illustrates a couple examples from the field survey. If there is an assessment value for larger structures on individual properties, it is usually only a component of the overall building assessment value with the primary lived-in structures representing a larger (but not necessarily consistent) proportion of the value. In the context of the development of a flood damage evaluation tool for Rainy Lake and the Namakan chain of lakes, the primary requirement was to establish a ***reasonable*** estimate for non-lived-in buildings in the area recognizing that it would not be possible to account for the wide range of variability in value that exists within the study area. Although gazebos and boathouses were identified as separate building types within the geospatial database, information was not available to provide unique building values for this project and they were instead included within the values captured for non-lived-in buildings. The primary sources for establishing a value estimate were the property owner responses to the 2013 field survey and the 2014 online property owner survey of flood damages, along with input from Baird & Associates (2015).

As part of the 2013 field survey and site visits, property owners and KRC staff identified non-lived-in structures on individual properties that were considered potentially at risk of flooding based on the historical flood of record (approximately 1950 levels). For the structures identified, property owners were asked to estimate the approximate replacement value. There were 25 respondents that provided an estimate of the replacement value of their non-lived-in structures. Based on all the responses, the average replacement cost was $25,680 (Table 2-12) and the median value was $13,333. Figure 2-26 shows the distribution of responses. On Rainy Lake, there were estimates for 20 sites and the average value was $23,680. Of the 12 Canadian sites, the average was $33,680 while for the eight US sites, the average was $8,688. There were only five responses on the Namakan chain of lakes with the average value of $33,667 (Table 2-13).

	Total	Count	Percent Reporting	Total replacement cost	Average replacement cost
Rainy (Can)	47	12	25.5	$404,167	$33,681
Rainy (US)	41	8	19.5	$69,500	$8,688
Kabetogama	22	4	18.2	$138,333	$34,583
Ash River	7	1	14.3	$30,000	$30,000
Crane	14	0	0	$0	$0
All Sites	*131*	*25*	*19.1*	*$642,000*	$25,680

Table 2-12: Summary of responses related to estimated outbuilding replacement costs, by priority area

	Total	Count	Percent Reporting	Total $ replacement cost	Average replacement cost
Rainy	88	20	22.7	$473,667	$23,683
Namakan Chain	43	5	11.6	$168,333	$33,667
All Sites	*131*	*25*	*19.1*	*$642,000*	$25,680

Table 2-13: Summary of responses related to estimated outbuilding replacement costs, by lake

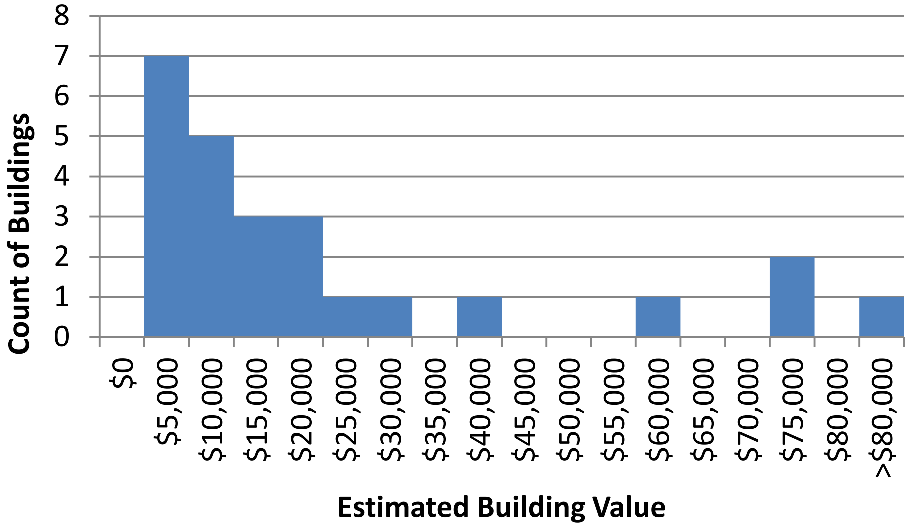


Figure 2-26: Distribution of non-lived-in building value based on 2013 survey

To further refine the results and to establish a baseline cost per m^2 ($xxx/$m^2$) value using building footprint, the estimated values provided by property owners were compared with the size of the specific building footprint as available from the geospatial database (Figure 2-27). There was a very poor relationship between the building size and the owner value estimates when all sites are used (note intercept set to 0). In some cases, small buildings have a high replacement value and in other cases, large buildings have a relatively low replacement value. Removing some of the outliers from the comparison (Screened Value Estimates on Figure 2-27, intercept set to 0), the relationship remained poor (r^2 of only 0.2295). However, the characteristics and uses of the identified structures varied considerably and building size (footprint) was only one factor that would contribute to an estimate of value. Given that this was the only factor that could be considered in the current analysis in order to provide value estimates for all the structures in the database, there may still be value in using the outcomes of the comparison. With the intercept set to zero, the building value can be estimated by multiplying a building footprint value by **$390/m^2**.

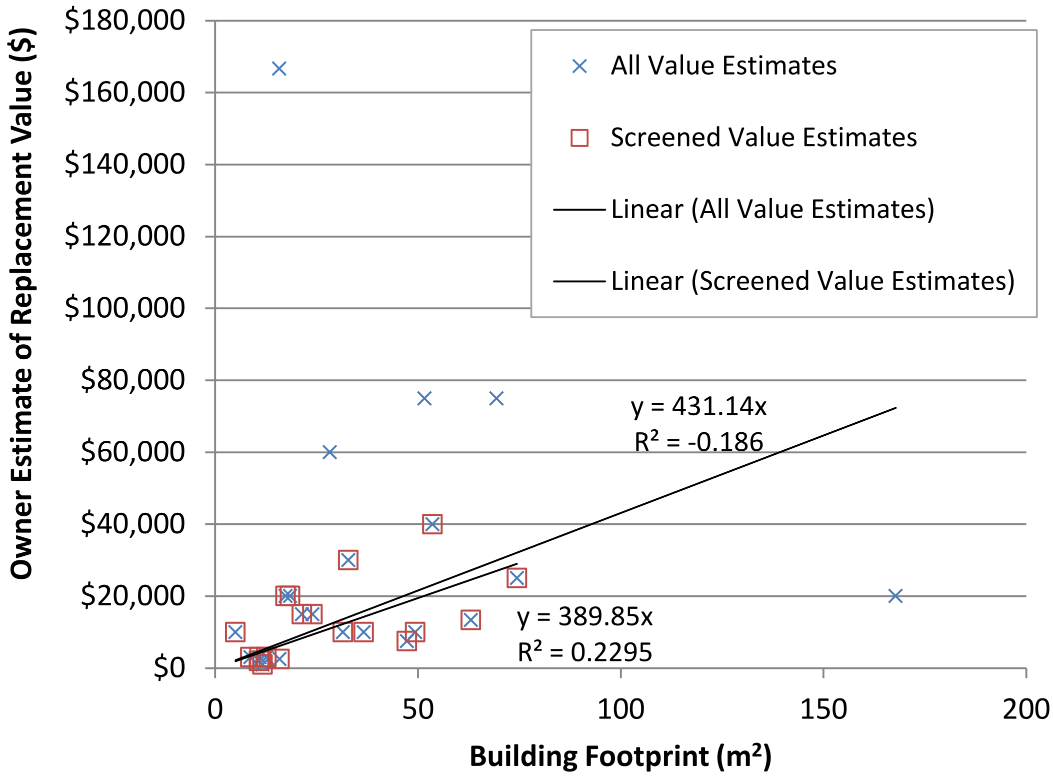


Figure 2-27: Comparison of building footprint size and owner estimates of replacement value from 2013 site visits

As part of the 2014 Property Owner survey, respondents that experienced flood damage to non-lived-in structures were asked about the damage ($) to their structures as well as the percent of total value the damage represented. Value estimates were provided for 87 structures that experienced flooding. Using this information, the average structure value was $9,667, although the median value was much lower at $4,167. The standard deviation was high at $19,357 based on reports for a few high value structures that were damaged. Just over 60 percent of the non-lived in structures where flood damages were reported had an estimated value of $5,000 or less and the highest reported value was over $50,000. The values estimated from the 2014 property owners survey were generally lower than the estimated values from the 2013 survey. In the 2013 survey, there were very high value buildings included in the estimates including 4 (of 25) building estimates >$60,000. With the high values removed (the "screened" subset), the average value was $12,649 and the median value $10,000 which was closer to the 2014 values.

Using all non-lived-in buildings from the Rainy Lake (US) database with an elevation below 338.8 m USC&GS 1912 (an approximation of the peak flood elevation from 2014) to be comparable with structures where flooding would have occurred, a distribution of building footprint size was produced (Figure 2-28). Figure 2-29 shows a distribution of the building values as estimated from the 2014 survey. There were many similarities in the appearance of the distribution (highly skewed with the majority of structures being small and very few being large). Table 2-14 shows the average and median building values based on the non-lived-in structures in the database along with the average and median values based on the 2014 survey results. Like the dock analysis, a cost per m^2 ($xxx/$m^2$) value estimate was determined by dividing the area by the value. Due to the skewed distribution, the median building size with the median reported building value from the 2014 survey results was identified as reasonable. Figure 2-30 shows the distribution of the estimated building value based the building footprints for Rainy Lake identified within the database and a value estimate of **$190**/$m^2$. This value is considerably lower than the **$390**/$m^2$ value estimated the 2013 survey results, however it also is based on a larger dataset and on the property owners true assessment of damages as the reports were based on real flooding conditions while the 2013 survey was not. As well, the 2013 survey included any building that could potentially be flooded up to the 1950 flood of record and it is possible that there were a number of higher value structures as the elevation increases and the long-term risk of flooding is reduced. The higher value could be used for sensitivity testing of model results as necessary.

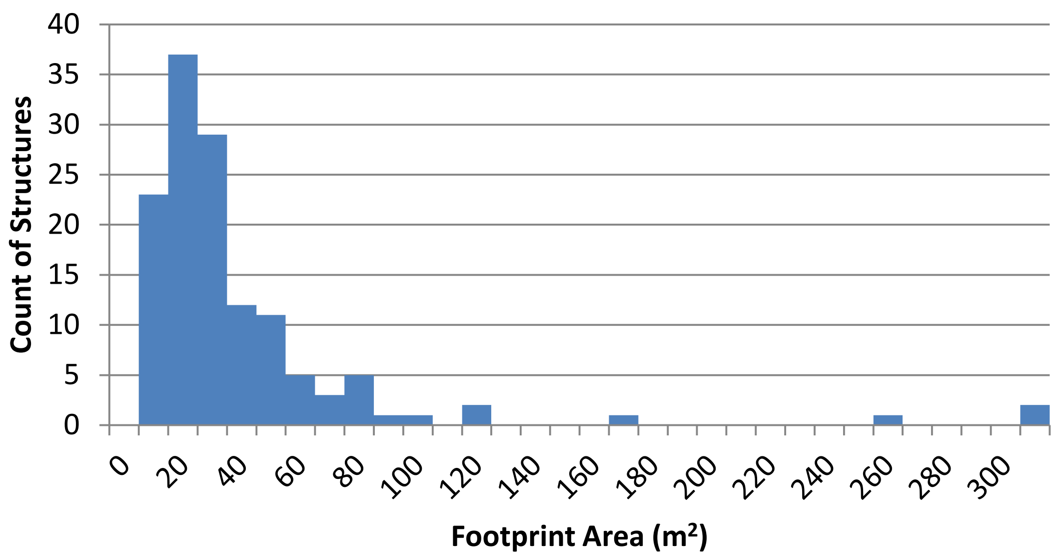


Figure 2-28: Distribution of building footprint area for non-lived-in buildings on the US shoreline of Rainy Lake below 338.8 m USC&GS

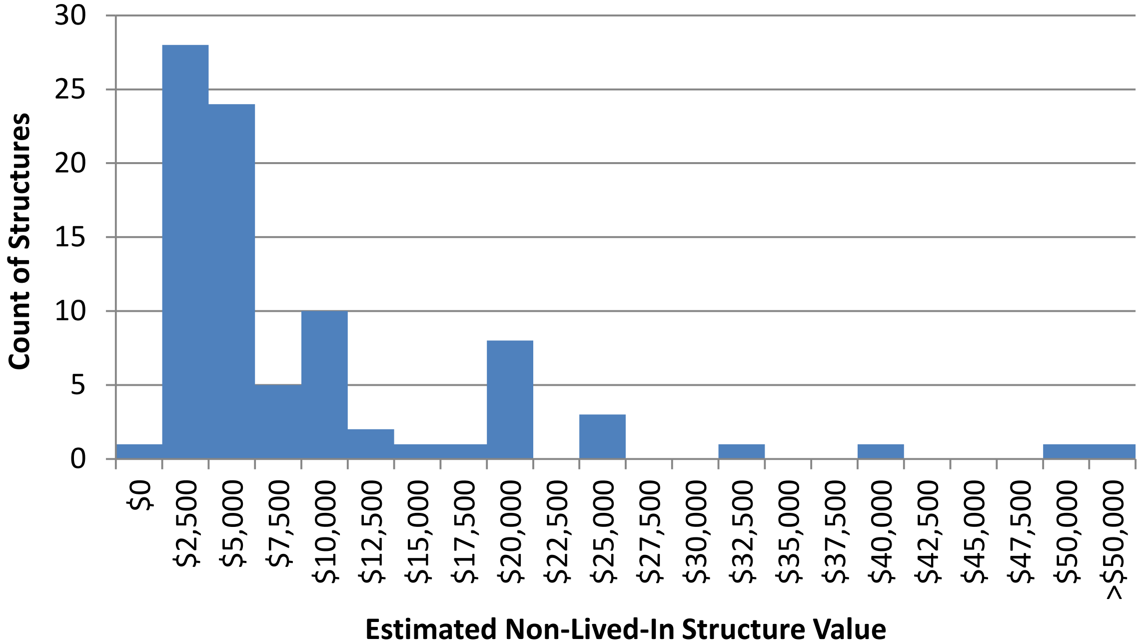


Figure 2-29: Distribution of estimated non-lived-in structure value based on 2014 property owner flood damage survey

	Building Area	Building Value	$/m^2
Average	47.21	$9,667	$205
Median	21.84	$4,167	$190

Table 2-14: Average and median building area, value, and $/m^2 estimate for non-lived-in buildings below 338.8 m USC&GS 1912

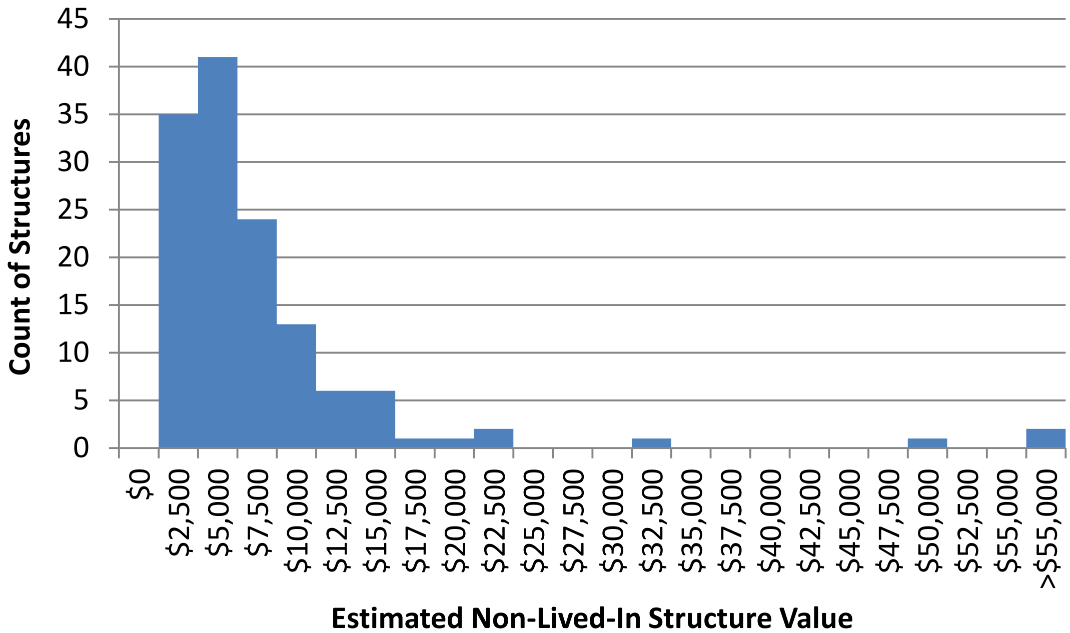


Figure 2-30: Distribution of estimated building value based on Rainy Lake (US) non-lived-in structure size and the median $/m^2 value estimate from the 2014 flood damage survey

Baird & Associates (2015) also looked at non-lived-in building values by reviewing construction costs for basic sheds and other structures with local hardware stores and builders. Based on their review, values for new structures ranged from $256/m^2 to $338/m^2 to $962/m^2 depending on the characteristics of the building being considered. For the baseline value used in the model, a value of **$338**/m^2 was used. This value was higher than the estimates developed by the survey techniques ($190/m^2 or $205/m^2) but was still at the lower estimate the Baird results for new construction.

2.6.1.3Value of lived-in buildings:

Various potential data sources for the estimation of building values were considered for use within the geospatial database. They include the results from the 2013 property owner survey, results from the 2014 online flood damage survey, builder estimates, and the use of assessment data.

Just like non-lived-in buildings, the value of lived-in buildings can vary considerably based on the use of the building (e.g., all year home vs. seasonal cottage), the construction and foundation type, whether the cottage is winterized for all-year use or whether it is only used in summer, and the geographic location relative to services (e.g., road access structures vs. boat-only access). The shoreline of Rainy and Namakan lakes has a range of building types that would be identified within the lived-in building category (see Table 2-5 in Section 2.4). Clearly, estimating building value based only on building footprint size is highly uncertain and is not expected to be a true representation of building value on a site-by-site basis. This is an area of the model with a high potential for improvement and refinement in the future including the opportunity to attribute site-specific building values. Despite the current uncertainty, the following discussion outlines sources of data for estimating building value in the context of the current development of a flood damage assessment tool for Rainy Lake and the Namakan chain of lakes.

During the 2013 field survey, lived-in (main) buildings that would potentially be flooded by water levels approaching the 1950 flood of record were identified and property owners were asked to estimate an approximate value. Value estimates were obtained for 16 of the 131 properties visited within the study area where there were lived-in buildings considered at risk (the remaining properties did not have buildings at risk). Due to the small sample size, there was a lot of variability in the average value. Based on all 16 respondents, the average replacement cost was estimated at $320,000 (see Table 2-15). For just the US properties, the average value was $237,000 while for just the Canadian properties, the average value was $458,000. On the Canadian side, three of the six buildings with estimated replacement costs were for business operations. They were generally valued higher than the residential buildings. For example, one Canadian estimated replacement cost was $1 million which greatly impacted the results due to the small sample size.

	Total	Count	Percent Reporting	Sum of Estimated Replacement Value	Average Replacement Value
Rainy (Can)	47	6	12.8	$2,750,000	$458,333
Rainy (US)	41	8	19.5	$1,770,000	$221,250
Kabetogama	22	1	4.5	$100,000	$100,000
Ash River	7	0	0	0	0
Crane	14	1	7.1	$500,000	$500,000
All Sites	*131*	*16*	*12.2*	*$5,120,000*	$320,000

Table 2-15: Summary of responses related to estimated main building replacement costs, by priority area

Using the building footprints digitized within the geospatial database, the estimated values (by property owner) were linked with the specific building footprint to relate two values. Figure 2-31 illustrates the relationship for 14 of the 16 buildings with estimated values. Two of the properties were removed from this comparison as they were considerably larger than the rest of the sample (in footprint size – one being twice as large as the next largest building and one being four times as large) and their use was considered sufficiently different that they should not be included in the comparison (one being a restaurant and one a hotel/restaurant). Using the 14 remaining buildings, the average estimated value was $273,000 and the median value was $250,000. Setting the x-intercept to zero, the estimated building value was $1,355/m^2. That is, using the owner estimates of building value for the small sample of 2013 site visit respondents would result in a building footprint area scalar of **$1,355**/m^2. There was a fair amount of variability with a low r^2 of 0.4299.

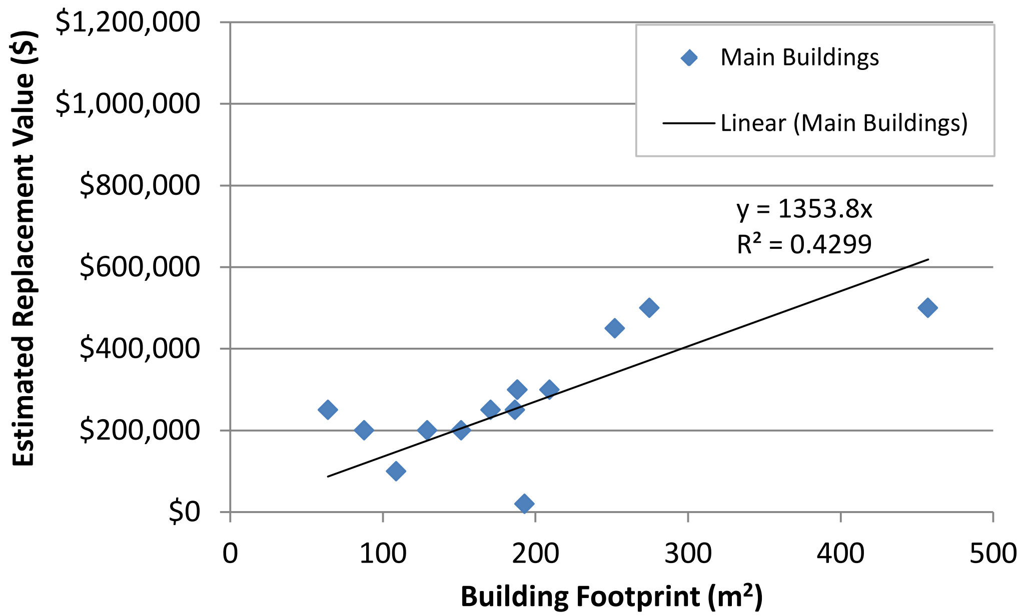


Figure 2-31: Comparison of building footprint and owner estimate of replacement value based on 2013 site visits

Respondents of the 2014 Property Owner survey were asked about the damage ($) to their lived-in structures as well as the percent of total value the damage represented. Value estimates were provided for 20 structures that experienced flooding. Using that information, the average structure value was $93,253, although the median value was much lower at $55,250. The standard deviation was high at $121,913 based on reports for a few high value structures that were damaged. All but two of the 20 reported structures were $140,000 or below. The remaining two were estimated at $350,000 and $500,000 respectively. The values estimated from the 2014 property owners survey were generally lower than the estimated values from the 2013 survey. The 2014 survey only represents buildings that were damaged by flooding and therefore at a low elevation whereas the 2013 survey includes buildings that could be flooded during higher water level conditions. It was reasonable to assume that some of the buildings at higher elevations would also have a higher value as they would be considered less vulnerable to flooding conditions in the long-term.

Using all buildings from the Rainy Lake (US) database with an elevation below 338.8 m USC&GS 1912 (an approximation of the peak flood elevation from 2014) to be comparable with structures where flooding would have occurred, Figure 2-32 shows a distribution of building footprint size. Figure 2-33 shows a distribution of the lived-in building values as estimated from the 2014 survey. As with the non-lived-in structures, the distributions are highly skewed with the majority of structures being small (low value) and very few being large (high value). Table 2-16 illustrates the potential building values using both the median and average building values from the 2014 survey and building size. Due to the skewed distribution, the median building size with the median reported building value from the 2014 survey results was identified as a reasonable. Figure 2-34 shows the distribution of the estimated building value based on **\$700**/m^2. This value was considerably lower than the **\$1,355**/m^2 value estimated the 2013 survey results, however it also was based on a slightly larger dataset and reflects buildings of lower elevation that would typically be more vulnerable to flooding.

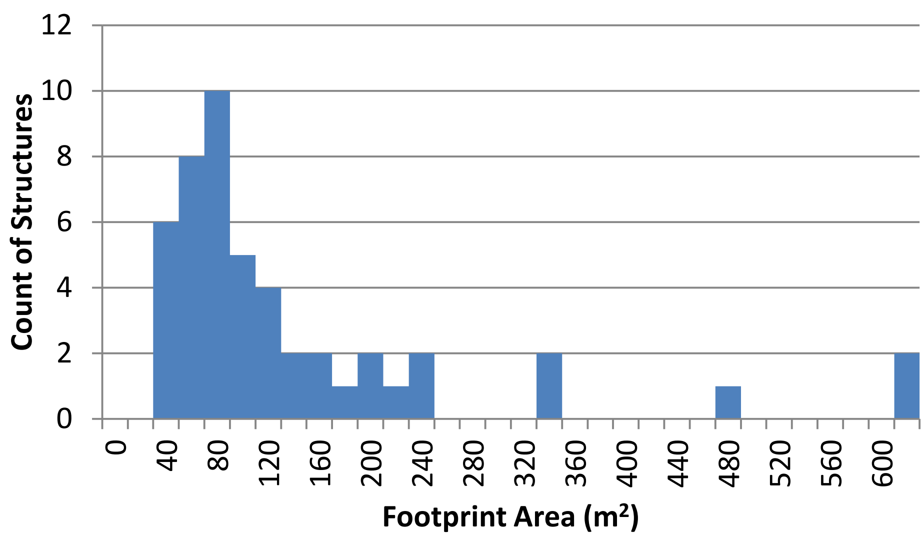


Figure 2-32: Distribution of building footprint area for lived-in structures on Rainy Lake (US) below 338.8 m USC&GS 1912

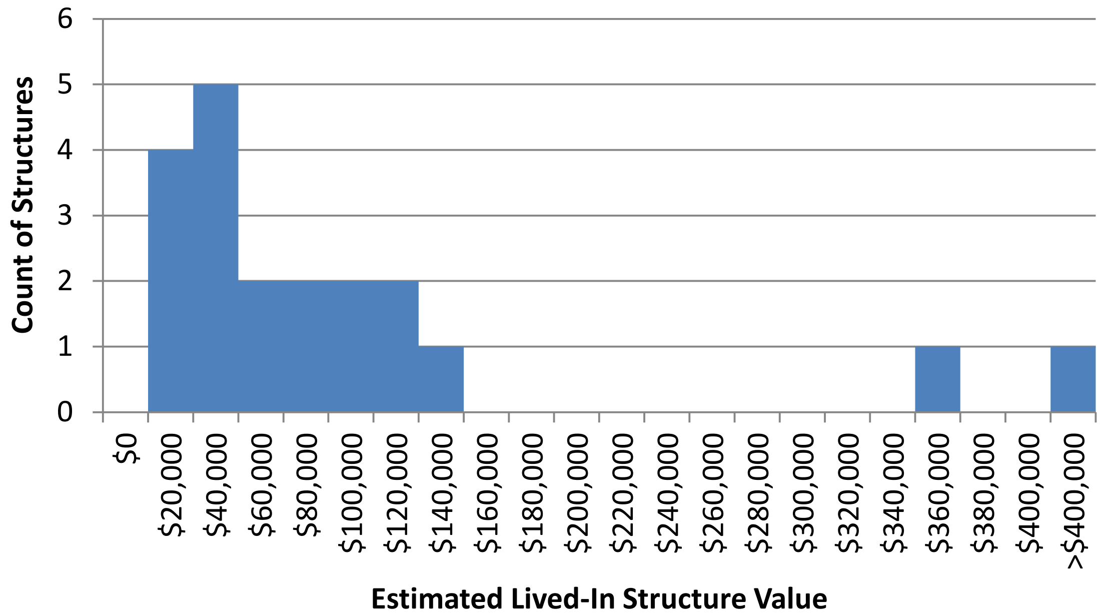


Figure 2-33: Distribution of estimated building value based on 2014 flood damage survey

	Building Area	Building Value	$/m^2
Average	145.40	$93,253	$640
Median	79.18	$55,250	$700

Table 2-16: Average and median building area, value, and $/m^2 estimate for lived-in buildings below 338.8 m USC&GS 1912

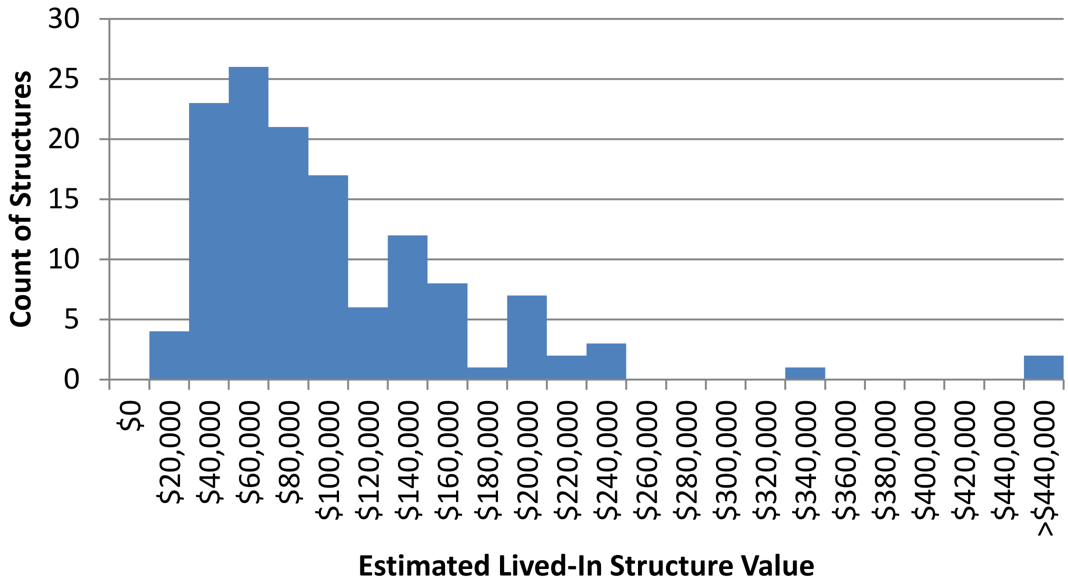


Figure 2-34: Distribution of estimated building value based on Rainy Lake (US) lived-in structure size and the median $/m^2 value estimate from the 2014 flood damage survey

Property assessment data represents an important source of property information which captures a range of building and property characteristics. Assessment data is usually reported as the land portion, the building portion, and the total assessment value. Access to property assessment data varied throughout the study area. In St. Louis County, assessment data was available in a database that could be linked to specific properties where the building outlines were created. The St. Louis County data covered the US shoreline of Kabetogama Lake and Crane Lake. The Koochiching County assessment data (US shore of Rainy Lake) was available online but not in a format that could be linked directly to individual buildings within the geospatial database while the Canadian assessment information must be purchased via TERANET.

Based on availability and cost, only the St. Louis County data was used for a comparison of building value and building size. The assessment database was screened to select only property outlines (parcels) that contained a lived-in building within the geospatial database that was developed for the flood damage project. In total, 70 properties were selected. Figure 2-35 shows the comparison of the main building footprint size and the assessed building value using all 70 properties. As expected, there was a high degree of variability resulting from a range of building characteristics. As well, it was possible that building footprints were not the only ones for a particular property. For example, some properties in the region contained two or more lived-in structures and it may be that only one of those was digitized due to its lower elevation. If that was the case, the assessed value would be representative of all the buildings on the property and not just the digitized one. In any event, a linear relationship is shown on Figure

2-35 with an r^2 of 0.5577 and an intercept set to 0 that results in a $**643**/$m^2$ estimate of building value. There were three outliers in the dataset that were thought to possibly impact the results and they were screened out for comparison purposes (Figure 2-35 – screened estimates). Even with the values screened out, there was little difference in the cost per m^2 (**$659/$m^2$** and an r^2 of 0.5051). Figure 2-36 illustrates the variability in the cost per m^2 values for individual structures in the dataset. For the full 70 property dataset, the average value was $620/$m^2$ and the median is $502/$m^2$ and the distribution was slightly skewed.

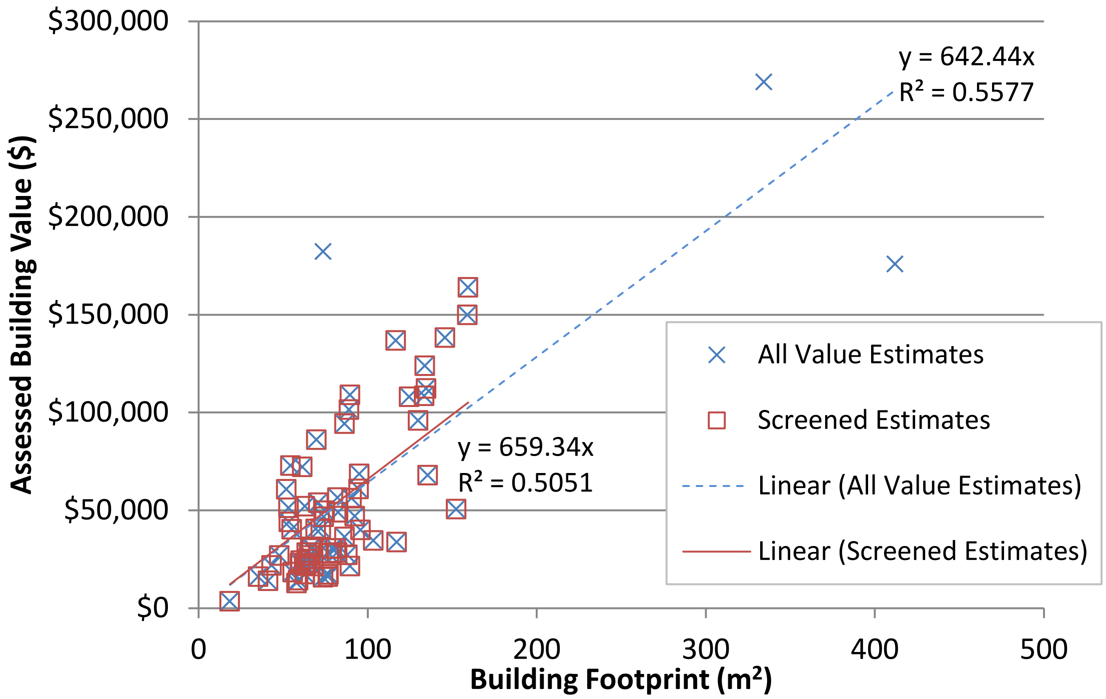


Figure 2-35: Comparison between building footprint and assessed building value for Kabetogama Lake

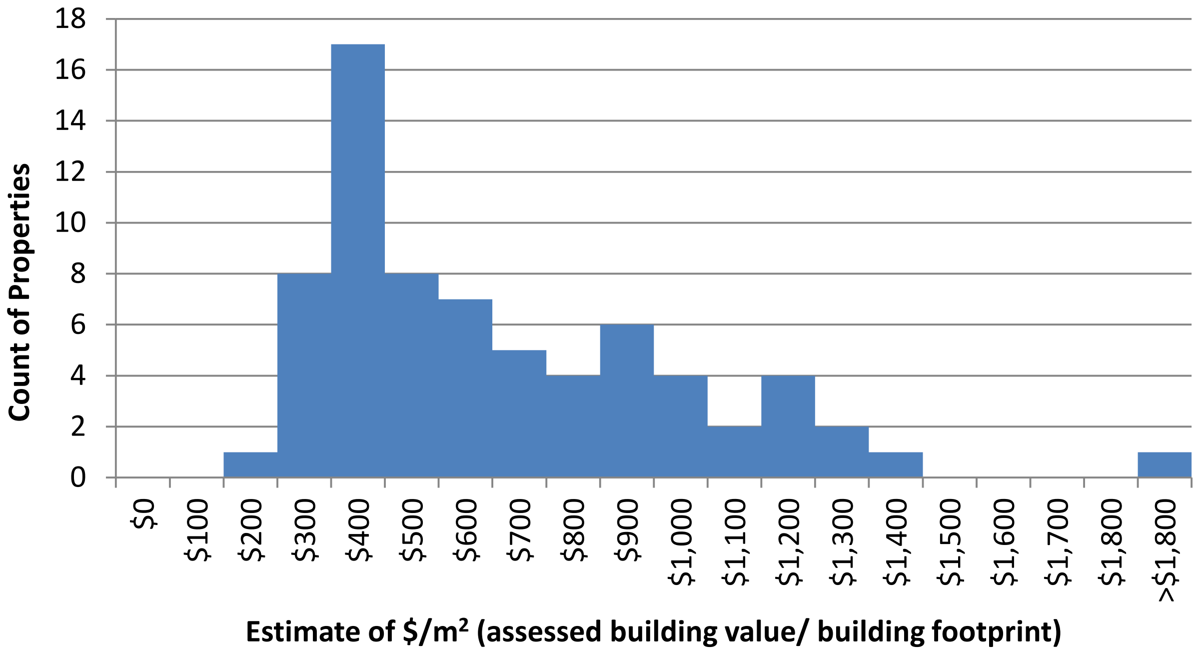


Figure 2-36: Distribution of the per $/m^2 estimates for buildings on Kabetogama Lake with an assessment value

Baird & Associates (2015) reviewed building costs for lived-in structures as part of their assessment of potential costs per m^2. The values represented the cost of *new* construction, which was slightly different than the other approaches. Values ranged from $1,176/m^2 to $1,776/m^2 for new construction which was in the range of the 2013 survey results but much higher than the 2014 survey results or results from the assessment value approaches.

2.6.1.4Value summary:

Based on the examples provided, there were a range of values that could be used for the scenario testing and model application. For docks, the current estimate was **$379**/m^2. For non-lived-in structures, the values range from **$190**/m^2 to **$962**/m^2, although the lower values seemed more reasonable for the current work. Boathouses were considered similar to the non-lived-in structure values. For lived-in structures, two of the approaches resulted in estimates in the **$640**/m^2 to **$700**/m^2 range while alternatives were as high as **$1,776**/m^2. Values in the mid to lower end of the observed ranges were considered most reasonable for use in the flood model as they were more consistent with property owner reported estimates of replacement costs as opposed to new construction estimates provided by Baird (i.e., perhaps more reflective of owner's willingness to pay, as opposed to a betterment).

2.6.2 Stage-damage functions/relationships for individual structures

The results from the 2013 KRC site visits and the 2014 online survey were used to establish stage-damage curves for individual structures within the Flood Tool. The stage-damage curves represented the extent of damage estimated for a specific structure given the depth of water inundation. There was considerable uncertainty in the development of these curves due to the high degree of variability in reported damage based on the depth of inundation. The baseline stage-damage curves for lived-in buildings were based on FEMA/USACE stage damage curves for one-floor residential buildings with no basement as defined in USACE (2000). Figure 2-37 provides the stage damage curves for both structure and contents for residential structures based on the level of inundation above the main floor.

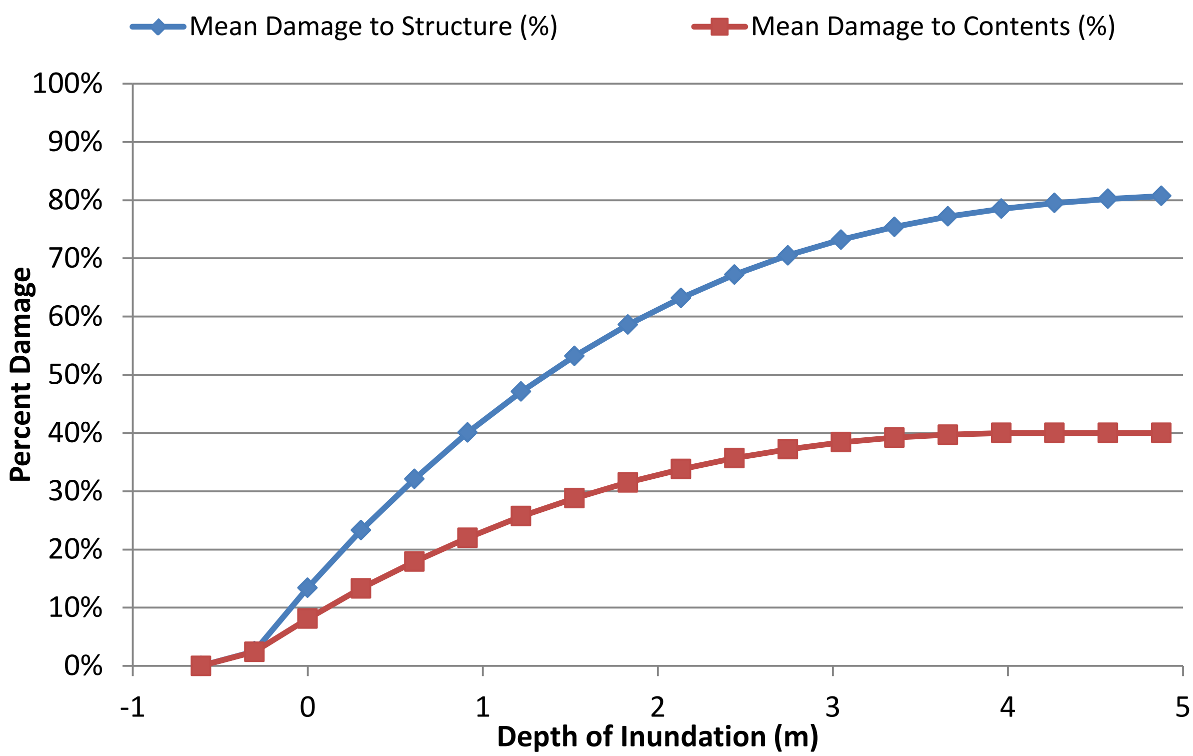


Figure 2-37: Graph of stage-damage curve for lived-in buildings (USACE, 2000)

It was more difficult to estimate damages for non-lived-in structures based on depth of inundation because there were few standard damage curves comparable to those available for lived-in buildings. Results from the 2014 property owner survey of flood damages showed a wide range of damage estimates based on the level of inundation. As well, there was a high degree of variability in structure function and construction. As an alternative, information from the 2014 property owner survey was used to create a stage-impact curve. While the survey results did not clearly link depth of inundation with extent of damage, it was assumed that such a relationship was likely to exist based on the residential stage-impact curves such as the one described previously. In the 2014 survey, the average estimated damage was 39 percent of the full replacement value and the standard deviation was 34 percent. It was assumed that average damages occurred at an inundation depth of 0.4 m. The standard deviation was used to estimate damages at the start of inundation (39 percent minus 34 percent) and at an upper amount (0.8 m) (39 percent plus 34 percent). Full damages were assumed at 2.1 m of inundation. These points were fit with a 2nd order polynomial equation which was then used to identify points for the damage curve. Damage to contents was assumed to be 75 percent of the residential building contents damage estimate for each elevation bin. Figure 2-38 provides a graphic representation. Damages were assumed to begin once inundation begins, but not before.

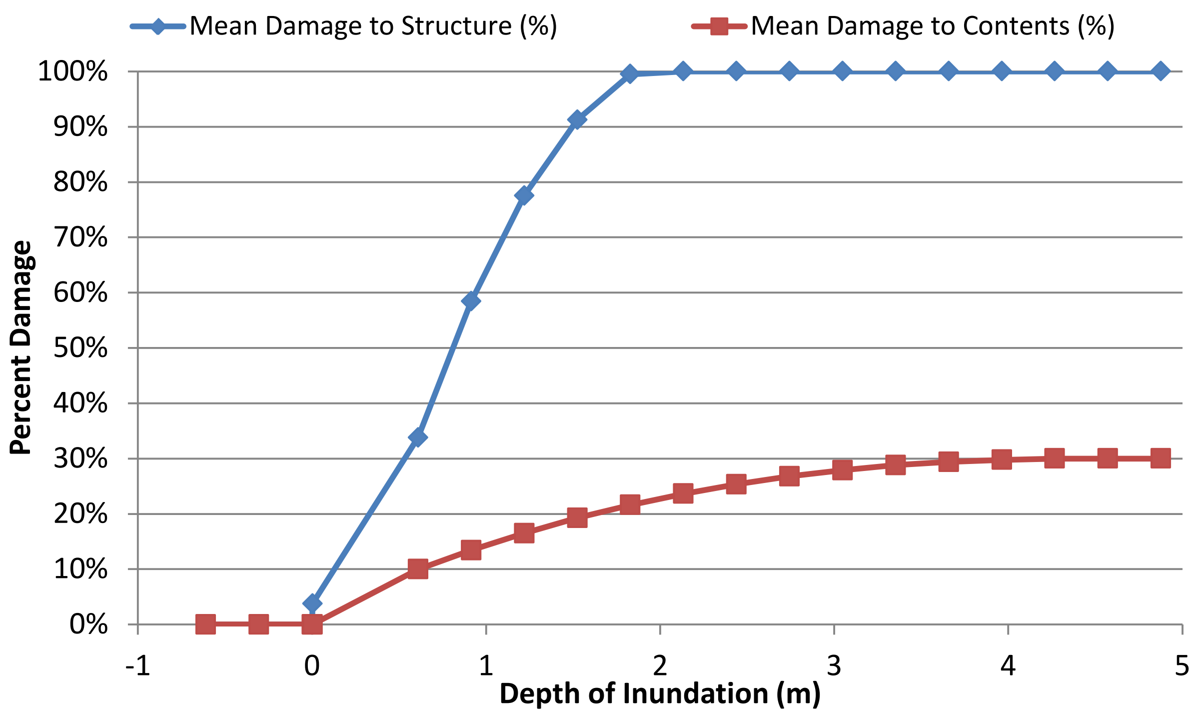


Figure 2-38: Graph of stage-damage curve for non-lived-in buildings and boathouses

For boathouses, damages were estimated by applying a similar stage-impact function to the non-lived-in buildings discussed previously. For the development of the Excel Tool, boathouses were assumed to suffer no damages until water levels exceeded the deck surface at which time economic damages would occur. There was considerable uncertainty in applying a contents damage curve to estimate damages for contents of a boathouse. However, there was no consistent information on boathouse contents value (excluding any actual boats) which could include equipment for various purposes. As such, estimates of contents damage for boathouses was represented as 75 percent of the contents value in the residential stage-impact function, just as with the non-lived-in buildings. The exception was that the residential, single story, no basement stage-impact was modified so that no damages started until the water level exceeded the estimated deck surface of the boathouse (Figure 2-38).

No standard stage-impact functions exist for docks. Based on the 2014 flood survey, there were a wide range of impacts to individual structures based on the depth and duration of inundation. No standard relationship was evident linking an estimated percent damage with a depth inundation. Some docks had very little damage and some were almost completely damaged. While exposure to waves was reported to play an important role in the results, damages were not universal for particular stretches of shoreline. Property owners with dock flooding very commonly undertook some sort of response effort to reduce potential impacts. A primary approach was to put barrels or other heavy objects on the dock to hold it in place. As such, a modified approach was required based on the survey responses received. There were 163 responses with a percent damage estimate for dock structures. The average value for the percent damage was 49.4 percent of the replacement value and the median value was 49.0 percent which was assumed to occur at 0.6 m of inundation. For development of the Excel Flood Tool, any fixed or combo dock where the water level exceeded the elevation estimate for the dock surface was considered to be inundated and subject to buoyancy issues and/or saturation that could potentially cause damages. The standard deviation of the survey results was used to estimate damages at the start of inundation (49 percent minus 35.7 percent) and at an upper amount (1.2 m) (49 percent plus 35.7 percent). Full damages were assumed at 1.8 m of inundation. These points were fit with a 2nd order polynomial equation which was then used to identify points for the damage curve (Figure 2-39). There was no contents component for the dock stage-impact functions.

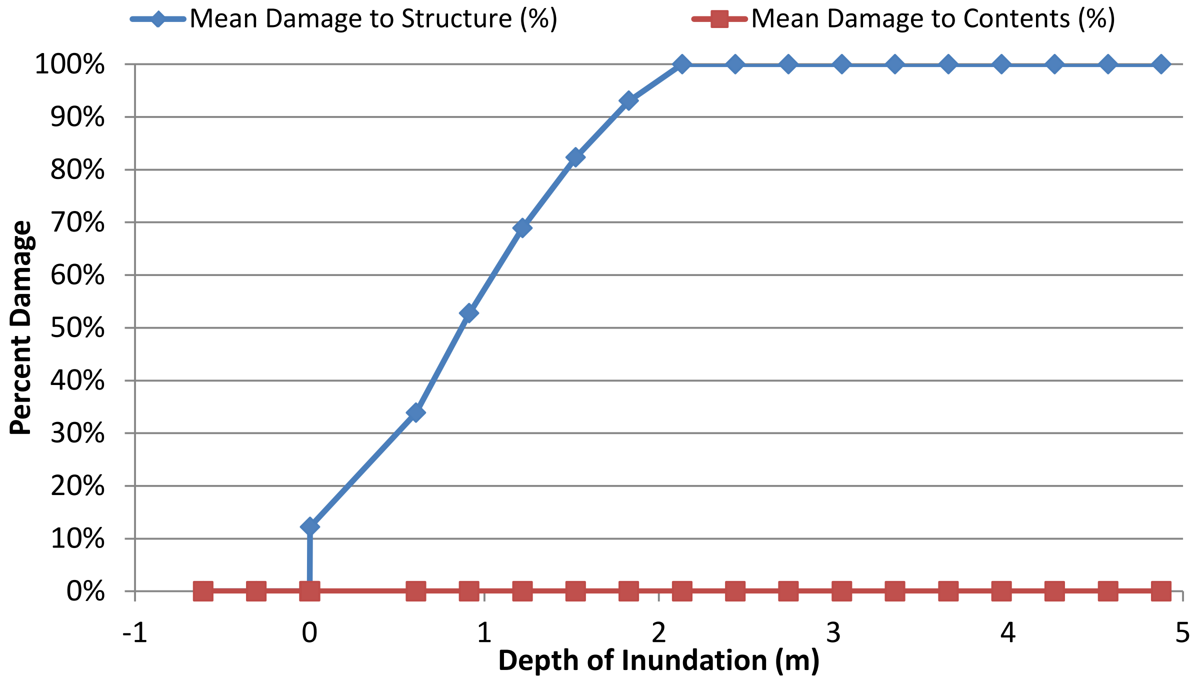


Figure 2-39: Graph of stage-damage curve for docks

Within the project database, floating docks were docks that were exclusively floating and were differentiated from combo docks as combo docks have both a fixed and floating component. Some floating docks can be quite resilient to flood conditions while others are not. Due to lack of supporting information within the current project, floating dock damages were estimated using the same curve as the fixed and combo docks. However, damages were not included in the final report at this time as it was not clear that the curve adequately represented the appropriate damage mechanisms.

3 Flood Damage Evaluation Tool

3.1 Overall flood tool framework

A spreadsheet based evaluation tool was developed to undertake the overall calculations needed to estimate flood damages to buildings, docks, and boathouses throughout the study area under a range of water level scenarios. The evaluation tool had two primary components: 1) the Input Excel Database of baseline structure characteristics, and 2) the Excel based (VBA) Flood Tool to undertake the flood damage calculations. Figure 3-1 illustrates the general framework. The following sections describe each component of the framework in further detail.

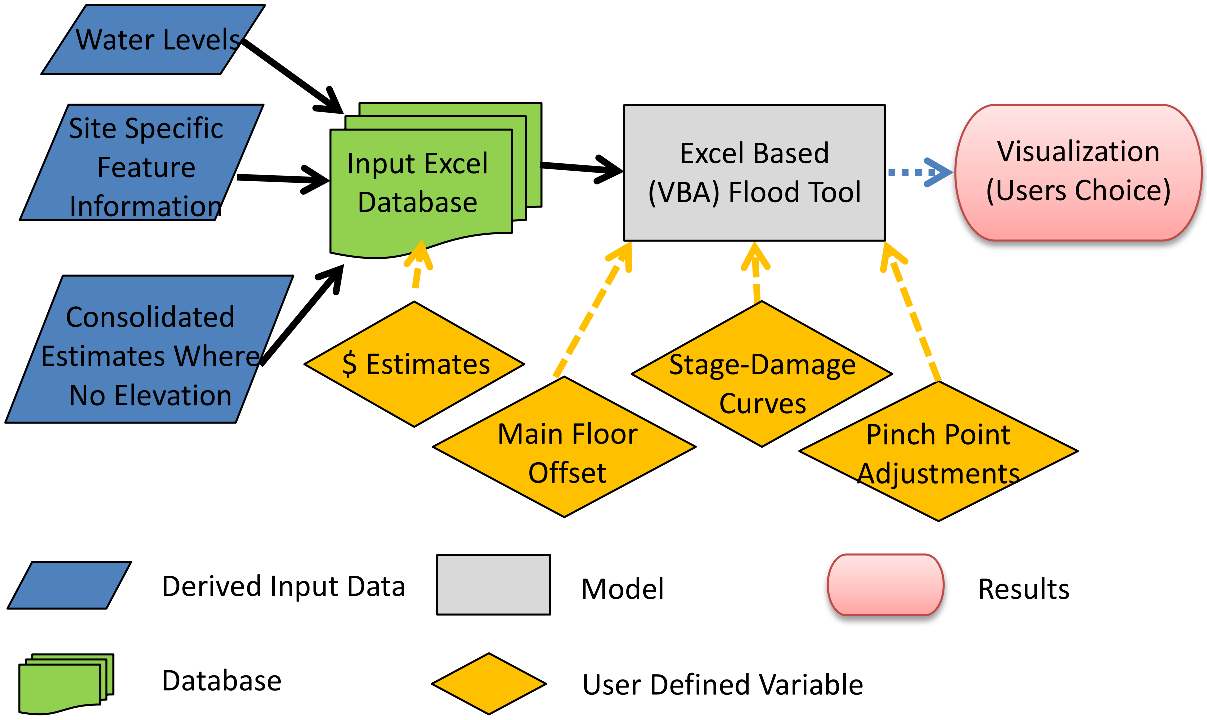


Figure 3-1: Schematic of general Flood Tool components

3.2 Flood tool development – creation of input database

An Excel file (Input Excel Database) was developed to house the site-specific input data necessary to estimate flood damages. The Input Excel Database included:

- water level data (currently based on Thompson, 2014, using updated 2016 values);
- site-specific structure information for each individual structure within the database where a site-specific elevation estimate was determined; and,
- where individual structures in the database did not have an elevation estimate, consolidated distributions of structure count and area grouped by 5 cm elevation bins.

Structures without an elevation estimate were grouped together and their distribution scaled relative to a comparable distribution using available elevation information. For example, Figure 3-2 represents the count and cumulative percent of buildings with elevation estimates at or below a particular elevation for lived-in and non-lived-in buildings on the US shore of Rainy Lake using a five cm elevation interval. Using this information, structures without known elevations were also distributed into these five cm bins, based on the assumption that they had the same elevation distribution as the buildings with known elevations. Similarly, all structures in the database were attributed based on their footprint area and that area was multiplied by a $/m^2 value (see Section 2.6.1) to estimate the replacement value of the structure needed to calculate flood damages within the Flood Tool. The footprint area of structures in the database with elevation estimates was used directly by the Flood Tool. Structures without an elevation estimate were grouped together and their total footprint area summed. The total footprint area was then scaled based on the cumulative distribution of the building footprint area for buildings in the database with an elevation estimate. The cumulative distribution was determined using five cm elevation bins.

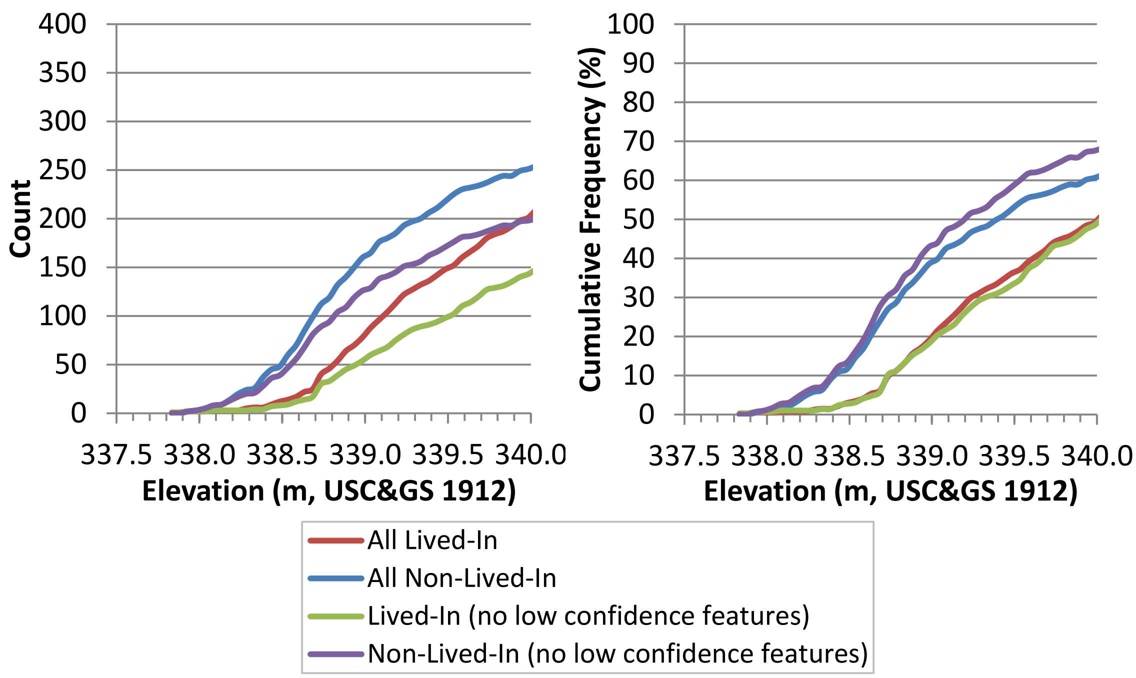


Figure 3-2: Summary of the count and percent frequency of lived-in and non-lived-in structures for the Rainy Lake (US) shoreline (note: low confidence features are ones where the structure type of lived-in or non-lived-in was assigned but with low confidence. The graph includes all buildings and ones whether the classification is high confidence)

Table 3-1 illustrates how the distributions were applied for an example of the Rainy Lake (US) shoreline. The table includes the elevation bins in USC&GS 1912 and NAVD88 in the two columns on the left hand side. The Scaler-Area and Scaler-Count represent the cumulative distribution of footprint area and lived-in structure count based on all the Rainy Lake (US) locations with known elevations (only a portion of each distribution is included in Table 2-16 to reduce the size of the table). The blue highlighted cells in the Lived-In Area and Lived-In Count columns represent the total footprint area and number of lived-in structures in the database for Rainy Lake (US) without elevation estimates. The rest of the values in those columns represent the total value multiplied by the value in the appropriate scaler column. In this case, 19.5 percent of the Lived-In area is below 338.984 m USC&GS 1912 and that represents 241.7 m^2. For the Lived-In Structure count, 19.7 percent of the structures with known elevation were below 338.984 m USC&GS 1912 which converts to two of the 11 structures without elevation estimates. Note that the Lived-In Count column cannot represent a part of a structure, so values only begin when the first whole structure is identified and are represented as whole numbers in the table. The final column (Value) represents the footprint area multiplied by the appropriate $/m^2 value as defined in the Flood Tool based on the type of structure. This process was applied for all geographic regions where a known cumulative distribution was available and there were adjacent areas on the same lake where there were structures with no elevation estimates.

Rainy Lake – US (Lived-in Structures)						
5 cm bins in USC&GS 1912	**5 cm bins in NAVD88**	**Scaler – Area**	**Scaler – Count**	**Lived-In Area**	**Lived-In Count**	**Value**
				1235.624	11	
338.684	338.85	0.054706	0.067873	0.00	0	$0.00
338.734	338.90	0.108774	0.104072	134.40	1	$86,018.26
338.784	338.95	0.122344	0.117647	151.17	1	$96,749.28
338.834	339.00	0.140309	0.135747	173.37	1	$110,956.24
338.884	339.05	0.164033	0.162896	202.68	2	$129,717.14
338.934	339.10	0.176732	0.178733	218.37	2	$139,759.94
338.984	339.15	0.195179	0.196833	241.17	2	$154,347.18
339.034	339.20	0.216138	0.219457	267.07	2	$170,922.08
339.084	339.25	0.230620	0.237557	284.96	3	$182,374.27

Table 3-1: Example of database structure for input to the Flood Tool where structure specific elevation estimates were not available (Rainy Lake US, lived-in structures)

The Input Excel Database was set up with unique tabs for different structures in the database (e.g., docks, buildings, and boathouses) and geographic area (e.g., US and Canadian shoreline of 1) Rainy Lake, 2) Namakan and Kabetogama Lakes, and 3) Crane, Sand Point, and Little Vermilion Lakes)).

Much of the site-specific data for the Excel file was extracted directly from the geospatial database or was based on information extracted from the database as described previously in Section 2.4. The $/m^2 value estimate and the estimated structure value were calculated within the Excel file based on user defined estimates selected on the "SetupAndEconomic" tab of the input Excel workbook using $/m^2 values discussed in Section 2.6.1 above. The summary report by Baird & Associates (2015) discusses the operation of the Tool. There was a high degree of uncertainty in the user defined value estimates so it was felt that various options would be provided to the Flood Tool user based on a range of potential data sources to allow for sensitivity testing with the model results.

Given the uncertainty in establishing elevation estimates for individual structures using the DEM and LiDAR extraction techniques utilized in the project, the geospatial database contained a few unexpectedly low elevation values (e.g., elevations for docks or buildings that would suggest inundation under routine water levels observed historically). All structures with DEM or LiDAR derived site-specific elevation estimates below the upper bound of the rule curves were considered to have no elevation estimates and were included in the distributions for no-elevation estimate structures. This essentially created an elevation threshold within the database that limited damages when water levels were within the existing operational range. Such a threshold was consistent with results from the KRC 2013 property owner survey which did not provide significant evidence that flood damages have been reported within the operational rule curve ranges for the 1970 or 2000 rule curves. For example, only 5.3 percent and 6.1 percent of survey respondents indicated inundation damages to lived-in and non-lived-in buildings, respectively, during the 2001 and 2002 flood years. In addition, there have been few reports of inundation damage during normal operational years (i.e., water levels within the rule curves) (Gail Faveri, Environment Canada – MSC, personal communication).

In addition to the structure specific information, the current Input Excel Database contained quarter-monthly water levels as provided by Thompson (2014). The water levels represented simulations of the 1970 and 2000 rule curves under historical hydrological conditions from 1950 to 2014. The database allows for additional water level time series (e.g., alternative management strategies or simulated hydrological conditions), although none were employed in this analysis.

3.3 Flood tool development – macro driven excel file

Baird & Associates, a Canadian based coastal engineering firm, was retained to develop the Excel Based (VBA) Flood Tool. The Flood Tool calculates flood damages due to inundation for lived-in buildings, non-lived-in buildings, fixed/combo docks, floating docks, and boathouses on an annual basis based on the information available in the Input Excel Database. **Wave impacts were not incorporated into the Flood Tool for the current project.** Where site-specific elevation estimates existed, the annual potential damages were calculated on a structure-by-structure basis, in addition to the sum totals by geographic region. Where site-specific elevation estimates were not available, the Flood Tool estimated annual damages based on the maximum flood level and the building count and area distributions available in the Input Excel Database. The Flood Tool summarized damages by structure type and by geographic region.

The Flood Tool included a series of user defined parameters necessary to calculate the flood damage estimates as outlined on the "Configuration" tab of the Tool. These included a scenario name, a main floor offset estimate and the choice of input water level sequence. In addition, the "Configuration" tab contained the stage-damage curves used in the flood damage estimates (as previously described in Section 2.6.2) and water level offset amounts used to adjust the Rainy and Namakan Lake water level time series for localized pinch-point impacts which can result in higher water levels in upstream portions of the Namakan chain of lakes during high inflow conditions. Both the stage-damage curves and the pinch point offsets could be adjusted by the user for sensitivity testing and future application, although changes were not required to use the Flood Tool for baseline operation. Damage estimates for a specific level of inundation were linearly interpolated between the points. The input for the building elevation was the lowest ground surface adjacent to the building and so a main floor offset needed to be applied within the Flood Tool. This was applied as a single, common input value for all sites. It was recognized that there was a high degree of variability both in structure type (e.g., one story vs. multi-story buildings) and in main floor offsets. However, information was not available to characterize buildings on a site-by-site basis with those specific attributes and generalized estimates needed to be applied in the current evaluation. Future database and model updates could look at incorporating this information.

Baird's 2015 summary report (Appendix E) contains the details regarding the Flood Tool structure and operation. The calculations were handled using a series of VBA coding functions and operations. Using the existing Excel Input Database and Flood Tool setup along with a standard desktop computer, it took between one and two minutes to run a simulation for all lakes using one water level sequence covering the 1950 to 2014 time period. The Flood Tool itself did not contain visualization options for the completed simulation. Future users are free to generate their own visualization approaches based on the available simulation results (either the structure specific results or the summed annual totals).

3.4 Economic considerations

The estimates of economic damage in the study represented how the development that was there now would be damaged under a variety of different water supplies and the application of different rule curves. The water levels from Thompson (2014) including the historical inflow time series from 1950 to 2014 were used to represent possible water supplies that could impact current development. Hence, no adjustment for inflation (i.e., representing 1950 damages in 1950 dollars) was needed.

In its current form, the Flood Tool did not distinguish between damage estimates in Canadian and US dollars. Between 2011 and 2014, the exchange rate of the Canadian dollar fluctuated +/- five percent relative to the US dollar so no effort was made to provide different value estimates of impacts across the border. Given the structure of the model output, it is possible to adjust results on a country level. This was not considered necessary for the current project but may be critical as results from a range of economic studies are pulled together as part of the upcoming rule curve review if attempts are made to report relative to a common baseline or measure relative benefits between different metrics (e.g., flood damage, hydropower production, tourism, etc.).

The Flood Tool only included replacement costs for fixed infrastructure (e.g., the cost to replace a damaged dock). There was no labour or flood response cost incorporated into the Tool even though both the 2013 property owner site visits and the 2014 online flood damage survey revealed that it was common for property owners to invest some time and effort to try and reduce potential damages (e.g., putting weight on docks, sandbagging buildings). To incorporate these costs into the Flood Tool, efforts to reduce flood damages would need to have some relationship with the direct damages (i.e., taking measures to protect property may reduce flood damages by a certain amount). Since this information was not readily available, the Flood Tool only reported replacement costs. This approach therefore underestimates the costs associated with flood response but also may overestimate the replacement cost proportion of flood damages because the depreciated value of individual structures was not considered.

4 Ice Damages – Water Level Metric

Ice impacts within the current project were estimated completely separately from the previously described Flood Tool. Basic water level metrics were utilized to illustrate potential differences between water level management options during the ice period including the time of freeze up, ice cover, and ice-off while economic damages ($) due to ice were not included in the current assessment. The water level metrics looked at differentiating water levels at the time of ice-on and ice-off on the lakes, as well as the magnitude of water level fluctuation over the assumed ice cover period.

There were two important and somewhat contradictory conditions that could contribute to ice problems. The first was the potential magnitude of change (drop and subsequent rise) in water levels over the winter period once ice has formed in and around docks and other shoreline structures. If ice has formed around the dock and the water level fluctuates considerably, the vertical movement of the ice (if attached to the structure) may lead to some damages. More commonly, property owners have indicated ice related damages due to wind induced shifting of the ice cover once it has formed moving docks with it. Ice movement will occur under any water level conditions but if water levels drop so low that they no longer inundate a particular dock, subsequent movement of the ice will not incur damages. The choice of metrics was partly influenced by the results of the 2013 property owner survey in the context of observed water level conditions. Ice damages were reported by 38 percent of Rainy Lake and 49 percent of

Namakan chain of lake respondents. However, the nature of the damages was not fully described in all cases.

There were four water level metrics used to compare rule curves including:

- Average water level during ice formation period;
- Average water level during the ice-off period;
- The average drop in water levels between ice formation and the minimum winter level;
- The average rise in water levels between the winter minimum level and the ice-off period.

The water level metric related to the ice formation period used the average water level during a 3 quarter-month period during the last quarter-month of October and the first two quarter-months of November to represent the initiation of ice formation on both Rainy and Namakan lakes. This time period was based on work by Jean Morin (Environment Canada – MSC, personal communication) looking at when air temperatures were likely to induce freeze up. The water level metric for the ice-off period was represented by a historical average ice-off date on each lake. On Namakan Lake, this was represented by the last quarter-month of April while on Rainy Lake, the first quarter-month of May was used. The maximum drop in water levels was determined based on the change in water levels between the assumed ice-on period and the minimum winter level. The average rise in water levels was determined by the change in water levels between the minimum winter level and ice-off periods. The four water level metrics were calculated for each year of the 1950 to 2014 water level simulations and average and standard deviation values were determined for the simulation period. Comparison of performance between two rule curves was based on differences in the average and standard deviations of the four water level metrics for the 1950 to 2014 simulation period.

5 1970 vs. 2000 Flood Simulation Results – Baseline Comparison

The Flood Tool was used to simulate estimated flood damages due to inundation on both Rainy Lake and the Namakan chain of lakes based on modelled 1970 and 2000 rule curve water levels originally provided by Thompson (2014) and using the most recent version of his Excel model (released January 2016). Some of the baseline user-defined input values for the simulation are provided in Table 5-1. The $/m^2 used to represent the structure values represent the lower to midrange of the options as described in Section 2.6.1. The pinch point water level offsets were set at 0.06 m and 0.03 m for Crane and Sand Point Lakes and the stage-damage curves were represented by the baseline curves as described in Section 2.6.2.

	Lived-In	Non-Lived-In	Boathouse	Docks
Baseline Input Value ($/m^2)	$640	$338	$338	$379
Main Floor Offset (m)	0.3028	N/A	N/A	N/A

Table 5-1: Baseline input values ($/m^2) used for the Flood Tool evaluations

The 2000 rule curves represent the change in management strategy from the previously applied 1970 rule curves. In the context of the 2009 Plan Of Study, the various projects were set up to assess whether the change to the 2000 rule curves improved outcomes in the system relative to the performance of the 1970 rule curves. As a result, this project used the simulation results for the 1970 rule curves as the baseline conditions and the simulation results for the 2000 rule curves as the alternative. The simulation results were reported as impacts with greater values representing greater impacts. The primary metrics were reported on an annual basis and include the count of structures impacted and the estimated economic cost of impacts. Net results for the 2000 rule curve simulation relative to the 1970 rule curve simulation are provided in Figure 5-1, summarized as annual impacts for both Rainy Lake (left side) and the Namakan chain of lakes (right side). The upper graphs represent the water levels for the two lakes, the middle graphs represent the count of structures impacted in each category (e.g., lived-in and non-lived-in buildings, docks, and boathouses) as a stacked column, and the lower graphs represent the estimated damages ($ million) for each category (e.g., lived-in and non-lived-in buildings, docks, and boathouses).

Looking strictly at water levels, the simulated water levels had very little difference between the 1970 and 2000 rule curve simulations for Rainy Lake. There were some small differences in summer draw down as well as differences in peak and low levels in some years but overall, the rule curves perform similarly. Differences were much more apparent on the Namakan chain of lakes. The 1970 rule curves have much lower winter levels and slightly higher summer peaks when compared with the 2000 rule curves. As well, the 2000 rule curves showed differences in the summer draw down period. Given the observed water level differences between the plans, differences in impacts between rule curves was expected to be lower for Rainy Lake when compared to the Namakan chain of lakes.

The relative difference in impacts between the two rule curves was small (Figure 5-1). Positive values indicate that the 2000 rule curve impacted a greater number of structures or caused greater economic impacts relative to the 1970 rule curve and therefore performed worse.

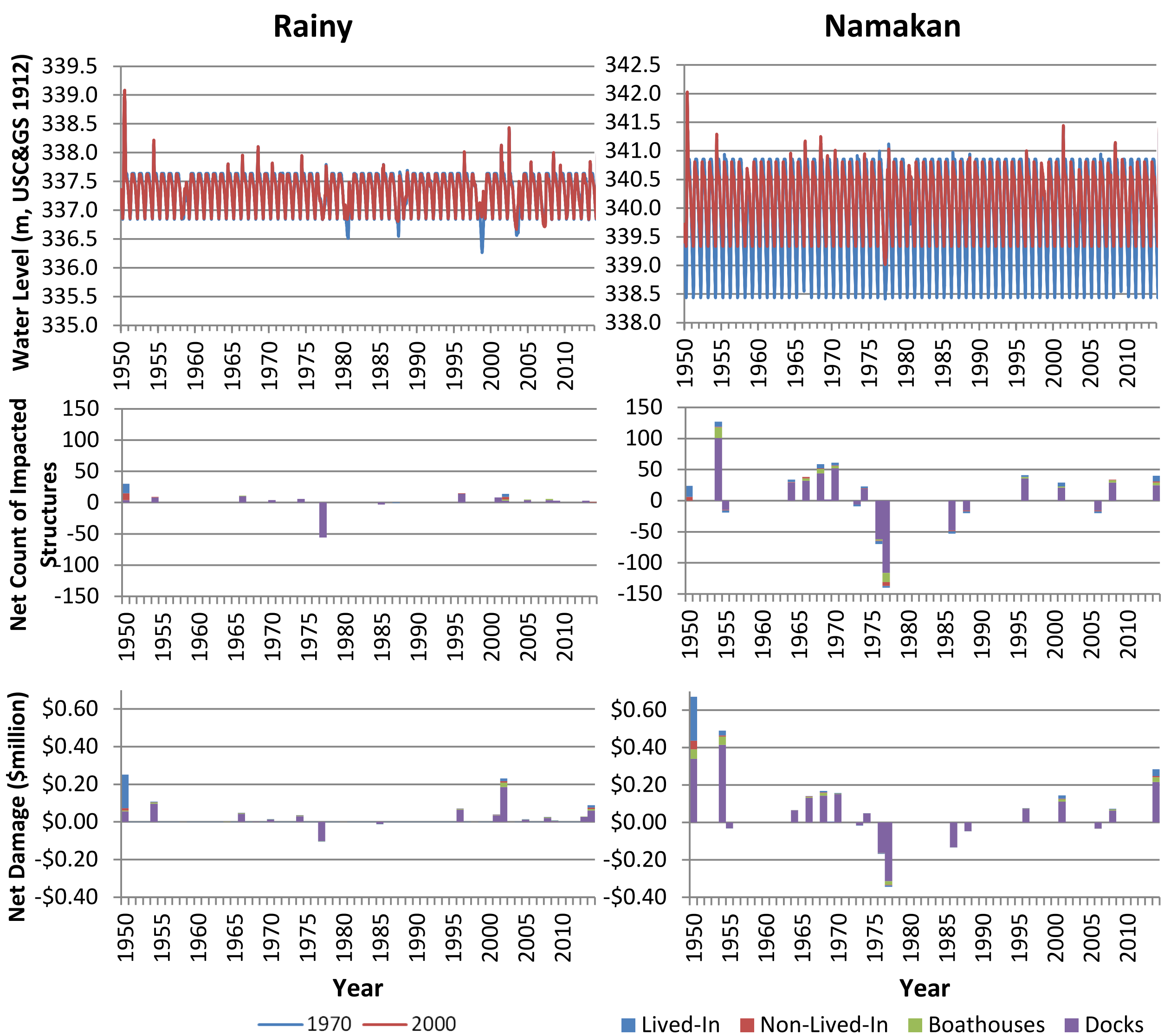


Figure 5-1: Estimates of net damages for Rainy Lake and the Namakan chain of lakes using the Flood Tool and baseline input parameters for the 2000 rule curve simulation relative to the 1970 rule curve simulation (positive values represent greater impacts for the 2000 rule curves) (the 1970 rule curve water levels are in blue and the 2000 rule curve water levels in red)

For both Rainy Lake and the Namakan chain of lakes, there were more years of the simulation (out of a total of 65 years) where the 2000 rule curve increased the number of structures impacted (e.g., lived-in, non-lived-in, boathouse, and docks) relative to the 1970 rule curves. However even for the most sensitive damage category (fixed/crib docks), over 72 percent of the years of the simulation had no difference in the number of structures impacted on either Rainy or the Namakan chain of lakes. For the years that did show a greater number of structures impacted, the differences tended to be small relative to the number of structures in the database. For example, there were two years of the simulation (~3 percent) where a greater number of lived-in buildings were considered impacted in the Flood Tool under the 2000 rule curves for Rainy Lake and the average increase in the number of structures impacted for those years was 10 lived-in structures which represents only 0.5 percent of the lived-in buildings in the database.

The relative difference in estimated economic damages between the 1970 and 2000 rule curves was slightly greater than for the number of structures impacted. This was because even in years of the simulation where the same structures were impacted, the potential economic impacts could be slightly different if there were small differences in associated water levels and in turn the depth of inundation for the structures impacted. The economic differences were associated with a difference in the depth of inundation that was occurring (greater inundation equaled greater damage estimates) and not a difference in which buildings were being inundated. For example, there were two years in the simulation where there were more non-lived-in structures impacted on Rainy Lake for the 2000 rule curves when compared with the 1970 rule curves and there were 12 years of the simulation where the economic impacts were greater. However, the average increase in damages was generally not large. For example, the damages to non-lived-in structures was only around $3,200 for the years in which damages for the 2000 rule curve were estimated to be greater than the 1970 rule curve results.

The switch from the 1970 to the 2000 rule curves impacted Namakan Lake more than Rainy Lake, but even around Namakan Lake, the increase in damages was still fairly small. Based on the simulation results, the net differences for the 2000 rule curves relative to the 1970 rule curves were generally greater for the Namakan chain of lakes when compared with Rainy Lake for years where differences were identified. There were nine years in the simulation (out of 65) where the 2000 rule curve water levels increased the number of lived-in buildings impacted. The average increase in the number of lived-in buildings impacted was 6.9 for those nine years which was less than the 10 lived-in buildings impacted on Rainy Lake (although the Rainy average was only based on two years). Given that there were fewer lived-in buildings in the database for the Namakan chain of lakes (when compared to Rainy Lake), the 6.9 lived-in buildings represented a 0.8 percent increase in the number of lived-in buildings in the database that were considered impacted compared with a 0.5 percent increase for Rainy Lake lived-in buildings. For both Rainy Lake and the Namakan chain of lakes, the 2000 rule curves increased the number of lived-in buildings impacted by less than 1 percent of the buildings in the database.

There were a greater number of structures in the database for Rainy Lake relative to the other lakes. As a result, the total number of structures impacted on Rainy Lake was greater than on the Namakan chain of lakes when looking at either the 1970 or 2000 rule curve simulations individually (Figure 5-2 and Figure 5-3) as opposed to the net comparison in Figure 5-1. Docks (purple colour in Figure 5-2 and Figure 5-3) were the most commonly impacted structure type along the shoreline based on the count of impacted structures. Non-lived-in buildings were the next most commonly impacted structure. These results were consistent with the 2013 and 2014 property owner survey findings. There were relatively few boathouses impacted (by count) which was partly a function of the low number of boathouses in the database. The two largest events on Rainy Lake occurred at the start of the simulation (1950) and the end (2014). On the Namakan chain of lakes, 2001 was also an important event. There were few flood events in either the 1970 or 2000 rule curve simulations during the 1970's and 1980's. Since 1996, the simulations identified a number of years with some estimated structure inundation due to high water levels. Again, these events were primarily associated with dock inundation in terms of the count of structures impacted which was consistent with the damage reports that were available.

Economic damage estimates from the Flood Tool show some differences to the impacts associated with the count of structures inundated. This was primarily associated with the economic damage estimates in both 1950 and 2014 in the simulation which represented the highest damages on both Rainy and Namakan lakes for the 65 years of the simulation. The 1950 event was the flood of record for the simulation and this was illustrated in the large potential economic impacts associated with the simulations of both the 1970 and 2000 rule curves.

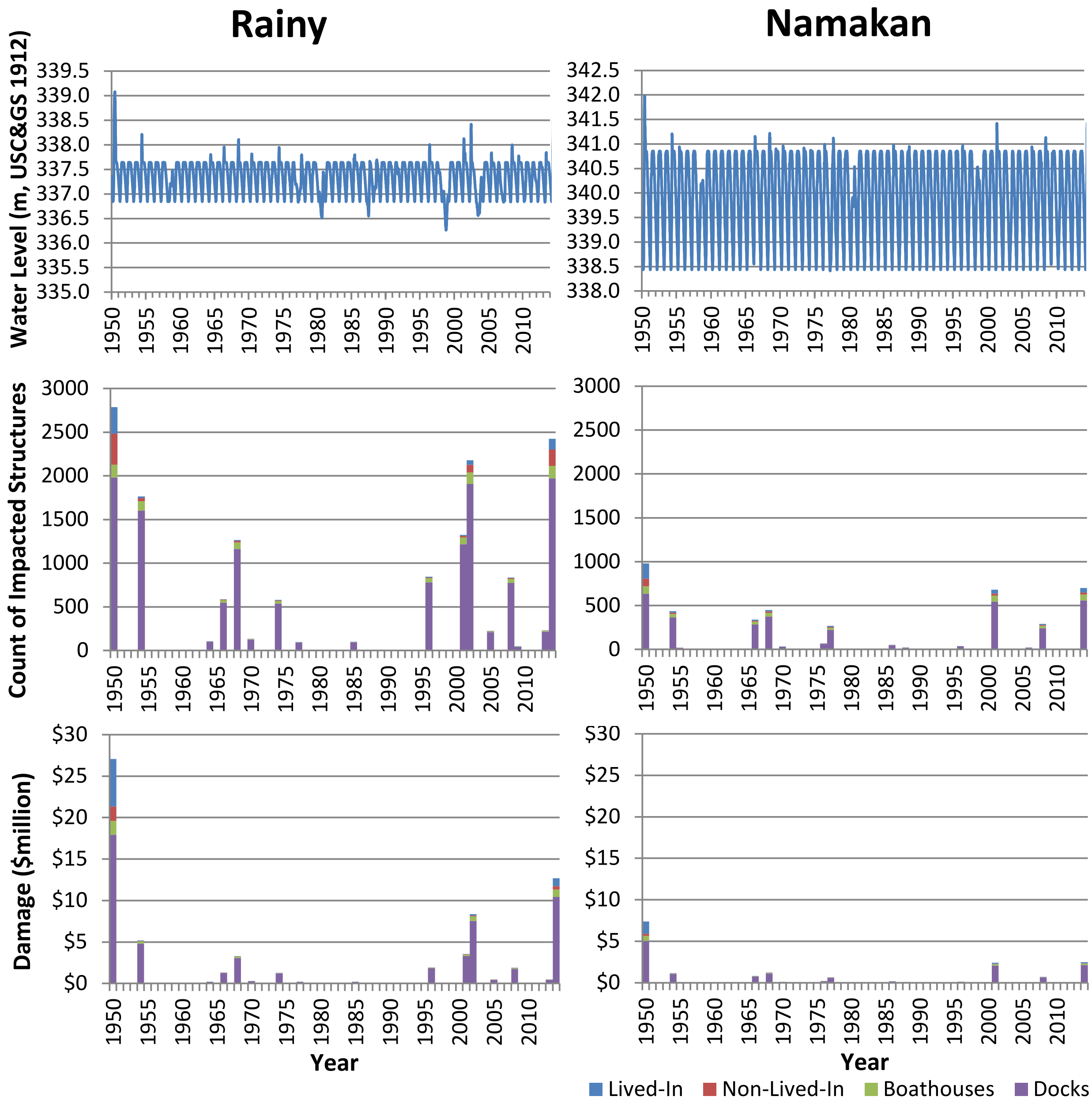


Figure 5-2: Estimates of damages for Rainy Lake and the Namakan chain of lakes using the Flood Tool and baseline input parameters for the 1970 rule curve simulation

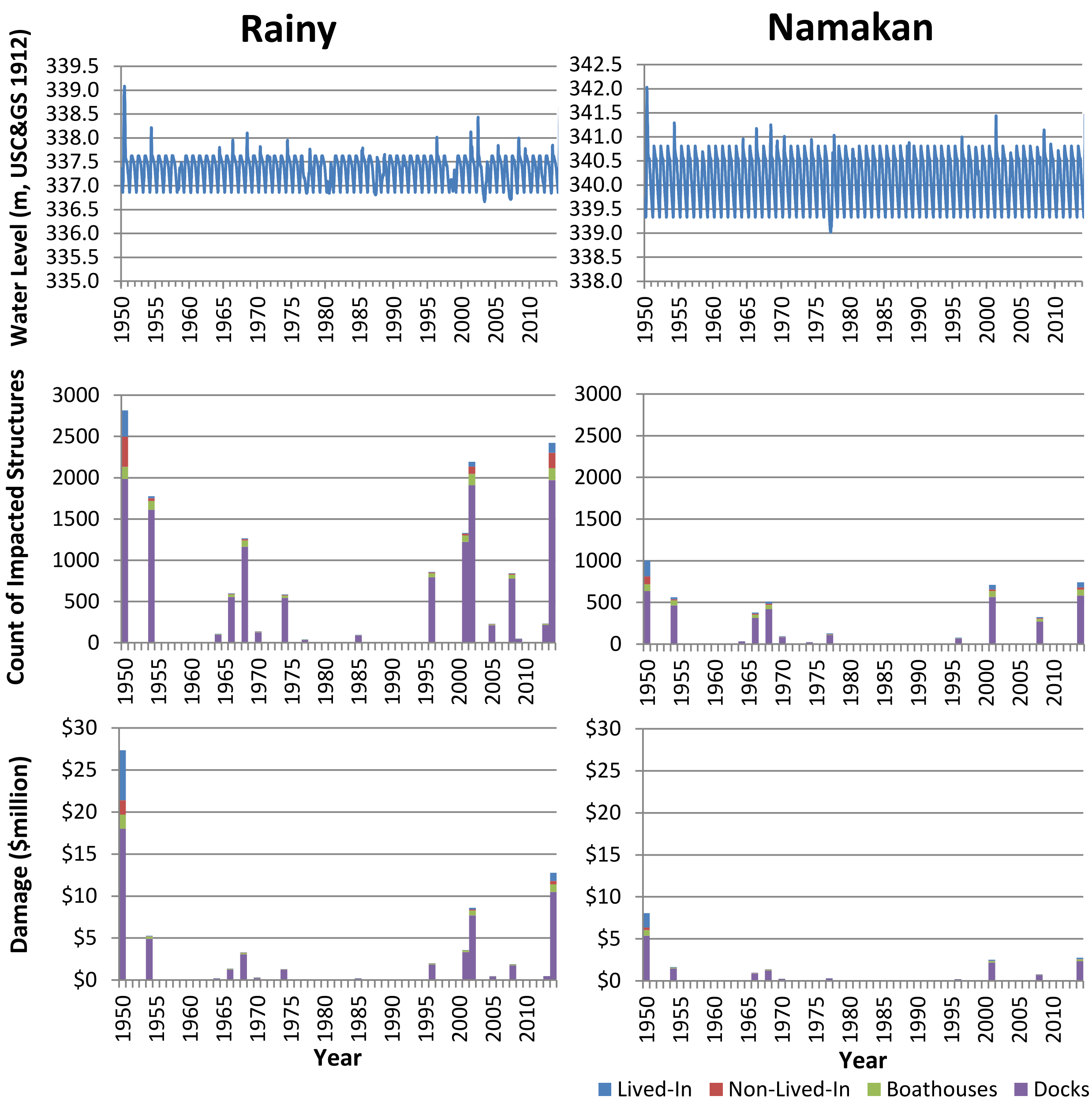


Figure 5-3: Estimates of damages for Rainy Lake and the Namakan chain of lakes using the Flood Tool and baseline input parameters for the 2000 rule curve simulation

When the two rule curve plans were compared using average annual number of structures flooded (i.e., the average performance on a yearly basis using the 65 years of the simulation), the results were similar; the 1970 rule curve impacted slightly fewer structures, with a more marked difference around the Namakan chain of lakes than Rainy Lake. Table 5-2 summarizes the simulation results for both the 1970 and 2000 rule curves for Rainy Lake and the Namakan chain of lakes based on the count of structures impacted. The table also provides the net difference as a percent. The average annual simulation results represent the average number of structures impacted (by each category) for the different geographic areas on an annual basis (i.e., the total number of impacted structures over the course of the simulation divided by the number of years of the simulation). For the net results portion of Table 5-2, a positive value indicates a greater number of structures impacted by the 2000 rule curve simulation when compared with the baseline 1970 rule curve simulation. With the exception of the non-lived-in buildings, the net change in average annual results tended to be slightly larger for the Namakan chain of lakes when compared with Rainy Lake, although the absolute average annual values for Rainy Lake were always larger. For example, there was a 9.2 percent increase in the average annual number of lived-in buildings impacted on the Nakaman chain of lakes and a 3.0 percent increase on Rainy Lake. However, there were a greater number of lived-in buildings impacted on Rainy Lake on an average annual basis. For the study area as a whole, there was an increase of 5.5 percent in the average annual number of lived-in, 2.4 percent in non-lived-in, 2.6 percent in boathouse, and 0.7 percent in dock structures that were impacted using the 2000 rule curves relative to the 1970 rule curves (collectively a 1.2 percent increase).

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
1970	Rainy Lake	9.34	11.38	13.40	205.62
	Namakan/Kabetogama, Crane, Sand Point	5.75	3.02	5.95	53.18
	Total	**15.09**	**14.40**	**19.35**	**258.80**
2000	Rainy Lake	9.63	11.66	13.49	205.80
	Namakan/Kabetogama, Crane, Sand Point	6.34	3.09	6.37	54.89
	Total	**15.97**	**14.75**	**19.86**	**260.69**
Net Difference (Percent)	*Rainy Lake*	*3.0%*	*2.4%*	*0.7%*	*0.1%*
	Namakan/Kabetogama, Crane, Sand Point	*9.2%*	*2.5%*	*6.5%*	*3.1%*
	Total	***5.5%***	***2.4%***	***2.6%***	***0.7%***

Table 5-2: Estimates of the average annual number (count) of structures impacted under baseline conditions for the 1970 and 2000 rule curves and a comparison of net differences (percent) (positive percent values represent greater impacts for the 2000 rule curves)

Similar patterns were evident for the average annual economic impacts associated with the 1970 and 2000 rule curve simulations with the Flood Tool and baseline input parameters (Table 5-3). For both Rainy Lake and the Namakan chain of Lakes, the 2000 rule curve simulation resulted in greater impacts relative to the 1970 rule curve simulation regardless of structure category or geographic area. This was consistent with the findings of the IRLBC (1999) report. There was a greater percentage difference in the Namakan chain of lakes results between the two rule curve simulations when compared with the Rainy Lake results, although the net average annual impacts on the Namakan chain of lakes were about a quarter of the magnitude of the average annual impacts on Rainy Lake under either simulation. For the overall study area, the net difference in the number of structures impacted was slightly greater than the net change in estimated economic damages for non-lived-in buildings, boathouses, and docks. For the number of impacted structures, the overall increase in impacts on an average annual basis for the 2000 rule curves relative to the 1970 rule curves ranged from 0.7 percent for docks to 5.5 percent for lived-in buildings (Table 5-2) while the economic damages increased anywhere from 2.2 percent for docks to 5.5 percent for lived-in buildings (Table 5-3). Collectively, this represented at 2.7 percent increase.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
1970	Rainy Lake	$0.11	$0.04	$0.06	$0.85
	Namakan/Kabetogama, Crane, Sand Point	$0.03	$0.01	$0.02	$0.23
	Total	**$0.15**	**$0.04**	**$0.08**	**$1.08**
2000	Rainy Lake	$0.11	$0.04	$0.06	$0.84
	Namakan/Kabetogama, Crane, Sand Point	$0.03	$0.01	$0.02	$0.21
	Total	**$0.14**	**$0.04**	**$0.08**	**$1.06**
Net Difference (Percent)	*Rainy Lake*	*2.8%*	*1.3%*	*1.4%*	*1.0%*
	Namakan/Kabetogama, Crane, Sand Point	*14.7%*	*14.9%*	*10.8%*	*6.9%*
	Total	***5.5%***	***3.5%***	***3.7%***	***2.2%***

Table 5-3: Estimates of the average annual economic impacts ($ million) of structures impacted under baseline conditions for the 1970 and 2000 rule curves and a comparison of net differences (percent) (positive percent values represent greater impacts for the 2000 rule curves)

Within both the 2000 and 1970 rule curves simulations, 1950 is the flood of record for Rainy Lake and the Namakan chain of lakes. Table 5-4 shows the baseline Flood Tool simulation results for 1950 for both rule curve simulations based on the count of structures impacted in both categories to illustrate the potential difference in impacts associated with the modelled rule curve water levels under extreme conditions. As with the previous average annual results in Table 5-2 and Table 5-3, there was a greater percent change in the Namakan chain of lakes results relative to the Rainy Lake results for the 2000 rule curves simulation when compared with the 1970 rule curves simulation. The Rainy Lake portion of the study area had a greater proportion of the impacted structures under both rule curves. Unlike the previous average annual comparisons, there was almost no difference in the boathouse and dock impacts under the 1970 and 2000 rule curves for the 1950 flood of record. That was because almost all dock and boathouse structures in the database were inundated under both scenarios.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
1970	Rainy Lake	304	355	146	1981
	Namakan/Kabetogama, Crane, Sand Point	173	87	84	635
	Total	**477**	**442**	**231**	**2616**
2000	Rainy Lake	319	366	147	1985
	Namakan/Kabetogama, Crane, Sand Point	191	93	84	635
	Total	**510**	**459**	**231**	**2620**
Net Difference (percent)	*Rainy Lake*	*4.7%*	*3.0%*	*0.0%*	*0.2%*
	Namakan/Kabetogama, Crane, Sand Point	*9.4%*	*6.5%*	*0.0%*	*0.0%*
	Total	***2.7%***	***1.3%***	***0.0%***	***0.0%***

Table 5-4: Estimates of the number (count) of structures impacted under baseline conditions during the 1950 flood of record for the 1970 and 2000 rule curves and a comparison of net differences (percent) (positive values represent greater impacts for the 2000 rule curves)

The 2014 flood resulted in impacts on both Rainy and Namakan lakes. Table 5-5 summarizes the model estimates of structure impacts for both the 2000 rule curves and the 1970 rule curves. Based on the model results, it was estimated that the number of structures impacted would have been reduced by 3.5 percent, 1.0 percent, 1.4 percent, and 0.9 percent for lived-in, non-lived-in, boathouse, and dock structures, respectively, had the 1970 rule curves been in operation instead of the 2000 rule curves. Note however that Rainy Lake had a greater proportion of structures impacted relative to the Namakan chain of lakes and there was almost no difference in impacts on Rainy Lake (only 0.6 percent for non-lived-in) between the 1970 and 2000 rule curves.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
1970	Rainy Lake	122	187	143	1971
	Namakan/Kabetogama, Crane, Sand Point	52	23	68	557
	Total	**174**	**210**	**211**	**2528**
2000	Rainy Lake	122	188	143	1971
	Namakan/Kabetogama, Crane, Sand Point	61	25	72	582
	Total	**183**	**213**	**215**	**2553**
Net Difference (percent)	*Rainy Lake*	*0.0%*	*0.6%*	*0.0%*	*0.0%*
	Namakan/Kabetogama, Crane, Sand Point	*10.3%*	*4.2%*	*4.2%*	*4.0%*
	Total	***3.5%***	***1.0%***	***1.4%***	***0.9%***

Table 5-5: Estimates of the number (count) of structures impacted under baseline conditions during the 2014 flood for the 1970 and 2000 rule curves and a comparison of net differences (percent) (positive values represent greater impacts for the 2000 rule curves)

6 1970 vs. 2000 Ice Impact Results –Baseline Comparison

The ice impact metrics were determined independently from the Flood Tool as they were typically not associated with extreme high water conditions. Estimates of economic damages were not calculated. Instead, basic water level metrics were used to compare water level conditions at ice-on and ice-off, along with the magnitude of change in water levels over the ice coverage period. The water levels were as documented in the Thompson (2014) report and the January 2016 version of the hydrologic model. The reason that economic impacts were not included in the current analysis was due to the uncertainty around the significance of water levels as a contributor to ice damages. Water level metrics were compared using the:

- average water level during the time ice was expected to form (the "ice-on" period from late October through early November);
- maximum water level drop between ice-on and the annual winter low water level;
- maximum water level rise between the minimum winter level and the ice-off period; and
- expected water level at the time of ice-off.

These metrics were defined to show differences in water levels for the two rule curves during the time ice forms, the magnitude of change in water levels throughout the winter, and the water level at the time of ice-off. Differences between the two rule curves could contribute to ice damages during a time of year when water levels were typically approaching their annual low.

On Rainy Lake, the ice-on water levels were 0.05 m lower for the 2000 rule curves compared to the 1970 rule curves on average based on the 1950 to 2014 simulation time period provided by Thompson (2014) and updated in January 2016 with a standard deviation of (0.13 m) (Table 6-1). Water levels dropped an average of 0.69 m between the ice-on period and the minimum winter level in the 1970 simulated water levels, which was 0.07 m more than the average water level drop with the 2000 rule curve simulations (0.10 m standard deviation). There was almost no difference in the water levels at the assumed period of ice-off which was the first week of May based on the historical average ice-off dates. The difference between the two rule curves was 0.03 m with a standard deviation of 0.02 m. Overall, the two rule curves tended to perform similarly over the winter period on Rainy Lake, although there were a few outlier years with larger differences. Even though 38 percent of Rainy Lake respondents in the 2013 survey indicated that they had observed ice damages to their shoreline infrastructure, it was difficult to link those damages directly to water level management based on the two rule curve simulations currently available due to the similarity in winter water levels from year to year. It is quite possible that wind induced movement of ice did contribute to the reported damages and this would likely be a problem under either water level management strategy although this was not explicitly investigated in this study.

Winter water level management on the Namakan chain of lakes did show differences between the 1970 and 2000 rule curves (Table 6-1). Primarily, the difference was associated with a much greater drop in water levels between the assumed ice-on period and the minimum winter level. Based on the 1970 water level simulations, the average water level drop between the assumed ice-on period and the minimum winter level was 1.92 m (0.05 m standard deviation). This was over 0.97 m greater than the observed drop in the 2000 rule curve simulation. There was only about a 0.09 m difference in water levels at the time of assumed ice-on so the two rule curves tended to keep water at similar levels as ice was starting to form on the lakes. There was more variability in the differences in water levels at ice-off on the Namakan chain of lakes with the 2000 rule curve tending to have a higher water level (average 0.72 m higher than the 1970 rule curve water level during the simulation, standard deviation of 0.24 m).

Inferring potential ice impacts associated with the observed water level differences on the Namakan chain of lakes was unjustified given currently available information. Based on the 2013 property owner survey, 49 percent of Namakan chain of lakes respondents reported ice damages at some point in the past however the survey did not ask respondents to distinguish between damages that occurred under the 1970 rule curves, and in any event, there would have been differences in air temperatures and water supplies to the basin that would make any comparison suspect.

Overall, the water levels on Rainy Lake showed little difference between the 1970 and 2000 rule curves simulations during the ice-on and ice off period. There was also little difference in the magnitude of water level change during the ice cover period. On the Namakan chain of lakes, the 1970 and 2000 rule curves had similar levels during the ice-on period but the magnitude of water level change over the winter period was greater for the 1970 rule curves leading to differences in the water levels during the ice-off period.

The magnitude of the winter water level drawdown within the 1970 rule curves may cause some problems for docks along the shoreline if a significant ice cover is formed while water levels are still in contact with the dock. However, this issue is likely to be largely offset by the benefit of having water levels drop so low over the winter that the docks are essentially out of the water and are therefore not subject to the potential movement of ice (either vertically due to changing water levels or horizontally due to wind-induced movement). In the 2013 survey, one property owner on Kabetogama Lake made this specific comment noting that water levels prior to 2000 were preferred because the crib dock was “high and dry” over the winter and it was easier on the dock. The trade off from a property owner perspective is that a reduced drawdown and higher water levels at ice-off within the 2000 rule curves provide a benefit in terms of boating access. In fact, of the 22 survey responses on Kabetogama Lake during the 2013 site visits, only 1 respondent indicated that they thought the new rule curves increased their vulnerability to winter ice conditions. In contrast, 16 respondents noted their preference for the new rule curves primarily due to the improved boating access early in the season and the more stable levels.

	Ice-On		Maximum Drop		Maximum Rise		Ice-Off	
	Ave	STDEV	Ave	STDEV	Ave	STDEV	Ave	STDEV
Rainy Lake	-0.05	0.15	-0.07	0.10	0.01	0.07	0.03	0.02
Namakan/Kabetogama, Crane, Sand Point	-0.09	0.04	-0.97	0.03	-0.17	0.23	-0.72	0.24

Table 6-1: Differences between the 1970 and 2000 simulated rule curve water levels, in m. Negative numbers mean the lake was lower (for ice-on and ice-off) or the change less (for maximum drop and rise) under the 2000 rule curve. (note: Ave represents average values and STDEV represents the Standard Deviation)

7 Sensitivity Analysis for Flood Tool Results

There were a range of parameters and attributes of the Flood Tool that were uncertain and that could have impacted simulation results. There were two ways to adjust these parameters; using adjustments available to all users (e.g., main floor offset, stage-damage curves, pinch point water level offsets within the Flood Tool), or changing the input database (e.g., building elevation or structure economic values). One way to understand the importance of these items on the simulation results was to test the sensitivity of the model output to individual parameters. Given the number of input parameters within the Flood Tool, there were numerous combinations of changes that could possibly influence simulation results. For the current sensitivity analysis, only a small number of individual parameters that appeared to have great uncertainty and were important to the outcomes were considered as a way to illustrate potential impacts. **Note that the sensitivity analysis was undertaken using the Thompson (2014) model. The results were not updated with the January 2016 version of the hydrologic model as the sensitivity analysis was simply to test differences in how the tool would respond with various input parameters.**

7.1 Structure elevation in database

The structure elevations within the database were of uncertain accuracy. The original LiDAR data had some uncertainty, which varied depending on the equipment used for acquisition (see Section 2.3.1.1). The conversion of the LiDAR data to DEMs added uncertainty, as did the structure digitization process and the elevation extraction techniques. GPS based elevation estimates (field measurements) were used to help reduce uncertainty and there was good correlation between GPS measurements, water level offset measurements, and the elevation information used for the database. There was also good agreement between the database and interpretation of oblique photographs taken during the 2014 high water period.

Nonetheless, a test was run to see how sensitive the increase in damages from the 2000 rule curve was to possible errors in the database elevations. While uncertainty in the elevation data could be both positive and negative, all input elevation values within the database were adjusted down 15 cm for the test to represent a conservative assessment of potential impacts with the 15 cm value representing the range of RMSE for the input LiDAR datasets used in the DEMs. For the 1950 flood of record, lowering the structure elevations increased the number of lived-in buildings, non-lived-in buildings, and docks impacted within the Flood Tool by around 20.5 percent, 14.8 percent, and 0.3 percent respectively relative to the baseline conditions. There was no difference in the number of boathouses impacted as they were already all impacted under the baseline conditions. While changing the database elevations increased the number of potential structures impacted under the 1950 event, there was little relative difference between the 1970 and 2000 rule curve simulations under the two database conditions. Table 7-1 shows the percent change in the number of structures impacted during the 1950 flood of record between the two rule curves for the baseline conditions and the database with the structure elevations adjusted down 15 cm. There were only small differences between the performance of the plans in these two situations. Like the baseline conditions, the 2000 rule curves caused a slightly greater number of structures to be impacted relative to the 1970 rule curves during the flood of record when the structure elevations were lowered.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
Baseline	Rainy Lake	0.3	0.3	0.0	0.1
	Namakan/Kabetogama, Crane, Sand Point	6.9	5.7	0.0	0.0
	Total	**2.7**	**1.4**	**0.0**	**0.0**
Adjusted (Structure elevation reduced by 0.15 m)	Rainy Lake	0.3	0.0	0.0	0.0
	Namakan/Kabetogama, Crane, Sand Point	4.7	4.3	0.0	0.0
	Total	**1.9**	**1.0**	**0.0**	**0.0**

Table 7-1: Estimates of the percent change in number of structures impacted during the 1950 flood of record between the 1970 and 2000 rule curves for the baseline simulation and for adjusted structure elevations (positive values represent greater impacts for the 2000 rule curves)

The estimates of average annual impacts based on the Flood Tool results were sensitive to changes in structure elevation. In general, there were few reports of high water impacts during years in which water levels remain within the rule curves (both prior and since the implementation of the 2000 rule curves). Accordingly, the database was screened to ensure no structures were inundated when water levels stayed within the operating range. But in the sensitivity test, when the database structures had the elevations lowered, some structures appeared to be inundated annually which influenced the average results (e.g., a few buildings apparently impacted year after year which impacts the overall average). This complicated interpretation because the historical record did not identify significant flooding issues during "normal" years when water levels remained in the rule curve and the critical comparison was the performance of the rule curves when water levels exceeded normal operational conditions.

7.2 Structure replacement value

All structures within the database had an estimated replacement value based on the footprint size of the structure and an associated $/m^2 value (square metre area of structure) for the particular structure type. There was a high degree of uncertainty in the $/m^2 value estimates based on different methods for developing the values (see Section 2.6.1). The input values were increased to test the potential sensitivity of the Flood Tool results. Changing the replacement values did not impact the number of structures considered at risk but did influence the absolute damage estimates for any given simulation. There was a linear relationship between changes in the $/m^2 values and the estimated damages and as such, the relative difference between the 1970 and 2000 rule curves remained consistent whenever changing $/m^2 value, although changing the input values directly impacted the estimate of absolute damages for both rule curves under consideration.

7.3 Pinch point water level offsets

The current version of the Flood Tool used input water levels from Rainy Lake and Namakan Lake to estimate flood damages in the study area. There were known water level "pinch point" influences on certain lakes in the system upstream of Namakan Lake, in particular Sand Point and Crane Lakes (Stevenson and Thompson, 2013). Within the Flood Tool, user-defined water level offsets were applied for particular reaches. These offsets were estimates of the rise in water surface elevation local to those locations. Figure 7-1 illustrates the critical reaches on both the Canadian and US shoreline, particularly further upstream from Namakan Lake. These include the shoreline of Sand Point Lake (broken into an upper and lower section), Little Vermilion Lake, and Crane Lake.

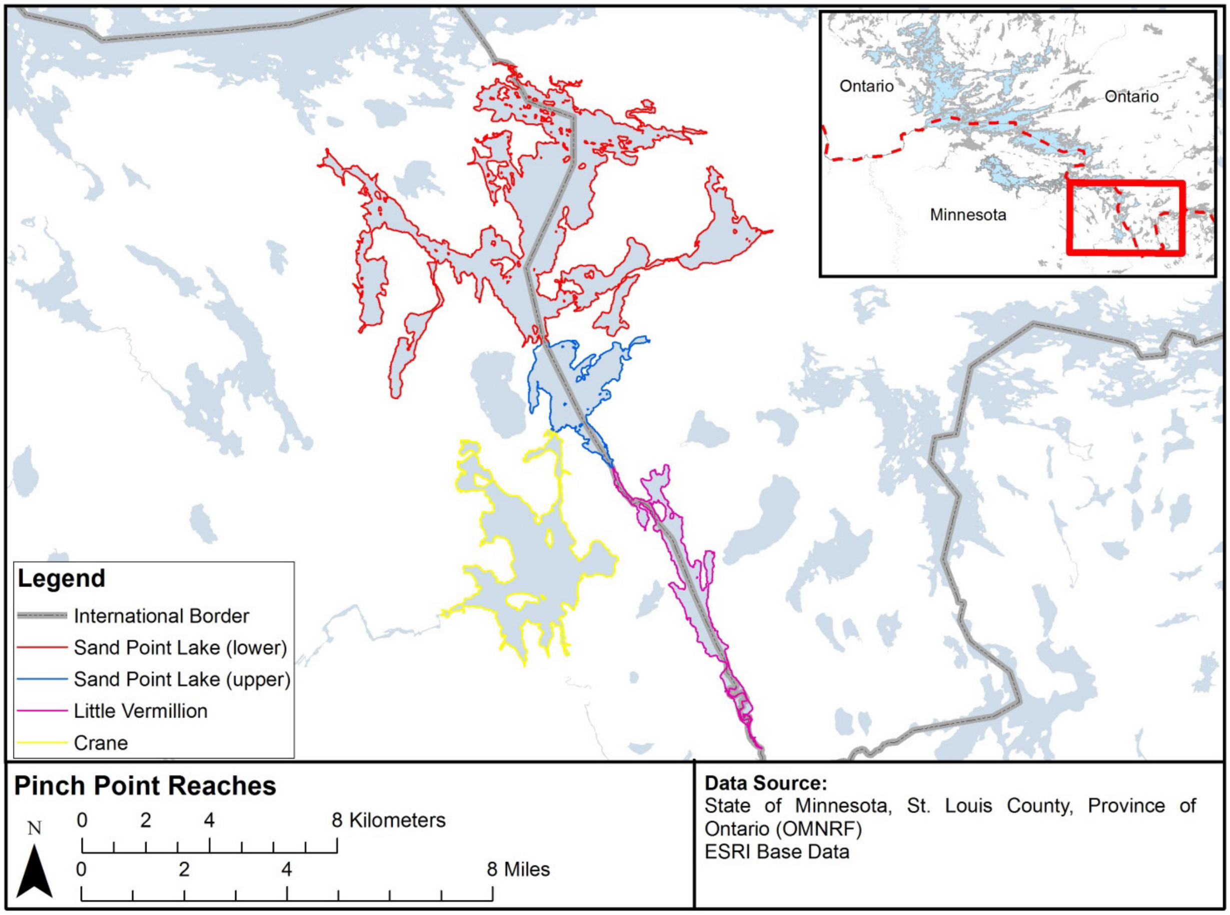


Figure 7-1: Identification of pinch point reaches used in Flood Tool

The water level offsets were included as a single value for each stretch of shoreline that was applied throughout the simulation. A single offset value was applied for Crane Lake and a single value for Sand Point and Little Vermilion. Higher offset values lead to greater impacts for the stretches of shoreline in which they were applied (the Namakan chain of lakes results) because the water levels from any given management scenario were higher and were more likely to impact structures in any given year (Table 7-2). As a result, there was also some influence on the relative comparison of the 2000 and 1970 rule curves for the damage estimates (Table 7-3), likely because using higher offsets could cause one scenario to reach particular thresholds within the database while the other did not. That being said, the relative difference between the rule curve simulations remained fairly consistent with the baseline scenario.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
Baseline	Rainy Lake	2.1	2.7	1.6	1.3
	Namakan/Kabetogama, Crane, Sand Point	6.9	0.5	5.2	3.7
	Total	**3.9**	**2.2**	**2.7**	**1.8**
Adjusted (water level offset of 0.09m for Crane and 0.06m for Sand Point)	Rainy Lake	2.1	2.7	1.6	1.3
	Namakan/Kabetogama, Crane, Sand Point	7.3	2.0	4.8	0.4
	Total	**4.1**	**2.6**	**2.6**	**1.1**

Table 7-2: Estimates of the percent change in number (count) of impacted structures between the 1970 and 2000 rule curves for the baseline simulation and for adjusted water level offset (positive values represent greater impacts for the 2000 rule curves)

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
Baseline	Rainy Lake	0.9	1.7	1.7	1.4
	Namakan/Kabetogama, Crane, Sand Point	14.6	14.6	9.7	7.1
	Total	**3.8**	**3.5**	**3.6**	**2.5**
Adjusted (water level offset of 0.09m for Crane and 0.06m for Sand Point)	Rainy Lake	0.9	1.7	1.7	1.4
	Namakan/Kabetogama, Crane, Sand Point	14.5	13.9	9.6	6.4
	Total	**3.9**	**3.4**	**3.7**	**2.4**

Table 7-3: Estimates of the percent change in average annual economic impacts between the 1970 and 2000 rule curves for the baseline simulation and for adjusted water level offset (positive values represent greater impacts for the 2000 rule curves)

7.4 Main Floor Offset

The calculation of flood damages for lived-in structures using the USACE stage damage curve was relative to the main floor elevation. The current Flood Tool database did not include an attribute for main floor offset for individual lived-in structures. As a result, a generic offset was applied to all lived-in structures in the database prior to the damage estimates. In the baseline assessment, a 0.3 m offset was applied to all lived-in structures. On an absolute basis, changing the main floor offset did impact the Flood Tool damage estimates for individual scenarios. Table 7-4 shows the sensitivity of the relative economic performance of the rule curves if the main floor offset was reduced to 0.1 m. The lived-in buildings on the Namakan chain of lakes portion of the study area appeared sensitive to the change in main floor offset in terms of the potential number of structures impacted. This was likely because the database had a particular threshold that ensured lived-in buildings were not consistently flooded year after year in the simulation when there was little evidence to support such results based on flood damage reports. The reduction in the main floor offset allowed a few lived-in buildings to be considered impacted on a regular basis, thus influencing the average annual results. For particular flood years, the 2000 rule curve continued to show slightly higher impacts. From an economic perspective (Table 7-4), the 2000 rule curve continued to show increased economic impacts relative to the 1970 rule curves, although the relative change was reduced for lower main floor offsets for both the Namakan chain of lakes and the system overall. The results of the non-lived-in buildings, boathouses, and docks were not influenced by changes in the main floor offset parameter and therefore did not change.

Scenario	Lake	Inundated Lived-In Structure Count
Baseline	Rainy Lake	0.9
	Namakan/Kabetogama, Crane, Sand Point	14.6
	Total	**3.8**
Adjusted (Main floor offset of 0.1 m)	Rainy Lake	1.0
	Namakan/Kabetogama, Crane, Sand Point	3.1
	Total	**1.7**

Table 7-4: Estimates of the percent change in average annual economic impacts between the 1970 and 2000 rule curves for the baseline simulation and for adjusted main floor offset (positive values represent greater impacts for the 2000 rule curves)

7.5 Stage-Damage Curves

There was a high degree of uncertainty in the relationship between water stage and the percentage of structure value lost because of flooding that formed the basis of the stage-damage curves applied within the Flood Tool (Section 2.6.2). Only the lived-in buildings used a standard stage-damage curve (USACE, 2000). That curve was meant to represent damages that would happen to one story buildings with no basement, but there were likely to be buildings with basements or more than one story in the floodplain. For non-lived-in buildings, boathouses and docks, generic stage-damage curves were not generally available and placeholder curves were developed using information from the study including responses from shoreline property owners in the 2013 and 2014 surveys. For non-lived-in buildings, boathouses, and docks, the baseline Flood Tool assumed damages started once inundation began. The rate of damage increase associated with particular depth of inundation was estimated and at least the absolute damages estimated by the model were likely to be misleading when there were damages that increase more rapidly or more gradually with the depth of inundation. Table 7-5 illustrates the relative comparison in scenario performance between the 2000 and 1970 rule curves based on a +10 percent and -10 percent change in the curves. Changing the stage-damage curves +10 percent and -10 percent did not impact the general trend of the average annual Flood Tool results and the 2000 rule curves continued to have slightly increased flood impacts relative to the 1970 rule curves. However, the absolute magnitude of the damage estimates produced by the Flood Tool varied if alterations were be made to the stage-damage curves. There were other changes that could have been made to the shape of the stage-damage curves for non-lived-in buildings, docks, and boathouses but they were not tested given the initial results of the sensitivity analysis.

Scenario	Lake	Inundated Lived-In Structure Count	Inundated Non-Lived-In Structure Count	Inundated Boathouse Count	Inundated Dock Count
Baseline	Rainy Lake	0.9	1.7	1.7	1.4
	Namakan/Kabetogama, Crane, Sand Point	14.6	14.6	9.7	7.1
	Total	**3.8**	**3.5**	**3.6**	**2.5**
Adjusted (All curves increased by 10 percent)	Rainy Lake	0.9	1.7	1.7	1.4
	Namakan/Kabetogama, Crane, Sand Point	14.6	14.6	9.7	7.1
	Total	**3.8**	**3.5**	**3.6**	**2.5**
Adjusted (All curves decreased by 10 percent)	Rainy Lake	1.0	1.7	1.7	1.4
	Namakan/Kabetogama, Crane, Sand Point	14.6	14.6	9.8	7.1
	Total	**3.8**	**3.5**	**3.6**	**2.5**

Table 7-5: Estimates of the percent change in average annual economic impacts between the 1970 and 2000 rule curves for the baseline simulation and for adjusted stage-damage curves (+/- 10 percent) (positive values represent greater impacts for the 2000 rule curves)

8 Possible Follow-Up Activities Regarding the Flood Tool and Ice Impacts

In its current form, the Flood Tool for Rainy Lake and the Namakan chain of lakes allowed for the relative comparison of impacts between simulations of the 1970 and 2000 rule curves. Given that these two simulations showed relatively small differences in peak annual flood levels during years in which water levels exceeded the upper rule curve bounds (3 cm and 0 cm on average for Namakan Lake and Rainy Lake, respectively), the estimated net differences between the two management strategies were also relatively small. The development of the geospatial database and Flood Tool along with the sensitivity testing identified a number of areas where uncertainty existed and where further work may help reduce those uncertainties. In all cases, the need to undertake the work and the benefits of doing so must be judged against the expected investment and the intended use of the Flood Tool results. Many of the possible areas for future development are likely to lead to a more technically robust evaluation tool but may not have considerable impact on the net comparison. Should more extreme alternative water level management scenarios be considered or should there be interest in using the Flood Tool as a means to estimate absolute flood damages with more confidence (this could support floodplain management measures), consideration could be given to further testing of the importance of the suggestions identified below. Implications for the ice impact component are also discussed.

8.1 Elevation Estimates for Canadian Shore of Rainy Lake

Only limited elevation data was available for the Canadian shore of Rainy Lake (e.g., only 4.5 percent of buildings in the database had elevation data). Better elevation estimates for the Canadian shoreline could be used to ensure the current approach to estimating impacts in areas where elevation estimates could not be obtained did not over or underestimate flood risks in the area. Updates could be made directly to the geospatial database as new information becomes available. That information would then have to be attributed to the Excel input file for the Flood Tool as any structures with elevation estimates added would have to be removed from the “no elevation” portion of the database to ensure impacts would not be double counted.

8.2 Elevation (Datum) Adjustments

Elevation data used in the Flood Study was based on a range of datums (e.g., USC&GS 1912, NAVD88, etc.). Attempts were made to convert to a common datum used to report water levels (USC&GS 1912). Recent elevation survey work has been completed on behalf of the International Rainy-Lake of the Woods Watershed Board to identify new datum adjustment factors within the basin. These adjustment factors were not available as part of the Flood Damage Study. Consideration should be given as to the impact of the new datum adjustment factors on the Flood Tool database. It may be that corrections need to be made to the database based on the new information but further evaluation is required to determine the appropriate steps (i.e., whether the database could be converted directly or whether a second conversion needs to take place outside the database first). The adjustments will be critical when applying the Flood Tool in any future rule curve comparison (e.g., alternative rule curves, alternative input hydrology).

8.3 Inclusion of Rainy River Impacts

The Flood Tool used Rainy Lake levels to estimate flood damage. Between the International railway bridge and the control structure, the stage-fall relationship of water levels varied based on both lake levels and releases from the dam and so damages were not estimated for that region within the Flood Tool. In general, this was not expected to lead to large differences in estimates between the management scenarios. However, the elevations might cause critical issues under extreme water level conditions. For example, extreme water levels near or above the historical maximum could lead to critical issues in the Town of Fort Frances that were not captured in the Flood Tool. In addition, the project boundary did not include the Rainy River below the control structure; that region must be included to assess trade-offs between upstream and downstream impacts that could occur with larger releases from Rainy Lake.

8.4 Stage-Damage Curves

Currently, only the lived-in buildings component of the Flood Tool used a standard stage-damage curve (USACE, 2000). The curves for non-lived-in buildings, docks, and boathouses were estimated within the study based on information from property owners. There was a high degree of uncertainty in those curves and further work could be considered to refine the estimates. In particular, the use of the curves for docks was questionable because inundation alone was not the key driver of dock damage. It is possible that the dock damage estimates in the model overestimate expected damages based on the findings of the 2013 and 2014 surveys.

8.5 Economic Considerations

Efforts would need to be made to establish a common economic baseline with other evaluation metrics (i.e., hydropower generation, tourism impacts, etc.) if direct comparisons are made with results from those studies.

8.6 Structure Values

The Input Excel Database estimated structure value by using $/m^2 estimates and structure footprint area. The database allowed for site-specific value estimates to be used if there were means to obtain them. Further consideration could be given to identifying options for refining the value estimates.

8.7 Pinch-Point Offsets

The Flood Tool utilized a generic pinch-point offset for Crane Lake and Sand Point Lake even though the offset was likely to vary throughout the year. Consideration could be given to making the pinch-point offsets more dynamic within the Flood Tool.

8.8 Further Sensitivity Analysis

The current sensitivity analysis only considered changes in single parameters as a test of the relative performance of the 2000 and 1970 rule curves. Further efforts should be examined for looking at combining changes to multiple parameters to ensure the expected trends in relative performance remain consistent.

8.9 Wave Action

The 2014 high water event illustrated the importance of wave action in causing shoreline damages. The current Flood Tool was based solely on inundation impacts and did not incorporate wave action in the damage calculation, in part because the relative difference between plans was so small (the same waves would occur; only the static water levels change when the rule curves change). However, further work could be done to see how sensitive the evaluation results would be if wave impacts were included. Given the structure of the ecological model developed by Morin *et al.* (2016), it may be possible to utilize that model along with the Flood Tool database to support wave impact calculations.

8.10 Alternative Measures of Inundation Impacts

The Flood Tool evaluated damages to lived-in and non-lived in buildings, docks, and boathouses. The 2014 high water conditions and associated survey results illustrated a range of other damage categories that could be considered (e.g., roads, other infrastructure, etc.) along with potential indirect costs (e.g., loss of use, loss of income, etc.). All of these additional items were anticipated to respond in a similar manner to the indicators currently used in the analysis (i.e., higher water increases damages). Further additions to the Flood Tool should be prioritized based on indicators that are expected to respond in a different manner to the current indicators or ones that can be readily quantified based on existing shoreline information.

8.11 Estimating Ice Impacts

In addition to the flood impacts addressed through the Flood Tool, ice impacts were considered as part of this project although no predictive tool was developed. Clearly, further work is needed to assess the sensitivity of shoreline structures to ice impacts under alternative rule curve scenarios. The work would need to include a better understanding of the damage mechanism associated with ice impacts as well as a tool to predict such impacts. A more comprehensive literature review may be adequate to improve the understanding of damage mechanisms, as well as further discussions with property owners. It is important that ice impacts are considered collectively with other benefits and impacts associated with water level management. For example, low winter water levels may limit ice impacts because docks and boathouses would be out of the water but those low water levels may also limit boat access in the late fall or early spring.

9 Conclusions

The flood damage project was undertaken with the following objectives:

- Establish a geospatial database for the Rainy/Namakan Lake system with a classification of shoreline activities as they relate to flooding and ice damage vulnerabilities to allow a general estimation of overall economic impacts.
- Undertake field verification for representative focus sites to verify flooding and ice damage vulnerabilities (e.g., elevation) and update geospatial database accordingly.
- Develop stage-damage functions of potential flooding and ice impacts for the Rainy/Namakan Lake system.
- Utilize stage-damage functions to estimate potential differences in overall flooding and ice impacts between the 1970 and 2000 rule curves.
- Provide a data storage framework in the form of the attributed geospatial database that can be maintained and updated in the future to incorporate new information on vulnerabilities

A geospatial database was developed that attributed key vulnerabilities along the Rainy Lake and Namakan chain of lakes shoreline. The database was provided as a deliverable for the project and it can be updated and modified in the future as more information and data become available. A series of property owner site visits were undertaken in 2013 to gather input and perspectives on flood and ice damage vulnerabilities and an additional online survey was undertaken in 2014 in response to observed high water conditions. The information from both those surveys was used to characterize the critical shoreline vulnerabilities and the expected impacts under various water level conditions. An Excel based Flood Tool was developed that calculated flood damages to lived-in and non-lived-in buildings, docks, and boathouses on an annual basis based on water level inundation.

Using the Flood Tool, results from the simulated 1970 and 2000 rule curves were compared for the 1950 to 2014 period. On an average annual basis, estimated high water impacts (count) through the study area increased by 5.5, 2.4, 2.6 and 0.7 percent for lived-in, non-lived-in, boathouse, and dock structures respectively (1.2 percent collectively) with the 2000 rule curves. Economic damages increased anywhere from 2.2 percent for docks to 5.5 percent for lived-in buildings for the system as a whole (2.7 percent collectively). The general response of a slight increase in impacts under the 2000 rule curves was consistent with the 1999 IRLBC report.

Docks were most commonly impacted and generally represented the largest portion of the damages based on the current modelling approach which was consistent with the 2013 and 2014 property owner surveys. Non-lived-in buildings represented an important component of the number of structures impacted but a much smaller component of the economic damage estimates due to the generally low replacement costs associated with such structures. Lived-in buildings represented a relatively small proportion of the number of structures flooded within the existing simulations but were generally of high value and therefore were the second highest contributor to the overall damages on an average annual basis. The net changes of the 2000 rule curve results as a percent of the 1970 rule curve results tended to be greater for the Namakan chain of lakes, although the average annual impacts were about four times greater on Rainy Lake due to the greater number of structures that could potentially be impacted (i.e., higher amount of development).

The Flood Tool and associated input databases were developed with the anticipation that updates would be made in the future as new information becomes available. For example, alternative water management scenarios could be easily input into the database and results generated. The input database can also be readily updated as new information becomes available. If improved elevation data becomes available for portions of the Canadian shoreline, the database can be updated and the Flood Tool re-run to look at the differences.

Evaluation of ice impacts was much more limited in the current assessment and the results inconclusive. There was little evidence that could be used to quantify a change in ice damage caused by a change in water levels regime, but there was a plausible concern that damage could increase if levels were higher when the ice forms and if the water levels dropped more over the ice cover period. Based on those water level metrics, there was little difference in the 1970 and 2000 rule curve water levels on Rainy Lake. While historical ice damages were reported in the 2013 site visits and associated surveys (38 percent of respondents), it was unlikely that the move to the 2000 rule curve contributed greatly to an increase or decrease in ice related damages relative to what would have occurred using the 1970 rule curves because water levels were so similar during the ice cover period within the two rule curve simulations used in the assessment. Results on the Namakan chain of lakes were more uncertain and further work should be considered specifically for this area to verify and refine the results. On the Namakan chain of lakes, the 2000 rule curve did reduce the magnitude of winter drawdown relative to the 1970 rule curve with water levels generally being much higher throughout the ice cover period. The implication was that the 1970 rule curve left some docks out of the water over the ice cover period reducing potential problems associated with ice movement. The trade-off was that low water levels under the 1970 rule curves also reduced boating access in the period just after ice-out. While not specifically asked in the 2013 survey, respondents from Kabetogama Lake were much more likely to express their support for the 2000 rule curves due to increased early season boat access and more stable overall water levels than they were to identify concerns associated with potential ice impacts (16 of 17 comments received for Kabetogama Lake surveys).

As with all simulation tools, there were assumptions, limitations and uncertainties associated with the existing Flood Tool and analysis. The significance of the limitations needs to be assessed in the context of the rule curve evaluation process. The Flood Tool did not estimate all types of flood damages that could be accounted for during any particular high water event. An initial comparison between the project database and photographic evidence from the 2014 flood indicated good agreement between two approaches in terms of the location of vulnerable shoreline development. However, information was not currently available on a site-specific basis to compare modelled damage estimates at particular locations with reported damages. In its current form, the Flood Tool for Rainy Lake and the Namakan chain of lakes allowed for the relative comparison of impacts between water level simulations based on metrics associated with replacement costs for commonly found shoreline structures. Given that these two simulations used for the current analysis, the 1970 and 2000 rule curves, showed relatively small differences in peak annual flood levels during years in which water levels exceeded the upper rule curve bounds (3 cm and 0 cm on average for Namakan Lake and Rainy Lake, respectively), the estimated net differences between the two management strategies were also relatively small (~1.2 percent overall). As outlined in the suggestions for future work, this study could be expanded to add additional metrics of flood impacts to the Flood Tool (e.g., flooding of roads, etc.). In all cases, the need to undertake the work and the benefits of doing so must be judged against the expected investment and the intended use of the Flood Tool results. Many of the possible areas for future development are likely to lead to a more technically robust evaluation tool, particularly in the context of estimating absolute damages, but may not have considerable impact on the net comparison unless differences between alternative management strategies is expected to increase.

10 Recommendations

Based on the current study, the following recommendations have been identified for future consideration as a means to improve the overall analysis and enhance the understanding of flood and ice vulnerability within the Rainy Lake and Namakan chain of lakes study area:

1. Acquire better elevation estimates of structures on the Canadian shoreline and update database appropriately, with focus on priority vulnerable structures as identified through the 2013 Environment Canada photos.
2. Improve understanding of the vulnerability of shoreline structures from ice under variable water level conditions.
3. Develop a complementary tool to include flood vulnerability for the Rainy River downstream of the Rainy Lake outlet.
4. Use updated elevation datum offsets to validate offsets used in the project, and make adjustments to database as necessary based on the results.
5. Review stage-damage functions used to estimate inundation damages for individual structures.
6. Incorporate a component associated with wave energy to the overall impact assessment, possibly by linking the Flood Tool database and damage calculations with the physical processes calculated within the ecological response model developed by Morin *et al.* (2016).
7. Maintain and refine geospatial database as new information on structure vulnerability becomes available. For example, better classification of structure types as they relate to available stage-damage curves would improve the database and the application of the tool.
8. Evaluate the benefit of adding additional metrics of flood impact (e.g., flooding of roads, etc.) to the Flood Tool.

References

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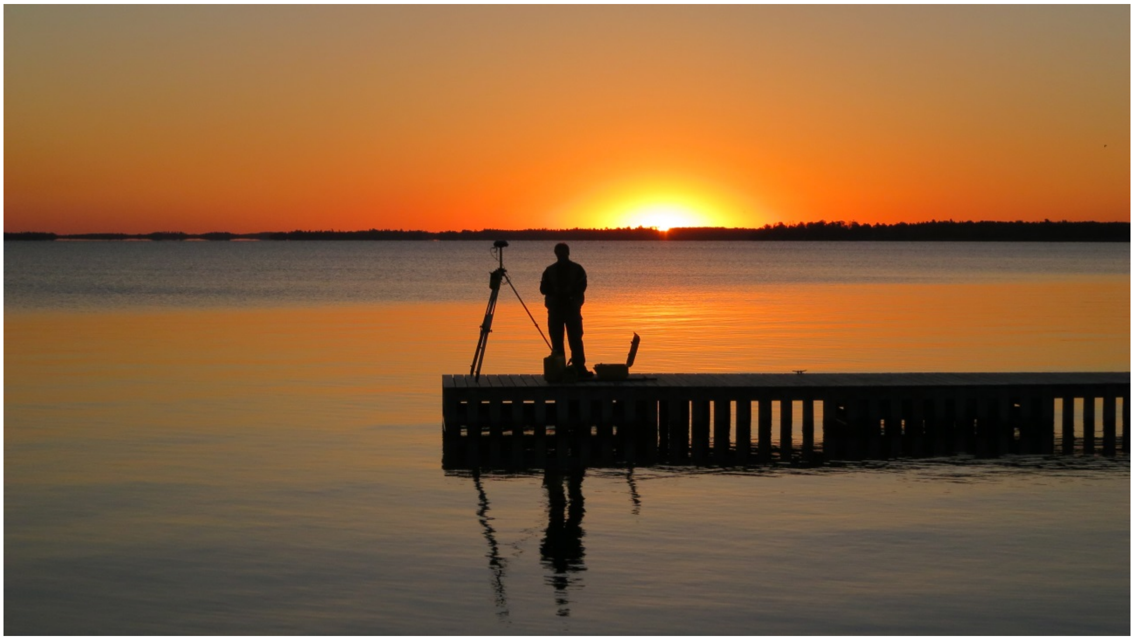
Appendix A: Copy of Supplementary KRC Report and Questionnaires

Supplementary Report



Information submitted to accompany field data and support the preparation of a Flood Vulnerability Assessment on the Rainy and Namakan Chain of Lakes

Submitted by Ryan Haines, Kenora Resource Consultants Inc.

Submitted to Mike Shantz, Environment Canada

December 2013

Introduction

This supplementary report provides information on the field work conducted by Kenora Resource Consultants Inc. during the fall of 2013. This information is intended to assist with the preparation of the Flood Vulnerability Assessment on the Rainy and Namakan Chain of Lakes. The supplementary report will provide an overview of the methodology used throughout the project in addition to a discussion of the field results to assist in the completion of the vulnerability assessment.

Field Work Scheduling

The field work was conducted in two distinct phases. The first phase occurred between August 29th and September 2nd at Bear's Passage on the Canadian side of Rainy Lake. The purpose of this initial field component was two-fold. The site visits conducted during the Labour Day weekend provided an opportunity to visit the area when there was a higher percentage of year-round and seasonal property owners, both Canadian and US residents, present at their properties. In addition, the initial field session provided an opportunity to test out the original field design of the project to allow for adjustments to be made to improve on the field survey methodology for the remainder of the watershed.

The second phase of the field work was conducted between October 1st and October 10th. This work commenced following Environment Canada and Kenora Resource Consultants staff having an opportunity to review the results of the work conducted at Bear's Passage, provide recommendations on how to improve upon the field work design, and make required changes to project equipment utilized.

Methodology

Access

For all of the field work conducted at Bear's Passage, the properties were accessed by boat. This approach had its benefits and drawbacks. The main benefit to accessing the properties by boat was the time savings in the deployment of the GPS equipment. Most of the structures that were documented using the equipment were found near the shoreline, so there was less time spent accessing the structures than if the properties were accessed by vehicle. The ability to locate property owners who were home when accessing by boat varied depending on the weather. Labour Day weekend in 2013 was a mix of beautiful, sunny days and cold, windy days. On the sunny days, determining the presence of property owners was relatively easy when accessing by boat as there was a great deal of activity outdoors including; property owners enjoying their dock areas and/or decks; property owners working in their yards; and property owners accessing their properties by boat. However, determining the presence of property owners by boat on the windy, cooler days proved to be very challenging. On these days a great deal of time was spent docking the boat, walking up to the main building, and knocking on people's doors only to find that no one was present at the property at that time. It was felt that under these conditions, accessing the properties by vehicle may prove beneficial as the presence of a vehicle at the property would provide an indication of the presence of the property owner and save a great deal of time locating available property owners.

In order to enable to field crew to conduct surveys at water access properties, the boat was again used at both Crane Lake and Ash River. However, for the remaining areas surveyed, a vehicle was used to access the properties to be surveyed. As anticipated during the Bear's Passage field work, it was much easier to determine if property owners were present when accessing their properties from the road given the cooler conditions found during the survey period.

Equipment

Residential GPS measurements were collected for the Bear's Passage portion of Rainy Lake with a GNSS enabled Trimble ProXRT receiver, with an Omnistar G2 subscription, and Zypher 2 antenna. Real-time vertical accuracy was measured using Trimble's TerraSync software. The distance-to-water and distance-to-structure centimetre measurements were taken with a tape-measure, and are from the surface of the GPS-measured structures. Due to longer than expected satellite initialization times for the ProXRT receiver, coupled with a restrictive dependence on having an unobstructed southern horizon to maintain a connection with the Omnistar service, a new hardware configuration was employed for the remaining field component of the project.

In order to reduce the satellite initialization times, an RTK system was used during the second phase of the field work. This system was comprised of a base station, antennae booster, and rover. Real-time vertical accuracy was measured using Trimble's TerraSync software. The distance-to-water and distance-to-structure centimetre measurements were taken with a tape-measure, and are from the surface of the GPS-measured structures.

Data Collection

During the first phase of the field work at Bear's Passage, the real-time measurements were recorded as found on the unit. The receiver was programmed to only log points if the vertical accuracy was within 10 cm of error. At each feature, 100 data points would be recorded providing the satellite initialization times and southern horizon view allowed for this many to be recorded.

During the second phase of the field work, benchmarks were used to ensure elevation accuracy of the units and height of antennae adjustments were made to the rover until the elevation measurements were consistently less than 3 cm from the benchmark data*. The rover/receiver was programmed to only log points if the vertical accuracy was within 10 cm of error. Once again, a minimum of100 data points were recorded for each feature provided that the amount of time required to get 100 points within 10 cm of accuracy was not prohibitive. For each feature, the level at which damage would begin to occur was the height of measurement. For dock structures, the end of the dock furthest from land was the primary measurement point. In cases where the dock was uneven at the end, the lowest side was selected for measurement. For shoreline structures, the lowest point where flood damages would begin to occur was selected for measurement. The interviews were used to determine the nature of damages, so when foundation damage was identified as the primary risk of flooding the lowest point of the foundation was selected for elevation measurements, when equipment or general water damage were identified the lowest opening was the elevation measurement point. Various sizes and lengths of lumber were used, along with a level, to obtain elevation measurements from structures where satellite initialization proved to be difficult immediately adjacent to the structure.

*It should be noted that, on October 9th, the height of rover measurements could not be adjusted to match the benchmark data (it required a negative height, which was not an option on the rover). Therefore, the raw data on October 9th requires a 1 m addition to all points to match with the benchmark data.

Data Analysis

<table>
<tr><th>Date</th><th>Sites</th><th>Geodetic Monument</th><th>Comments</th></tr>
<tr><td>Oct. 2</td><td>CDN01 to CDN16</td><td>MTO BM
738351</td><td>The elevation measurements were consistently lower than would be expected given the LOWCB lake level values for the day (337.58 m) and the distance to water measurements. It is likely that either the relationship between the benchmark used and the LOWCB data are off by approximately 39.5 cm, or the actual water levels at this section of Rainy Lake varied from the nearest gauge on October 2nd by approx. 39.5 cm, or a combination of the two resulted in the discrepancy. When this 39.5 cm discrepancy is taken into account, the Rainy Lake elevation measurements on October 2nd vary by a factor of +/- 9.5 cm.</td></tr>
<tr><td>Oct. 3</td><td>CDN 17 to CDN28</td><td>None</td><td>The height of the rover did not appear to require any adjustments on this date to match with LOWCB data. However, the elevation measurements were generally lower than would be expected given the LOWCB lake level values for the day (337.58 m) and the distance to water measurements. It is likely that either the height of the rover was slightly off, or the actual water levels along this section of Rainy Lake varied from the nearest gauge on October 3rd by approx. 8.5 cm, or a combination of the two resulted in the discrepancy. When this 8.5 cm discrepancy is taken into account, the Rainy Lake elevation measurements on October 3rd vary by a factor of +/- 8.5 cm.</td></tr>
<tr><td>Oct. 4</td><td>CL01 to CL10</td><td>GSID # 28366
GREG MNDT</td><td rowspan="2">The elevation measurements were consistently higher than would be expected given the LOWCB lake level values for the day (340.47 m) and the distance to water measurements. There was only one out of 26 measurements with an elevation measurement lower than would be expected (1 cm), which will be treated as an anomaly and excluded from the remaining data discussions. Therefore, it is likely that either the relationship between the benchmark used and the LOWCB data are off by approximately 9.5 cm, or the actual water levels at Crane Lake varied</td></tr>
<tr><td>Oct. 5</td><td>CL11 to CL14</td><td>GSID # 28366
GREG MNDT</td></tr>
</table>

			from the nearest gauge on October 4th and 5th by approx. 9.5 cm, or a combination of the two resulted in the discrepancy. When this 9.5 cm discrepancy is taken into account, the Crane Lake elevation measurements vary by a factor of +/- 4.5 cm.
Oct. 5	AR01 to AR07	GSID # 27739 ART MN137	The elevation measurements were consistently higher than would be expected given the LOWCB lake level values for the day (340.46 m) and the distance to water measurements. It is likely that either the relationship between the benchmark used and the LOWCB data are off by approximately 6.5 cm, or the actual water levels at Ash River varied from the nearest gauge on October 5th by approx. 6.5 cm, or a combination of the two resulted in the discrepancy. When this 6.5 cm discrepancy is taken into account, the Ash River elevation measurements vary by a factor of +/- 5.5 cm.
Oct. 6	KL01 to KL17	GSID # 27780 B 208	The elevation measurements were consistently higher than would be expected given the LOWCB lake level values for the day (340.43 m) and the distance to water measurements. There was only one out of 48 measurements with an elevation measurement lower than would be expected (24 cm), which will be treated as an anomaly and excluded from the remaining data discussions. It is likely that either the relationship between the benchmark used and the LOWCB data are off by approximately 9.5 cm, or the actual water levels at Kabetogama Lake varied from the nearest gauge on October 6th and 7th by approx. 9.5 cm, or a combination of the two resulted in the discrepancy. When this 9.5 cm discrepancy is taken into account, the Kabetogama elevation measurements vary by a factor of +/- 9.5 cm.
Oct. 7	KL18 to KL22	GSID # 27780 B 208	
Oct. 8	US01 to US21	GSID # 94615 REINAR and	The elevation measurements were consistently higher than would be expected given the LOWCB lake level values for the day (337.55 m) and the distance to water measurements. It is likely that either the relationship between the benchmark(s) used and the LOWCB data are off by approximately 9 cm, or the actual water levels along this US portion varied from the nearest gauge on October 8th by approx. 9 cm, or a combination of the two resulted in the discrepancy. When this 9 cm discrepancy is taken into account, the US portion of Rainy Lake elevation measurements on October 8th vary by a factor of +/- 7 cm.

<table>
<tr><td></td><td></td><td>RANIER</td><td></td></tr>
<tr><td>Oct. 9</td><td>US22 to 25 and US 27 to 33</td><td>TBIRD</td><td rowspan="2">The elevation measurements were consistently higher than would be expected given the LOWCB lake level values for the day (337.55 m) and the distance to water measurements. There was only one out of 33 measurements with an elevation measurement almost exactly as would be expected (off by 2 cm), which will be treated as an anomaly and excluded from the remaining data discussions. It is likely that either the relationship between the benchmark used and the LOWCB data are off by approximately 11.5 cm, or the actual water levels at Rainy Lake varied from the nearest gauge on October 9th by approx. 11.5 cm, or a combination of the two resulted in the discrepancy. When this 11.5 cm discrepancy is taken into account, the US portion of Rainy Lake elevation measurements on October 9th vary by a factor of +/- 4.5 cm.</td></tr>
<tr><td>Oct. 9</td><td>US26, US 34 to 41</td><td>KENOS</td></tr>
<tr><td>Oct. 10</td><td>CDNNWO</td><td>MTO BM 738351</td><td>Elevation measurements all either 29 cm or 30 cm less than would be expected given lake level and distance to water measurements. These discrepancies likely due to both a difference in datums and distance to the gauges. With discrepancies taken into account, these measurements would vary by a factor of +/- 0.5 cm.</td></tr>
<tr><td>Oct. 10</td><td>CDNRV</td><td>MTO BM 738351</td><td>Elevation measurements are between 4 cm and 16 cm less than would be expected given lake level and distance to water measurements. These discrepancies likely due to both a difference in datums and distance to the gauges. With a 10 cm discrepancy taken into account, these measurements would vary by a factor of +/- 6 cm.</td></tr>
</table>

Data Analysis (cont'd)

In order to increase the accuracy of the data and remove outliers from the data points collected, some post-processing was conducted. To provide more accurate data, only data points collected that occurred between the 25th and 75th percentiles for each feature/structure were used in the final elevation calculations.

Bear's Passage Data Analysis and Lessons Learned

With only a couple of exceptions, elevation data from the Bear's Passage area was consistently lower than would be expected given the LOWCB lake level values for the time period (337.62 m) and the distance to water measurements. However, even with an adjustment to account for any potential discrepancies, the data would vary by a factor greater than +/- 20 cm. This amount of error does not meet the requirements of the project and indicates that, in addition to the long satellite initialization times that plagued the use of the GNSS enabled Trimble ProXRT receiver with Omnistar G2 subscription and Zypher 2 antenna, this set up does not provide the level of accuracy required to conduct this type of work. The RTK system used for the remainder of the field work rectified both the length of time and accuracy challenges that were posed with the GPS field equipment used at Bear's Passage.

Interviews

The interviews conducted went extremely well and with very few exceptions property owners were happy to have the opportunity to share their experiences. There was also a sense of appreciation as property owners indicated that they were encouraged by the IJC's efforts to seek their input. Conducting interviews proved to be very easy once property owners were found to be home. Only one property owner expressed a preference to not be interviewed due to suspicions regarding the nature and/or intent of the survey. There were a few property owners that who too busy at the time of the initial visit to their property, with some of these people successfully interviewed when the field crew undertook a subsequent interview visit later the same day. Property owners tended to be very welcoming of the field crew and were eager to share information, provide tours of their property, and share photographs of past water level events.

With the timing of the field work in the fall, often the property owners interviewed focussed on those that were still present at their properties instead of those with the highest risk properties as had been hoped. However, it is felt that, despite the limited number of property owners using their property in October, the quantity and nature of the property owners that were interviewed does provide an excellent summary of the majority of the areas visited. While a subsequent summer visit would likely provide the ability to interview more property owners or select those with properties most at risk, it is felt that the October field work was able to provide interviews with a broad cross section of property owners that provide an excellent summary of property impacts due to water levels and property owner attitudes towards the 2000 rule curve.

Initial Questionnaire Draft

Rainy/Namakan Flood Vulnerability Fall 2013

Lake/Site: ____________________ Date: ____________________

Type of Residence: _________________ (Full-time/Part-time/Seasonal)

If seasonal, what months: ___________________

Years at Location: _______________

Main Building at Risk (Y/N): _____ Estimated Replacement Cost: ____________

Foundation Type: ___________ (basement/crawlspace/piles/concrete pad (no basement)/other)

Flood Proofing: ____

Type of Damage if Flooded: ____

____

Septic Field (Y/N): _____ Septic Field at Risk (Y/N): _____

Number of Out Building(s) at Risk: _____ Estimated Replacement Cost: ___________

Out Building(s) Foundation Type: ____
(basement/crawlspace/piles/concrete pad (no basement)/other)

Flood Proofing: ____

Type of Damage if Flooded: ____

____

Dock Type: ________________ (Crib/Floating/Combo)

Boathouse: ________________ (Permanent/Seasonal)

Past Dock/Boathouse Damage: ____

Flood Damage Incurred in 2001 or 2002: ____

Flood Damage Incurred in Other Years: ____

Other Water Level Related Problems: ____

Updated Questionnaire

Rainy/Namakan Flood Vulnerability **Fall 2013**

Date:____________________________ Water level:________________

Waterbody: _____________________ Site:_____________________

Type of Residence: Full-time/Part-time/Seasonal. If seasonal, which months:________________

Years at Location:_______________ Access: Boat / Road

Flood Damage 2001 or 2002: ____

Flood Damage Other Years: ____

Ice Damage at Property:____

Past Dock/Boathouse Damage: ____

Other Water Level Related Problems: ____

Flood Proofing Costs: Time / Money / Both:____

Main Building at Risk (Y/N):_____ Estimated Replacement Cost:_____________

Foundation Type:_____________ (basement/crawlspace/piles/concrete pad (no basement)/other)

Flood Prevention:____

Type of Damage if Flooded:____

Septic Field (Y/N):_____ Septic Field at Risk (Y/N):_____

Number of Out Building(s) at Risk:_____ Estimated Replacement Cost:____________

Out Building(s) #:____

Foundation Type: ____
(basement/crawlspace/piles/concrete pad (no basement)/other)

Flood Prevention:____

Type of Damage if Flooded:____

____

Dock(s) #:____
(Crib/Floating/Combo)

Boathouse(s) #:____
(Permanent/Seasonal

Date: Waterbody: Water Level: Site:

Structure Type	Length	Width	Coordinates x	Coordinates y	Height Above Water	Elevation

Appendix B: Summary of KRC Questionnaire Responses

KRC completed a total of 131 property owner surveys in August, September, and October 2013. Notification of the survey was posted to the International Rainy-Lake of the Woods Watershed Board (IRLWWB) website with an announcement asking for interested property owners to contact the flood damage study coordinator if they wanted to participate in the survey. In addition, announcements were made at the summer 2013 public meeting of the IRLWWB inviting property owners to participate in the survey and contact was made with members of the Border Lakes Association executive informing them of the survey and encouraging them to let their members know about the survey in case they wanted to participate. There were 47 surveys undertaken on the Canadian shoreline and 84 on the US shoreline.

The field survey notes (completed questionnaires) were summarized into an Excel spreadsheet by KRC staff. The spreadsheet was further modified by Environment Canada staff (Mike Shantz) to adjust formatting, to link responses from the preliminary Bear's Pass field visit to the responses from the rest of the surveys, and to further categorize responses for specific questions to support summary statistics and reporting.

Results:

Property Owner Information:

Of the 131 respondents, 85 (64.9 percent) considered themselves to be full time residents, that is they lived at their shoreline property year round. Another 39 (29.8 percent) property owners considered themselves to be primarily seasonal residents who lived at their shoreline property full time but only for a portion of the year. The remaining property owners considered themselves to be part time residents who visited at all times of the year but only stayed for short periods of time. Of the seasonal residents, the majority spent at least the summer months (June-August) at their shoreline property with many of them also using the property in May, September, and October.

On average, the survey respondents had spent 23.6 years at their location with the shortest period of residence being less than 1 year and the longest period or residence being 91 years. There was very little difference between the Canadian and US respondents on Rainy Lake in terms of the average years spent at the location. For the Canadian respondents, the average number of years at their location was 24.4 years while the average number of years at their location was 23.2 years for the US Rainy Lake respondents. There was also little difference when comparing the responses when grouped by priority area. Table B-1 summarizes the results and shows a range between 21.5 years for the Kabetogama area and 24.4 years for the Canadian Rainy Lake. When comparing all Rainy Lake responses to those on the Namakan chain of lakes, the difference remained small with the Rainy respondents averaging 24.2 years and the Namakan chain respondents averaging 22.5 years (Table B-2).

	Average	Min	Max
Rainy (Can)	24.4	1	59
Rainy (US)	23.9	1	91
Kabetogama	21.5	1	59
Ash River	22.1	6	44
Crane	24.3	6	50
All Sites	*23.6*	*1*	*91*

Table B-1: Length of residency, by priority area

	Average	Min	Max
Rainy	24.2	1	91
Namakan Chain	22.5	1	59
All Sites	*23.6*	*0*	*91*

Table B-2: Length of residency, by lake

2001 and 2002 Flood Damages:

Between the implementation of the new rule curves at the beginning of 2001 and the time of the survey in 2013, water levels on Rainy exceeded the all-gates open level in 2001, 2002, 2005, 2008 and 2013. A number of the survey questions were intended to gather information from property owners on their experiences related to flooding at their property, specifically during 2001 and 2002 which were the highest levels observed on the lakes during the period. Property owners were asked if they experienced flood damage in either 2001 or 2002. Of the 131 respondents, 56 (42.7 percent) indicated that they experienced flooding damage in one or both of those years. A further 11 respondents (8.4 percent) reported some flooding of their property in those years but not to the extent that any damage was reported. Fifty-one of the respondents (38.9 percent) indicated that they did not experience any flooding damage in those years and the remaining 13 (9.9 percent) were not sure if flood damages occurred (generally because they did not own the property at that time). Table B-3 illustrates the relative breakdown of responses between different areas where the survey took place. Table B-4 shows the responses grouped for Rainy Lake and the Namakan chain of lakes and normalized as a percent of the total number of responses for that lake. 43.2 percent of the Rainy Lake respondents indicated flood damages in 2001 and/or 2002 compared with 41.9 percent on the Namakan chain of lakes.

	Total	As Count				As Percent (by Region)			
		Yes	No	flooding but no damage	unsure or n/a	Yes	No	flooding but no damage	unsure or n/a
Rainy (Can)	47	24	17	0	6	51.1	36.2	0.0	12.8
Rainy (US)	41	14	21	4	2	34.1	51.2	9.8	4.9
Kabetogama	22	8	7	4	3	36.4	31.8	18.2	13.6
Ash River	7	2	3	1	1	28.6	42.9	14.3	14.3
Crane	14	8	3	2	1	57.1	21.4	14.3	7.1
All Sites	*131*	*56*	*51*	*11*	*13*	*42.7*	*38.9*	*8.4*	*9.9*

Table B-3: Summary of responses related to observed 2001 or 2002 flood damages, by priority area

	Total	As Count				As Percent (by Lake)			
		Yes	No	flooding but no damage	unsure or n/a	Yes	No	flooding but no damage	unsure or n/a
Rainy	88	38	38	4	8	43.2	43.2	4.5	9.1
Namakan Chain	43	18	13	7	5	41.9	30.2	16.3	11.6
All Sites	*131*	*56*	*51*	*11*	*13*	*42.7*	*38.9*	*8.4*	*9.9*

Table B-4: Summary of responses related to observed 2001 or 2002 flood damages, by lake

Residents were asked about the types of damages experienced in 2001 and/or 2002, particularly related to main buildings (i.e., lived-in buildings) on their property, outbuildings or secondary buildings (i.e., non-lived-in buildings) on their property, and shoreline features such as docks. Residents were also asked whether there were additional damages that did not fall within the first three categories. Table B-5 provides the number of responses for each of the main damage categories by region and Table B-6 shows the breakdown between Rainy Lake and the Namakan chain of lakes. Only 7 (5.3 percent) of the respondents indicated any flooding to their main buildings during the 2001 and/or 2002 high water periods. On Rainy Lake, 5 respondents indicated some sort of main (lived-in) building damage during the high water periods representing 6 percent of the Rainy Lake respondents. For the Namakan chain of lakes, only 2 of the 43 respondents indicated main (lived-in) building damage in 2001 and/or 2002 representing 4.7 percent of respondents on those lakes.

	Survey Responses (count)	Respondents Reporting Main (Lived-In) Building Flooding (count)	Respondents Reporting Main (Lived-In) Building Flooding (Percent by Region)
Rainy (Can)	47	4	8.5
Rainy (US)	41	1	2.4
Kabetogama	22	0	0.0
Ash River	7	0	0.0
Crane	14	2	14.3
All Sites	*131*	*7*	*5.3*

Table B-5: Summary of responses related to main building damage in 2001 or 2002, by priority area

	Survey Responses (count)	Respondents Reporting Main (Lived-In) Building Flooding (count)	Respondents Reporting Main (Lived-In) Building Flooding (Percent by Lake)
Rainy	88	5	5.7
Namakan Chain	43	2	4.7
All Sites	*131*	*7*	*5.3*

Table B-6: Summary of responses related to main building damage in 2001 or 2002, by lake

A similar number of property owners reported damage to outbuildings (non-lived-in buildings) on their property during the 2001 and/or 2002 high water period. In total, 8 respondents indicated damage to their outbuildings (non-lived-in buildings) which represented 6.1 percent of the total respondents. Six of the damage reports were for Rainy Lake (6.8 percent of the Rainy Lake respondents) and 2 were for the Namakan chain of lakes (4.7 percent of the Namakan respondents) (Table B-7 and Table B-8). Considerably more respondents reported dock damage during the 2001 and/or 2002 high water period. In total, 33 respondents reported dock damage representing 25.2 percent of all 131 respondents. Eighteen of those reports were on Rainy Lake and 15 on the Namakan chain of lakes representing 20.5 percent and 34.9 percent respectively of respondents on those two lakes (Table B-9 and Table B-10).

	Survey Responses (count)	Respondents Reporting Secondary (non-lived-in) Building Flooding (count)	Respondents Reporting Secondary (non-lived-in) Building Flooding (Percent by Region)
Rainy (Can)	47	2	4.3
Rainy (US)	41	4	9.8
Kabetogama	22	0	0.0
Ash River	7	0	0.0
Crane	14	2	14.3
All Sites	*131*	*8*	*6.1*

Table B-7: Summary of responses related to outbuilding damage in 2001 or 2002, by priority area

	Survey Responses (count)	Respondents Reporting Secondary (non-lived-in) Building Flooding (count)	Respondents Reporting Secondary (non-lived-in) Building Flooding (Percent by Lake)
Rainy	88	6	6.8
Namakan Chain	43	2	4.7
All Sites	*131*	*8*	*6.1*

Table B-8: Summary of responses related to outbuilding damage in 2001 or 2002, by lake

	Survey Responses (count)	Respondents Reporting Dock Flooding (count)	Respondents Reporting Dock Flooding (Percent by Region)
Rainy (Can)	47	13	27.7
Rainy (US)	41	5	12.2
Kabetogama	22	11	50.0
Ash River	7	1	14.3
Crane	14	3	21.1
All Sites	*131*	*33*	*25.2*

Table B-9: Summary of responses related to dock damage in 2001 or 2002, by priority area

	Survey Responses (count)	Respondents Reporting Dock Flooding (count)	Respondents Reporting Dock Flooding (Percent by Lake)
Rainy	88	18	20.5
Namakan Chain	43	15	34.9
All Sites	*131*	*33*	*25.2*

Table B-10: Summary of responses related to dock damage in 2001 or 2002, by lake

For the open ended question on other types of flood damages, 19 of the 131 respondents (14.5 percent) reported some type of damage. A broad range of damages were consolidated into this category including issues related to shoreline erosion, property access (e.g., flooding of access roads), and lawn inundation. Table B-11 and Table B-12 summarize the responses by region and by lake. Thirteen of the 88 respondents (14.8 percent) on Rainy Lake reported damages in this category compared with 6 of 43 (14.0 percent) of respondents on Namakan Lake.

	Survey Responses (count)	Respondents Reporting Other Flooding (count)	Respondents Reporting Other Flooding (Percent by Region)
Rainy (Can)	47	5	10.6
Rainy (US)	41	8	19.5
Kabetogama	22	1	4.5
Ash River	7	2	28.6
Crane	14	3	21.4
All Sites	*131*	*19*	*14.5*

Table B-11: Summary of responses related to other flooding damage in 2001 or 2002, by priority area

	Survey Responses (count)	Respondents Reporting Other Flooding (count)	Respondents Reporting Other Flooding (Percent by Lake)
Rainy	88	13	14.8
Namakan Chain	43	6	14.0
All Sites	*131*	*19*	*14.5*

Table B-12: Summary of responses related to other flooding damage in 2001 or 2002, by lake

Shoreline residents were asked whether they experienced flooding problems in years other than 2001 and 2002. The question was added specifically to look at the post 2000 period but was not structured well and included some responses for the period prior to 2000. Where responses were clearly for the pre-2000 period, they were not included in the summary here. Overall, 22 respondents (16.8 percent) indicated that they had flood damages in other years and an additional 3 respondents (2.3 percent) indicated that they had flooding but no damages (Table B-13). When comparing between the lakes (Table B-14), 19.3 percent of the respondents on Rainy Lake indicated flood damages in other years while 11.6 percent of respondents on the Namakan chain of lakes indicated damages. Respondents were not asked to specify the type of damage observed.

	Total	As Count				As Percent (by Region)			
		Yes	No	flooding but no damage	unsure or n/a	Yes	No	flooding but no damage	unsure or n/a
Rainy (Can)	47	10	34	0	3	21.3	72.3	0.0	6.4
Rainy (US)	41	7	33	1	0	17.1	80.5	2.4	0.0
Kabetogama	22	3	16	2	1	13.6	72.7	9.1	4.5
Ash River	7	0	7	0	0	0.0	100.0	0.0	0.0
Crane	14	2	12	0	0	14.3	85.7	0.0	0.0

All Sites	*131*	*22*	*102*	*3*	*4*	*16.8*	*77.9*	*2.3*	*3.1*

Table B-13: Summary of responses related to flooding damage in years other than 2001 or 2002, by priority area

	Total	As Count				As Percent (by Lake)			
		Yes	No	flooding but no damage	unsure or n/a	Yes	No	flooding but no damage	unsure or n/a
Rainy	88	17	67	1	3	19.3	76.1	1.1	3.4
Namakan Chain	43	5	35	2	1	11.6	81.4	4.7	2.3
All Sites	*131*	*22*	*102*	*3*	*4*	*16.8*	*77.9*	*2.3*	*3.1*

Table B-14: Summary of responses related to flooding damage in years other than 2001 or 2002, by lake

A specific question was included regarding whether the property owners had experienced past dock and/or boathouse damages. The question was not explicit about a year of damage or the extent of damage. 51.9 percent of respondents reported some form of dock or boathouse damage in the past, while 44.3 percent said they had not experienced damage and another 3.8 percent were unsure (Table B-15). 51.1 percent of the Rainy Lake respondents indicated previous damage to docks and/or boathouses while 53.5 percent of the Namakan Lake respondents reported dock or boathouse damages in the past. On Rainy Lake, the percentage of Canadian respondents reporting dock and/or boathouse damages was 57.4 percent while the percentage of US respondents was lower at 43.9 percent.

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy	88	45	39	4	51.1	44.3	4.5
Namakan Chain	43	23	19	1	53.5	44.2	2.3
All Sites	*131*	*68*	*58*	*5*	*51.9*	*44.3*	*3.8*

Table B-15: Summary of responses related to past dock and boathouse damage, by lake

Ice Damages:

The questionnaire included a question regarding ice damages at the property. This question was not included in the preliminary Bear Pass survey but was subsequently added for the remaining site visits. Of the 114 property owners asked, 42.1 percent indicated that they had previously experienced ice damages. An additional 56.1 percent indicated they had not previously experienced ice damages and the remaining 1.8 percent were unsure or did not know. 38.0 percent of the 71 Rainy Lake respondents experienced ice damages while only 48.8 percent of the 43 Namakan chain of lakes respondents reported previous ice damages (Table B-16). On Rainy Lake, there were minimal differences between the Canadian and US responses.

In Canada, 40.0 percent of the respondents indicated past ice damage while on the US side, the percentage was closer to 36.6 percent.

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy	71	27	43	1	38.0	60.6	1.4
Namakan Chain	43	21	21	1	48.8	48.8	2.3
All Sites	*114*	*48*	*64*	*2*	*42.1*	*56.1*	*1.8*

Table B-16: Summary of responses related to ice damage, by lake

Flood Proofing Costs:

Flood proofing costs represent the cost incurred to reduce future flood damages. Property owners were asked about their past flood proofing costs to get a better understanding of the expenses incurred in responding to flood conditions or reducing flood risk. In some cases, property owners invested time and material in response to flood conditions. In other cases, repair costs were incurred. The responses were broken out to try and differentiate those investments. In reviewing the responses, many residents made reference to investments in flood response activities (e.g., placing barrels or other weights on docks). While such activities are considered separate from flood proofing (i.e., reducing flood vulnerability for future events), they were categorized together for this summary. This question was not included on the Bear Pass portion of the survey so only 114 responses were considered. Of the 114 responses, 68 (59.6 percent) indicated they invested some amount of person-hour labour into flood response. 34.1 percent of Rainy Lake respondents invested some amount of person-hour labour while 52.3 percent of Namakan chain of lake respondents invested a person-hour response (See Table B-17). There was little difference between the responses on the US and Canadian side of Rainy Lake. On the Canadian side, 17 of 30 respondents indicate spending time responding to flood conditions. On average the respondents spent 23.0 person-hours dealing with flood conditions (per event). However, that amount is highly skewed by the maximum value of 200 person-hours. Without that value, the average investment is closer to 5.3 person-hours per event. On the US side of Rainy Lake, 24 of 41 respondents indicate spending time responding to flood conditions. As with the Canadian side, the average is skewed by a few high values (200 and 100 person hours respectively). With those values, the average person-hour investment is 22.2 person-hours. Without those values, the average drops to 9.4 person-hours.

	Total	Count	Percent Reporting	Average Person Hours per Event	Max
Rainy (Can)	30	17	56.7	23.0	200
Rainy (US)	41	24	58.5	22.2	200
Kabetogama	22	17	77.3	16.1	40
Ash River	7	1	14.3	5.0	5
Crane	14	9	64.3	10.3	30
All Sites	*114*	*68*	*59.6*	*18.2*	

Table B-17: Summary of responses related to person-hour costs associated with past flood proofing activity, by priority area

From a dollar investment perspective, only 6 of the 114 respondents (5.3 percent) indicated a dollar amount in terms of flood response. The responses were distributed with 2 each on the Canadian and US side of Rainy Lake and another 1 on Kabetogama Lake and 1 on Crane Lake. The Kabetogama and Crane Lake investments were relatively small (at $1,000 per event for each). In comparison, the average investment for the Canadian side of Rainy Lake was $15,500 while the average investment on the US side was $10,500. Table B-18 and Table B-19 summarize the results by region and by lake.

	Total	Count	Percent Reporting	Average $ Damage per Event	Max
Rainy (Can)	30	2	6.7	$15,500	$30,000
Rainy (US)	41	2	4.9	$10,500	$20,000
Kabetogama	22	1	4.5	$1,000	$1,000
Ash River	7	0	0.0	$0	$0
Crane	14	1	7.1	$1,000	$1,000
All Sites	*114*	*6*	5.3	*$9,313*	

Table B-18: Summary of responses related to costs associated with past flood proofing activity, by priority area

	Total	Count	Percent Reporting	Average $ Damage per Event	Max
Rainy	71	4	5.6	$13,000	$30,000
Namakan Chain	43	2	4.7	$1,000	$1,000
All Sites	*114*	*6*	*5.3*	*$9,000*	

Table B-19: Summary of responses related to costs associated with past flood proofing activity, by lake

Main (Lived-In) Buildings:

A qualitative assessment was undertaken regarding the risk to main (lived-in) buildings on each of the properties visited. Main (lived-in) buildings on 8 of the 47 properties visited on the

Canadian side of Rainy Lake were considered at risk while 8 of the 41 properties visited on the US side of Rainy Lake were considered at risk (Table B-20). In the context of this question, “at risk” was an approximate assessment relative to the 1950 flood of record. When comparing Rainy Lake and Namakan Lake responses (Table B-21), 18.2 percent of 88 Rainy Lake responses had main (lived-in) buildings that were considered at risk while 9.3 percent of the 43 Namakan chain of lakes responses were considered at risk. Overall, 20 of the 131 visited properties were identified where the main (lived-in) building was considered at risk of flooding.

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy (Can)	47	8	39	0	17.0	83.0	0.0
Rainy (US)	41	8	33	0	19.5	80.5	0.0
Kabetogama	22	1	21	0	4.5	95.5	0.0
Ash River	7	0	7	0	0.0	100.0	0.0
Crane	14	3	11	0	21.4	78.6	0.0
All Sites	*131*	*20*	*111*	*0*	*15.3*	*84.7*	*0.0*

Table B-20: Summary of responses related to main (lived-in) building flood risk, by priority area

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy	88	16	72	0	18.2	81.8	0.0
Namakan Chain	43	4	39	0	9.3	90.7	0.0
All Sites	*131*	*20*	*111*	*0*	*15.3*	*84.7*	*0.0*

Table B-21: Summary of responses related to main (lived-in) building flood risk, by lake

Respondents were asked about the estimated replacement cost of their buildings (if they were considered at risk). Due to the small sample size, there is a lot of variability in the average value. Based on all 16 respondents, the average replacement cost was estimated at $320,000 (see Table B-22). For just the US properties, the average value was $237,000 while for just the Canadian properties, the average value was $458,000. On the Canadian side, 3 of the 6 buildings with estimated replacement costs were for business operations. They were generally valued higher than the residential buildings. For example, one Canadian estimated replacement cost was $1 million which greatly impacts the results due to the small sample size.

	Total	Count	Percent Reporting	Sum of Estimated Replacement Value	Average replacement value
Rainy (Can)	47	6	12.8	$2,750,000	$458,333
Rainy (US)	41	8	19.5	$1,770,000	$221,250
Kabetogama	22	1	4.5	$100,000	$100,000
Ash River	7	0	0.0	0	0
Crane	14	1	7.1	$500,000	$500,000
All Sites	*131*	*16*	*12.2*	*$5,120,000*	$320,000

Table B-22: Summary of responses related to estimated main (lived-in) building replacement costs, by priority area

Properties with main (lived-in) buildings considered to have potential flood risk were examined in more detail to consider potential flood vulnerabilities. Foundation type was identified for 20 properties. Of those properties, 7 had a concrete pad foundation, 5 a full basement, 1 and partial basement, 3 a crawl space, and 4 were some sort of combination. There were some difference between Rainy Lake and the Namakan chain of lakes in terms of the distribution of basement types for the at risk properties, although the relatively low sample size likely contributed to the observed results. Table B-23 provides the percentage relative to the number of buildings with reported foundation type on each lake.

	Total	As Percent (by Lake)				
		Concrete pad	Basement	Partial basement	Crawl space	Combo
Rainy	16	31.3	25.0	0.0	18.8	25.0
Namakan Chain	4	50.0	25.0	25.0	0.0	0.0
All Sites	*20*	*35.0*	*25.0*	*5.0*	*15.0*	*20.0*

Table B-23: Summary of responses related to main (lived-in) building foundation type, by lake

Property owners with main (lived-in) buildings considered to have potential flood risk were asked about their flood proofing efforts. Of the 21 responses, 52.4 percent identified sump pumps as their primary response, 4.8 percent identified sandbagging, 9.5 percent the addition of retaining walls, 9.5 percent other measures, and the remaining 23.8 percent with no response. Damage types varied in the responses. They were broadly categorized in the foundation/structural, basement, mechanical, interior/contents, and mould. The categories were identified as the broad themes that emerged from the survey responses and were not meant to reflect all potential flood damage categories. Table B-24 provides a summary of the results by priority area. The majority of the responses were for Rainy Lake so a comparison between the Rainy Lake and Namakan chain responses was not included.

	Total	As Percent (by Region)				
		Foundation / structural	Basement	Mechanical	Interior	Mould
Rainy (Can)	8	50.0	0.0	12.5	37.5	0.0
Rainy (US)	8	37.5	12.5	25.0	12.5	12.5
Kabetogama	1	0.0	0.0	0.0	0.0	100.0
Ash River	0	0.0	0.0	0.0	0.0	0.0
Crane	2	50.0	50.0	0.0	0.0	0.0
All Sites	*19*	*42.1*	*10.5*	*15.8*	*21.1*	*10.5*

Table B-24: Summary of responses related to main (lived-in) building flood damage type, by priority area

Septic System:

Property owners were asked about the presence of a septic system on their property and responses were received for all 131 field sites visited. Table B-25 shows the results by region and Table B-26 by lake. Overall, 54.2 percent of the respondents had a septic and 42.7 percent did not. The remaining 3.1 percent used a holding tank. On the Canadian shoreline of Rainy Lake, 78.7 percent of the 47 respondents had a septic system while the remaining 21.3 percent did not. This was quite different then the US side of Rainy Lake where 14.6 percent of the 41 respondents indicated the presence of a septic system while 85.4 percent did not. On the Namakan chain of lakes, 65.1 percent of the 43 responses used a septic system, 25.6 percent did not, and 9.3 percent identified themselves as using a holding tank. Of the 71 respondents with a septic system, only 11 percent were considered at risk of flooding (Table B-27) by the property owner. 10.8 percent of the 37 respondents on the Canadian shoreline of Rainy Lake with system systems were considered at risk while none of the US Rainy Lake respondents were. 14.3 percent of the 28 Namakan chain of lakes respondents with septic systems considered their septic system to be at risk of flooding.

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy (Can)	47	37	10	0	78.7	21.3	0.0
Rainy (US)	41	6	35	0	14.6	85.4	0.0
Kabetogama	22	14	4	4	63.6	18.2	18.2
Ash River	7	7	0	0	100.0	0.0	0.0
Crane	14	7	7	0	50.0	50.0	0.0
All Sites	*131*	*71*	*56*	*4*	*54.2*	*42.7*	*3.1*

Table B-25: Summary of responses related to the presence of septic systems, by priority area

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	Unsure or n/a
Rainy	88	43	45	0	48.9	51.1	0.0
Namakan Chain	43	28	11	4	65.1	25.6	9.3
All Sites	*131*	*71*	*56*	*4*	*54.2*	*42.7*	*3.1*

Table B-26: Summary of responses related to the presence of septic systems, by lake

	Total	As Count		As Percent of Total (by Lake)	
		Yes	No	Yes	No
Rainy	43	4	39	9.3	90.7
Namakan Chain	28	4	24	14.3	85.7
All Sites	*71*	*8*	*63*	*11.3*	*88.7*

Table B-27: Summary of responses related to septic systems at risk of flooding, by lake

Outbuildings (Non-Lived-In):

A series of questions were asked about outbuildings (non-lived-in) on each property and their potential flood vulnerability. 24.4 percent of the 131 respondents identified at least one outbuilding (non-lived-in) on their property with potential flood vulnerability. The remaining 75.6 percent did not consider any of their outbuildings (non-lived-in) to be at risk. Table B-28 shows the distribution of responses as the number of responses and the percent for both the Canadian and US responses. Table B-29 shows the number of responses and the percent for the Rainy Lake responses vs. the Namakan chain of lakes. The percentage of at-risk properties was slightly higher on the Canadian side of Rainy Lake (31.9 percent) when compared with the US side (24.4 percent). 28.4 percent of the Rainy Lake respondents indicated potential outbuilding (non-lived-in) flood risk while 16.3 percent of Namakan chain of lakes respondents identified potential outbuilding (non-lived-in) flood risk.

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	n/a	Yes	No	n/a
Rainy (Can)	47	15	32	0	31.9	68.1	0.0
Rainy (US)	41	10	31	0	24.4	75.6	0.0
Kabetogama	22	4	18	0	18.2	81.8	0.0
Ash River	7	1	6	0	14.3	85.7	0.0
Crane	14	2	12	0	14.3	85.7	0.0
All Sites	*131*	*32*	*99*	*0*	*24.4*	*75.6*	*0.0*

Table B-28: Summary of responses related to outbuildings at risk, by priority area

	Total	As Count			As Percent of Total (by Lake)		
		Yes	No	Unsure or n/a	Yes	No	n/a
Rainy	88	25	63	0	28.4	71.6	0.0
Namakan Chain	43	7	36	0	16.3	83.7	0.0
All Sites	*131*	*32*	*99*	*0*	*24.4*	*75.6*	*0.0*

Table B-29: Summary of responses related to outbuildings at risk, by lake

There were 25 respondents that provided an estimate of the replacement value of their outbuilding (non-lived-in). Based on all the responses, the average replacement cost was $25,681 (Table B-30) and the median value was $13,333. Figure B-1 shows the distribution of responses along with the location of the mean and median values. On Rainy Lake, there were estimates for 20 sites and the average value was $23,680. Of the 12 Canadian sites, the average was $33,680 while for the 8 US sites, the average was $8,688. There were only 5 responses on the Namakan chain of lakes with the average value of $33,667 (Table B-30 and Table B-31).

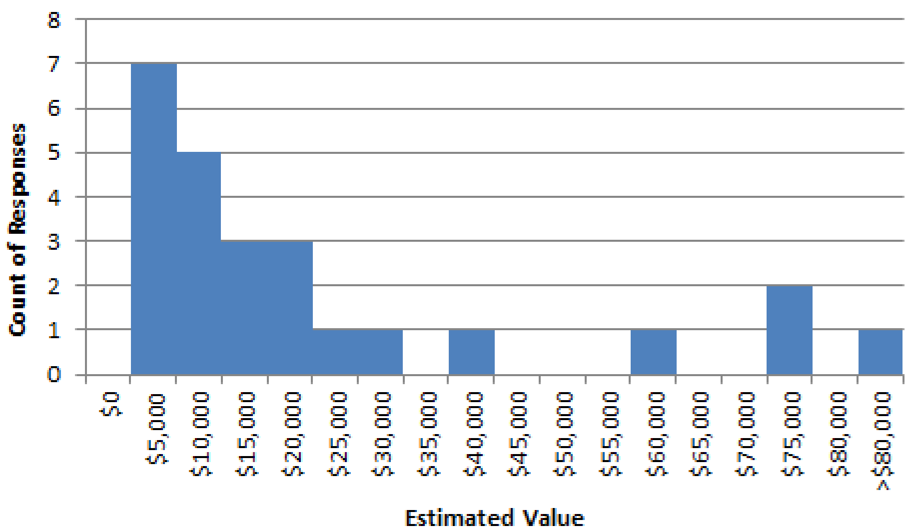


Figure B-1: Distribution of estimated replacement costs for outbuildings (non-lived-in) (full study area)

	Total	Count	Percent Reporting	Total replacement cost	Average replacement cost
Rainy (Can)	47	12	25.5	$404,167	$33,681
Rainy (US)	41	8	19.5	$69,500	$8,688
Kabetogama	22	4	18.2	$138,333	$34,583
Ash River	7	1	14.3	$30,000	$30,000
Crane	14	0	0.0	$0	$0
All Sites	*131*	*25*	*19.1*	*$642,000*	$25,680

Table B-30: Summary of responses related to estimated outbuilding (non-lived-in) replacement costs, by priority area

	Total	Count	Percent Reporting	Total $ replacement cost	Average replacement cost
Rainy	88	20	22.7	$473,667	$23,683
Namakan Chain	43	5	11.6	$168,333	$33,667
All Sites	*131*	*25*	*19.1*	*$642,000*	$25,680

Table B-31: Summary of responses related to estimated outbuilding (non-lived-in) replacement costs, by lake

A foundation type was determined for 30 outbuildings (non-lived-in) as part of the survey. The responses were broadly categorized into four groups including timber piers or cribs, concrete pad, cement footings, and cement or wood block. Table B-32 shows the distribution as a percent relative to the number of responses for Rainy and the Namakan chain of lakes. Of the 30 total responses, 93 percent indicated there were no flood proofing activities undertaken for the structure while 3 percent indicated they had raised the structure at some point (although not necessarily out of flood range) and another 3 percent indicated they had changed the building material to make them more resistant to water damage (Table B-33). It should be noted that in the case of boathouses that are on the water, there is no alternative to elevate the structure as its location is related to access to the water. In terms of damages observed to outbuildings (non-lived-in), interior and/or contents damage was the most commonly reported damage with 33 percent of the 30 responses falling within that damage category. Another 23 percent had structural problems, 13 percent had issues with mould and/or rot, and the remaining 30 percent were flooded to some degree but no damages were observed or the damages were considered minor by the property owner (Table B-34).

	Total	As Percent (by Lake)				
		n/a	Timber piers, crib, etc.	Concrete pad	Concrete footings, piers, etc.	Block (cement, wood, etc.)
Rainy	88	71.6	4.5	12.5	3.4	8.0
Namakan Chain	43	88.4	2.3	4.7	2.3	2.3
All Sites	*131*	*77.1*	*3.8*	*9.9*	*3.1*	*6.1*

Table B-32: Summary of responses related to outbuilding (non-lived-in) foundation type, by lake

	Total	As Percent (by Lake)		
		Nothing	Raised structure	Changed materials
Rainy	25	92.0	4.0	4.0
Namakan Chain	5	100.0	0.0	0.0
All Sites	*30*	*93.3*	*3.3*	*3.3*

Table B-33: Summary of responses related to outbuilding (non-lived-in) flood proofing activities, by lake

	Total	As Percent (by Lake)			
		No or minor damage	Structural	Interior and/or contents	Mould, rot
Rainy	25	32.0	24.0	40.0	4.0
Namakan Chain	5	20.0	20.0	0.0	60.0
All Sites	*30*	*30.0*	*23.3*	*33.3*	*13.3*

Table B-34: Summary of responses related to outbuilding (non-lived-in) damage types, by lake

Docks and Boathouses:

The remaining questions on the survey focused on the docks and boathouses present on the visited properties. Based on the responses, docks were categorized as either fixed (crib), floating, combo (some combination of fixed and crib), or removable (but not floating). On the Canadian shoreline or Rainy Lake, 28 of the 47 responses (59.6 percent) indicated they had a fixed dock with 6.4 percent being floating, 27.7 percent being a combination, and 2.1 percent being removable. Only 2 of the 47 properties visited did not have a dock. On the US shoreline of Rainy Lake, there were 41 responses and 63.4 percent were fixed, 9.8 percent floating, 19.5 percent combo, and 2.4 percent removable. Only 2 of the 41 properties visited did not have dock. Table B-36 shows the differences between the Rainy and Namakan chain responses. 61.4 percent of the Rainy Lake responses had fixed docks while that percent was closer to 46.5 percent on the Namakan Chain. In contrast, the Namakan chain had a higher percentage of combo docks (44.2 percent) when compared with Rainy Lake (23.9 percent). In all cases, floating docks and removable docks were a small percent of the responses. There were some differences between the various lakes on the Namakan chain of lakes. Table B-35 reports the total number of responses by each lake area and then the percent amount based on the category types (percent is relative to the total responses on that lake). On Kabetogama, 86.4 percent of the 22 responses were fixed docks while on Crane Lake, combination docks were the most commonly reported at almost 92.9 percent. The vast majority of docks were fixed/crib or combo (fixed and floating) at 56.6 percent and 30.5 percent respectively (Table B-36).

	Total	As Percent (by Region)				
		No dock	Fixed or crib	Floating	Combo (fixed and floating)	Removable (not floating)
Rainy (Can)	47	4.3	59.6	6.4	27.7	2.1
Rainy (US)	41	4.9	63.4	9.8	19.5	2.4
Kabetogama	22	0.0	86.4	0.0	13.6	0.0
Ash River	7	0.0	14.3	42.9	42.9	0.0
Crane	14	0.0	0.0	7.1	92.9	0.0
All Sites	*131*	*3.1*	*56.5*	*8.4*	*30.5*	*1.5*

Table B-35: Summary of responses related to dock type, by priority area

	Total	As Percent (by Lake)				
		No dock	Fixed or crib	Floating	Combo (fixed and floating)	Removable (not floating)
Rainy	88	4.5	61.4	8.0	23.9	2.3
Namakan Chain	43	0.0	46.5	9.3	44.2	0.0
All Sites	*131*	*3.1*	*56.5*	*8.4*	*30.5*	*1.5*

Table B-36: Summary of responses related to dock type, by lake

Only 16.0 percent of the 131 sites visited had a boathouse. The types of boathouses for the 21 sites were categorized as full structure – on land, full structure – on water, roof (no walls or boat lift), and boat lift (with or without roof). Table B-37 shows the total number of boathouses by lake. The percentage of responses in the full structure (on land), full structure (on water), and boat lift (with or without roof) categories was relatively comparable for both Rainy Lake and the Namakan chain of lakes. There was only one site visited with a structure that was considered to fall within the “roof (no walls or boat lift)” category.

	Total	As Percent (by Lake)				
		No boathouse	Full structure - on land	Full structure - on water	Roof, no walls and no boat lift	Boat lift, with or without cover
Rainy	88	83.0	4.5	4.5	0.0	8.0
Namakan Chain	43	86.0	4.7	7.0	2.3	0.0
All Sites	*131*	*84.0*	*4.6*	*5.3*	*0.8*	*5.3*

Table B-37: Summary of responses related to boathouse type, by lake

Results in the Context of Flood Damage Modelling:

One of the primary reasons for undertaking the property owner survey was to understand critical shoreline vulnerabilities as viewed by property owners and consider whether there were opportunities to reflect those issues within the flood damage modelling effort. As well, further information was sought on the scale of the impacts that needed to be considered within the development of the flood damage model. The questionnaire was structured to reflect the expected shoreline vulnerabilities as captured in the geospatial database that was developed as part of the flood damage study. In particular, information was sought on vulnerability of main (lived-in) buildings, outbuildings (non-lived-in), and docks as those were the main damage categories (along with boathouses) in the geospatial database. However, the survey also provided the opportunity for respondents to report on other types of flood vulnerability. This section summarizes some of the general observations from the survey related to the overall applicability of the results and the application in the context of the flood damage modelling, as interpreted by the project lead.

Observation 1: Respondents were Aware of Fluctuating Water Levels and Survey Provides Reasonable Representation of Potential Impacts

The survey respondents on Rainy Lake had been at their properties on average 24.2 years and for the Namakan chain respondents, that value was 22.5 years. The majority of survey respondents had been present at their property long enough to have experienced past high water conditions, particularly in 2001 and 2002. Due to the overall number of residents in the study area, particularly on Rainy Lake, it was not possible to undertake a full population survey. However, the site visits that were undertaken were considered to give a good indication of the types of flood vulnerabilities that exist within the Rainy-Namakan basin.

Observation 2: A High Percentage of Respondents Reported Flooding Damages in 2001 and 2002, With Flood Damage to Main (lived-in) Buildings and Outbuildings (non-lived-in) Representing a Relatively Small Component of Reported Damages

Over 43 percent of Rainy and 41 percent of Namakan chain of lakes respondents indicated they experienced some sort of flood damage during the 2001 and/or 2002 high water periods. This represented a high number of respondents even though the flood levels were well below the 1950 flood of record. As expected, a higher percentage of respondents reported flooding of docks (25 percent) when compared with main (lived-in) buildings (5 percent) or outbuildings (non-lived-in) (6 percent). In fact, building damage represented a fairly small component of the overall number of reported damages when looking at the number of damage reports. Of the damages that were reported for buildings, main (lived-in) building damages represented a small component of the overall value of the buildings. In other words, the respondents that experienced flood damage to main (lived-in) buildings in 2001 and/or 2002 were negatively impacted by the flood conditions but in no example did the flood conditions completely destroy the building being impacted. For secondary (non-lived-in) buildings, the flood impacts were generally greater as a percentage of the building replacement value. However, the percent of impacted properties was still relatively low at ~6 percent of respondents.

In terms of flood response, the vast majority of respondents identified that they invested time and effort into some sort of flood response. In many cases, this involved securing possessions or working to keep docks and other secondary (non-lived-in) buildings from floating away. However, only 6 of the 114 respondents (5.3 percent) indicated a dollar amount in terms of flood response. There were almost certainly situations where individuals chose not to provide an economic damage estimate or one was not known, however the results also suggested that many of respondents were directly inconvenienced by past flood conditions but that was not directly reflected as an economic damage where investments were required to repair damaged infrastructure.

The investment of time and effort could be considered for use within a flood damage estimate, even in a qualitative way, since it represented such a high percentage of responses. Overall, the average time invested per event (e.g., person hours) was in the range of 5.3 to 9.4 person hours per event which were the average values with the most extreme example removed.

Observation 3: Dock Flooding Was the Most Commonly Reported Flooding Damage in 2001 and/or 2002, Although Not All Docks Sustained Damages

25 percent of respondents identified dock damage due to high water conditions in either 2001 and/or 2002. This was the highest percentage for any single damage category and was expected based on the fact that docks are generally close to the water to facilitate ease of use.

Despite the relatively high percentage of reported damages, there remained a considerable number of respondents that have docks but that did not report damage. In some cases, residents did experience flooding and were required to undertake some sort of flood response effort (e.g., putting barrels on docks). In fact, 59.6 percent of respondents undertook some sort of time investment in flood response. However, given the high number of fixed and/or combination docks in the system, not all docks sustained permanent damages as a result of high water levels in 2001 and/or 2002. This represented a complicating factor when trying to model impacts as not all docks that were inundated would be permanently damaged. Other factors such as the age and construction of the dock, the length of inundation, and the exposure to wave conditions also impacted the vulnerability of specific docks and are more difficult to model using an inundation approach.

Observation 4: Shoreline Property Owners Reported Other Flooding Damages Beyond Damages to Main (Lived-In) Buildings, Outbuildings (Non-Lived-In), and Docks, Although Modelling Many of Those Damage Categories Can Be Challenging

15 percent of respondents indicated “other” types of flood problems beyond main (lived-in) building, outbuilding (non-lived-in), and dock specifically addressed in the questionnaire. These “other” flooding damages captured a range of issues including shoreline erosion, lawn inundation, access road flooding, and other similar issues. These types of flood problems were difficult to capture through inundation modelling either because they required specific types of information to understand vulnerability (e.g., for shoreline erosion) or they were difficult to quantify in an economic context (e.g., damages associated with lawn inundation). In some cases, the reported damages actually had no significant direct economic consequence but they directly impacted the ability of property owners to use and enjoy their property for a period of time and may have had some secondary economic impacts. In the context of the flood damage assessment, it was not possible to incorporate all these issues as direct economic consequences of high water conditions although it was important to acknowledge their impact on property owners.

Observation 5: Ice Damages Were Common Along the Study Shoreline But Were Not Strictly A Function of Water Levels and Therefore May Be Difficult To Incorporate Into the Flood Damage Model At This Point

Nearly 43 percent of survey respondents reported some sort of ice damage in the past. However, few of the reported ice damages were strictly a function of water levels. In many cases, the ice damages were more commonly caused by the movement of ice along the shoreline due to wind conditions. On Kabetogama Lake, a few respondents did make it clear that higher winter water levels (during ice period) with the 2000 rule curves did create greater risks for their docks compared with the 1970 rule curves. The 1970 rule curves used to keep the water level so low in winter that their docks were out of the water and not at risk of ice movement but that was not the case now. In general, Kabetogama respondents still preferred the 2000 rule curves because it afforded better late season and early season boating due to the higher water levels and this seemed to offset any potential ice risk in the winter.

Despite the high number of respondents with ice damages, very few undertook significant adaptive responses to address those issues. In particular, fixed docks and combination docks (both fixed and floating) were common on both Rainy Lake and the Namakan chain of lakes. Only 1.5 percent of respondents had a removable docking system which would have eliminated potential ice damage issues.

In the context of the damage modelling, the primary factor that could be included in the Excel model was a comparison of water level fluctuations between ice-on and ice-out on each of the different lakes under the different rule curves. Based on a few of the responses, a greater amount of fluctuation once ice has formed on the lakes can cause greater problems for existing infrastructure. A relative comparison of the rate of change of water levels could be undertaken by looking at how much water levels change over the winter period.

Observation 6: Although Septic Systems Were Common (Except on Portions of the US Shore of Rainy Lake), A Relatively Low Percentage Were Considered At Flood Risk

Over 54 percent of the properties surveyed had a septic system. The main exception is the portion of the US Shoreline of Rainy Lake where sewer and water service is being extended eastward from International Falls. As well, the Crane Lake community has a sewer system. Generally speaking, the US Rainy properties that did have a septic system were the locations further east towards the park (further from International Falls). Despite the high number of property owners reporting the use of a septic system, a relatively small number (11.3 percent) of those systems were considered at flood risk. Because the location of septic beds was not often readily apparent from air photos, site visits would be required in order to locate the septic beds and that was not feasible for the full population within the context of this study. As a result, it was not practical to incorporate flooded septic beds in the flood damage tool, although it was certainly a factor that could be qualitatively considered in the reporting of flood damages.

Observation 7: The Sample Size is Small for the Estimates of Building Values for At-Risk Buildings

The sample size for the estimated building values of main buildings and outbuildings was small with only 20 main (lived-in) buildings and 32 outbuildings (non-lived-in). As well, the survey did not directly link the building size to the estimated value. As such, there is a high degree of variability in the estimated values making it difficult to extrapolate generic values for the broader geospatial database from this dataset alone.

Observation 8: Outbuildings (Non-Lived-In) Were More Commonly Reported As Being At-Risk When Compared With Main (Lived-In) Buildings and Their Values Were Considerably Less

Overall, 24.4 percent of the respondents identified an outbuilding (non-lived-in) at potential flood risk while only 15.3 percent of respondents identified main (lived-in) buildings at flood risk. These general patterns were reflected in the overall geospatial database with more outbuilding (non-lived-in) being at lower elevation relative to main (lived-in) buildings. From a value perspective, the average value for the at-risk outbuildings (non-lived-in) was ~$23,000 while the value was much higher (~$320,000) for main (lived-in) buildings. Although the sample size was small, that represented a 14 times greater value for the main (lived-in) buildings when compared with the outbuildings (non-lived-in).

Observation 9: For the At-Risk Main (Lived-In) Buildings Identified, Some had a Basement or Crawl Space. For Outbuildings (Non-Lived-In), None Had Basements.

Foundation type plays a role in flood vulnerability of buildings. In the context of main buildings, the presence of a basement and/or crawl space can impact the elevation at which flooding starts and the overall extent of damage. Typical stage-damage functions utilized by FEMA or the USACE often differentiate buildings with or without basements when estimating impacts. For the at-risk buildings identified in the field survey, the basement type was quite varied and included full basements, crawl spaces, no basements (concrete slab), and some combination. This variability in basement type was an important factor in looking at flood vulnerability. Unfortunately, air photo interpretation was not a good way to differentiate basement types. A secondary data source such as oblique imagery would also be required to support general characterization and that information was not available throughout the study site. As a result, foundation type was not a characteristic that could be incorporated into the flood damage model but given the variability in basement type observed in the survey, it is something that could be considered in the future. As a short-term approximation, it was important to build in a main floor offset as most of the observed main (lived-in) buildings did have some offset. This was not the case for outbuildings (non-lived-in) as they tended to be at-grade. As such, no offset should be included in the flood damage calculations for the outbuildings (non-lived-in).

Appendix C: Description of Dock Elevation Extraction Approach

Elevation estimates were required for docks on the Rainy and Namakan system to compare with field survey points. The MNDNR and VNP LiDAR datasets represented significant resources for estimating elevations. In particular, the LiDAR points were used to generate average elevation characteristics for polygon features within the database. However to do this, the LiDAR datasets were manipulated in ArcGIS to extract the elevation information for the individual database features. This summary briefly outlines the specific steps used for this project.

Step 1: Develop polygon feature dataset

- Polygon features of interest were digitized using head's up digitizing as described in the main report.

Step 2: Acquire baseline .LAS datasets

- Using the dock features polygon dataset described in Step 1, all the .LAZ tiles containing a dock feature were identified.
- LiDAR datasets from MNDNR and VNP were obtained as compressed .LAZ files and stored on an EC network folder for use within the EC geospatial environment.

Step 3: Viewing .LAS data in ArcGIS

- ArcGIS 10.1 cannot import .LAS datasets directly for viewing, however .LAS data can be added to a .LAS dataset (.lasd file extension) within ArcGIS when using ArcGIS Advanced and the "Create LAS dataset" tool. (This step was only required as it was necessary to map/view the actual LiDAR data or to identify tile coverage.)

Step 4: Creation of multipoint shapefiles

- The LIDAR data was converted to multipoint shapefiles within ArcGIS (advanced) using the 3D analyst extension and the LAS to Multipoint tool (3D Analyst Tools > Conversion > From File > LAS to multipoint).
- The individual .LAS files were converted by using a batch mode for the tool (where multiple .LAS input files could be run at once and multiple output multipoint shapefiles were created). Within the tool, the input .LAS and output .shp file names were specified, along with a point spacing which was estimated at 0.5 (in this case in map units of metres).

- Note that a few of the tiles in the geographic area of interest already had multipoint files available. These were from the older Red River dataset. The newer LiDAR data (2011-present) already had multipoint files created within the geodatabases distributed through the MNDNR website but they were bare earth datasets that had been screened using a mask of the lake surface. The points of interest for dock features were generally screened out of the bare earth files and they were not helpful to the current analysis. As a result, it was necessary to create the new multipoint files directly from the .LAS data so that the dock features could be included.

Step 5: Clip the multi-point file based on the dock outlines

- Using Analysis Tools>Extract>Clip, the Input Feature (the multipoint file) was selected and the dataset clipped (the dock file of interest).

Step 6: Multipart to singlepart

- The clipped file was still in multipart format so that file was processed so that each point was a unique feature. This was done using the Data Management Tools> Features > Multipart to Singlepart tool.
- The input file was the clip file created in the previous step. The output file was chosen by the user.

Step 7: Merge individual point files

- All the point files were merged into a single point file to reduce repetition. Note however that there may be size limits for processing of adding point elevation from the LiDAR data. Where that was the case, some areas were merged into a couple files of reasonable size for processing.

Step 8: Add Elevation Information for the Points

- Using 3D Analyst>Functional Surface>Add Surface Information, the elevation (Z value) characteristics were added to the newly created Point file. The Input feature Class was the newly created Point file, the Input Surface is the LAS dataset, and the "Z" value check box needs to be selected.

Step 9: Add Spatial Information (Elevation) to the Dock Polygon Features

Using Analysis Tools>Overlay>Spatial Join, the average elevation based on the individual points within each polygon was added. The Target Feature was the polygon file of interest, the Join

Features was the clipped point file with elevation values >0, the output feature class was where the new shapefile was written, the Join Operation was one to one, the features were whatever the user wanted but needed to at least include the elevation value, and the match option should be Contains. Note that the default summary method was "first", in other words the first relevant cell value was the attribute for the polygon. The user manually needed to change that under "Field Map of Join Features" by right-clicking the attribute of interest and changing the merge rule to the method you want.

- In this case, the spatial join was run five (5) times to calculate the mean, min, max, median, and stdev values for each dock feature based on the input LiDAR points.
- The base dock feature layer was then opened and the values were transferred into that file by doing a join and then adding a new field and making it equal to the value in the joined table. This reduced the extraneous table information from the Spatial Join files.

Step 10: Screening of LiDAR points

- There was some degree of variability in using individual LiDAR points as they may or may not reflect the true dock surface. For example, the return could be from an object sitting on the dock. As a result, the elevation distributions of the LiDAR points for each dock were manually screened to remove outliers or to better reflect dock conditions. As an example, a dock with two distinct elevation groupings may be a result of a combination dock (both floating and fixed portions). As part of the screening, only the assumed fixed portion would be kept. Figure C-1 shows an example of unscreened LiDAR returns for two docks along the Kabetogama Lake shoreline along with histograms of the point elevations. Figure C-2 shows the screened LiDAR points along with the histograms of the point elevations. In the upper example, the standard deviation for the points goes from 0.45 m to 0.09 m and for the lower example, the standard deviation for the points goes from 0.41 m to 0.06 m (note the scales change on the histograms). The screening was not based solely on elevation but includes interpretation from the air photos regarding other related features that may help identify particular LiDAR points that should be screened. There was some amount of interpretation in the process by the GIS user.

Step 11: Re-calculate Step 9 statistics using screened LiDAR points

The dock elevation estimates (mean, min, max, median, standard deviation) were re-calculated as in Step 9 based on the screened LiDAR points. It was these updated estimates that were used to compare with field based measurements for specific docks.

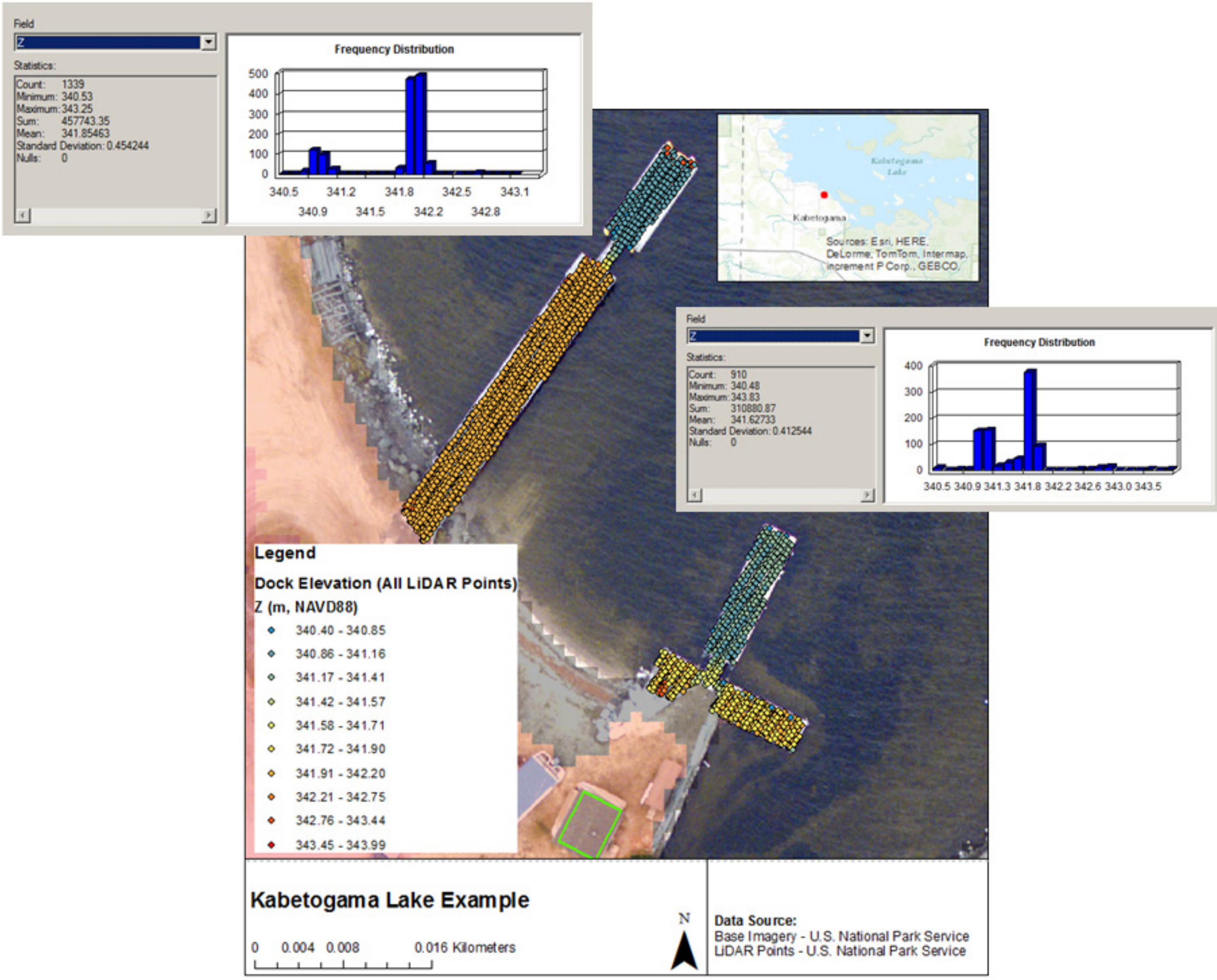


Figure C-1: Example of LiDAR returns for two docks on Kabetogama Lake, along with histograms of elevation values (not screened)

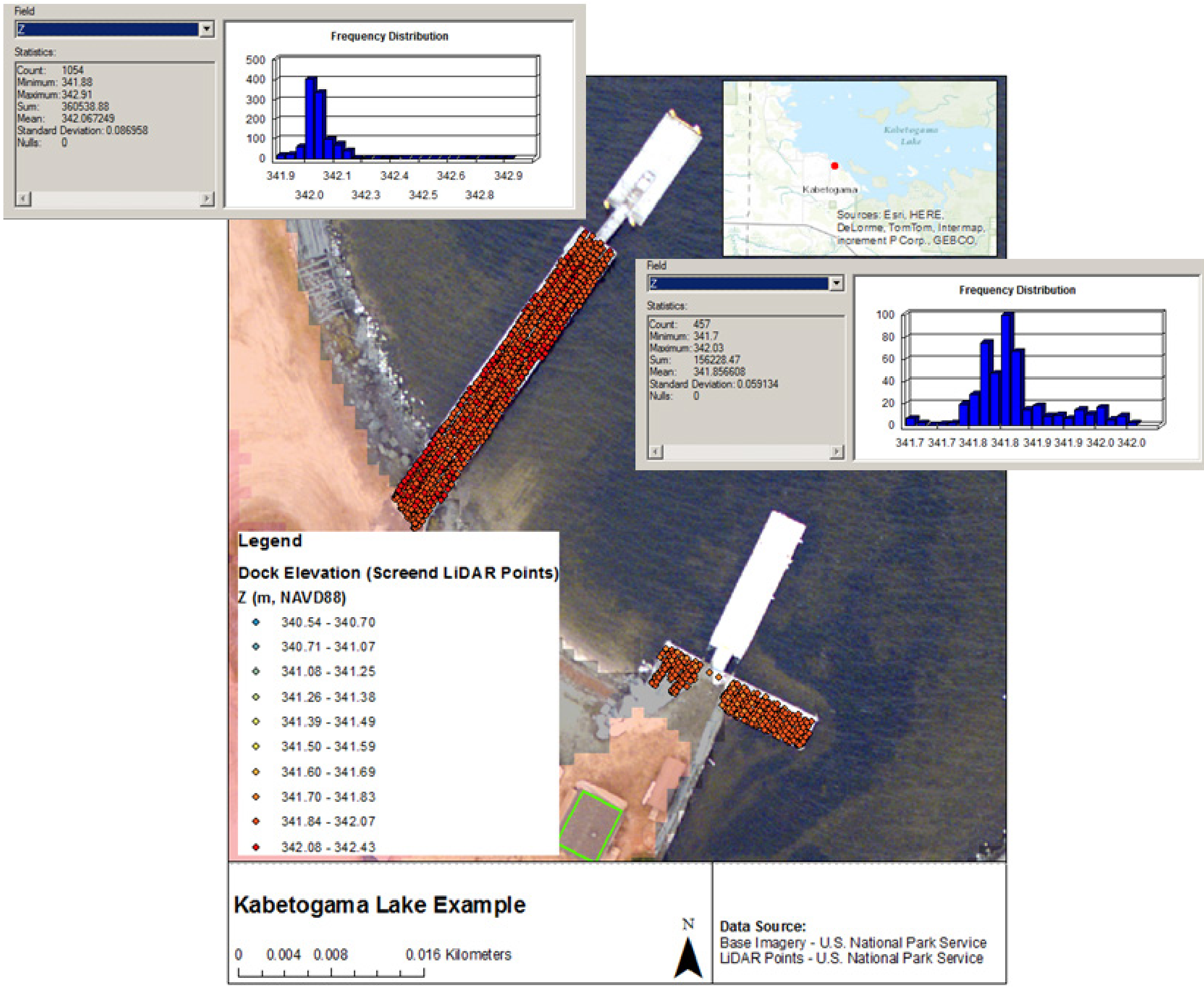


Figure C-2: Example of LiDAR returns for two docks on Kabetogama Lake, along with histograms of elevation values (screened)

Appendix D: Copy of 2014 Property Owner Survey

2014 Flood Damage Survey

0%

2014 property damage survey for the Rainy and Namakan basin as well as Lake of the Woods and the Rainy River

Answers to these questions will be used to help support future evaluations of the Rule Curve operations for water level management and other water management strategies in the basin. Please note this is not an application for assistance. This is a request for information on private property damage to support future review of water management strategies in the system. Thank you very much for your participation.

Next

Form Maker powered by FluidSurveys

2014 Flood Damage Survey

8%

Question 1

1. Which lake/river is your property on?

- A. Rainy Lake
- B. Namakan Lake
- C. Kabetogama Lake
- D. Sand Point Lake
- E. Crane Lake
- F. Little Vermillion Lake
- G. Rainy River
- H. Lake of the Woods

Question 1b

1b. Is your property in Ontario, Minnesota, or Manitoba?

- Ontario
- Minnesota
- Manitoba (for portion of Lake of the Woods)

Question 2

2. Please indicate which best describes your property usage:

- ◯ A. Seasonal private residence occupied for only a portion of the year (e.g. home, cottage, etc.)
- ◯ B. Year round private residence occupied as a primary full-time residence (e.g. home, cottage, etc.)
- ◯ C. Resort or business operation (please add details if necessary) [Type here]

Questions in the next three sections deal with damages to **docks**, **non-lived-in structures** on your property and to **lived-in structures** on your property.

Please respond to all that apply and skip those that do not.

2014 Flood Damage Survey

16%

Question 3a.

3a. Did you experience any flooding damage to your docks in 2014? If so, what date did the flooding start (if you know)?

- ◯ A. No
- ◯ B. Yes (if yes, approximately what date (YYYY/MM/DD) did the flooding start (if you know)?) [Type here]

DOCKS

Question 3b.

3b. Please describe the type of dock damage observed:

Type here

Question 3c.

3c. What is the estimated cost to repair the observed damages to your dock?

Move the slider left or right to select the estimated repair cost.

$0 | Over $100,000

Question 3d.

3d. What is the estimated percent of damage to your dock? (e.g. 100% means complete dock structure including pilings if applicable, had to be replaced, 0% means no damage)

Move the slider left or right to select the appropriate value.

No Damage | Fully Damaged

2014 Flood Damage Survey

33%

NON-LIVED-IN STRUCTURES

Question 4a.

4a. Did you experience any flooding damage to your non-lived-in structure(s) in 2014? (e.g. sheds, pumphouse, etc.)

- A. No
- B. Yes

Question 4b.

4b. Please select the type(s) of non-lived-in structure(s) that experienced flood damage:

- A. Boathouse
- B. Storage Shed
- C. Gazebo
- D. Pumphouse
- E. Other, please specify... Type here

Question 4c.

4c. Please describe the type of non-lived-in structure damage observed:

Type here

Question 4d.

4d. Please use the following table to identify observed damages to specific non-lived-in structures on your property. You can add information for up to 5 non-lived-in structures, if applicable:

	Type of Non-lived-in Structure	What is the approximate start date for the flooding (if known)? (YYYY/MM/DD format)	What is the estimated cost ($) to repair the observed damages to your non-lived-in structure?	What is the estimated percent damage to your non-lived-in structure? (100% means fully damaged requiring replacement of structure and foundation, 0% means no damage)
Non-lived-in Structure #1	---	Type here	$ Type here	Type here %
Non-lived-in Structure #2	---	Type here	$ Type here	Type here %
Non-lived-in Structure #3	---	Type here	$ Type here	Type here %
Non-lived-in Structure #4	---	Type here	$ Type here	Type here %
Non-lived-in Structure #5	---	Type here	$ Type here	Type here %

2014 Flood Damage Survey

50%

LIVED-IN STRUCTURES

Question 5a.

5a. Did you experience flooding damage to your lived-in structure in 2014? If so, what date did the flooding start (if known)?

- A. No
- B. Yes (if yes, approximately what date (YYYY/MM/DD) did the flooding start (if known)?) Type here

Question 5b.

5b. Please select the type(s) of lived-in structures that experienced flood damage:

- A. Primary or main lived-in structure (e.g. main living building)
- B. Secondary lived-in structure (e.g. 2nd cabin, bunkie, etc.)

Question 5c.

5c. Please describe the type of lived-in structure damage observed:

Type here

Question 5d.

5d. What is the estimated cost to repair the observed damages to your lived-in structure?

Move the slider left or right to select the estimated repair cost.

$0 $100,000

Question 5e.

5d. What is the estimated extent of damage to your lived-in structure (100% means fully damaged with the need to replace both structure and foundation, 0% means no damage)?

Move the slider left or right to select the appropriate value.

No Damage Fully Damaged

2014 Flood Damage Survey

66%

Question 6

6. Did wave or storm action contribute to damages to:

- A. Docks
- B. Non-Living Structures
- C. Living Structures

Question 7

7. Please describe any flood protection efforts undertaken (e.g. sandbagging, pumping water, etc.) and the approximate investment (e.g. materials and labour) in those efforts.

Type here

Question 8

8. Did you experience any additional flood damages not otherwise reported in this survey? This could include loss of use of property or loss of business. If so, please describe the nature of those damages.

Type here

2014 Flood Damage Survey

75%

Impacts on Human Health

Replies to the following questions will inform a project examining human health impacts of flooding in the Rainy River-Lake of the Woods basin that will be undertaken by the IJC's Health Professionals Advisory Board. Participants may opt not to answer the health questions if they are not comfortable doing so. Questions related to this project can be directed to Jennifer Boehme, HPAB Secretariat, IJC Great Lakes Regional Office, boehmej@windsor.ijc.org.

Question 9.

Has your health or wellbeing, or that of a family member, been affected by the flooding?

Yes No

2014 Flood Damage Survey

83%

Question 10

Is the effect:

- ☐ a) mainly related to damage to your property?
- ☐ b) mainly related to stress ?
- ☐ c) mainly related to financial loss?
- ☐ d) mainly related to a new or worsened health condition

2014 Flood Damage Survey

91%

Thank you for participating in this survey. Please click the "submit" button to complete the survey and submit your responses.

Back Submit

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Appendix E: Baird & Associates Flood Tool Documentation

Baird

oceans

engineering

lakes

design

rivers

science

watersheds

Rainy Lake Excel Flood Tool

July 31, 2015
12330.101

Rainy Lake Excel Flood Tool

Prepared for

The International Joint Commission

Prepared by

Baird

W.F. Baird & Associates Coastal Engineers Ltd.

For further information please contact
Pete Zuzek (905) 845 5385

12330.100

TABLE OF CONTENTS

1.0 INTRODUCTION

This report summarizes the development of the Rainy Lake Excel Flood Tool, hereinafter referred to as the Flood Tool. The scope of the investigation is summarized, along with software development, database requirements, and the generation of building replacement costs.

1.1 Scope for Flooding Tool Development

A detailed structure database was assembled by Environment Canada and provided to Baird at the onset of the investigation. The tool development focused on building the logic and algorithm for the flooding algorithm in MS Excel, as follows:

- Brief literature review to establish generic replacement costs for structures.
- Develop an Excel based flood damage assessment tool for the Rainy and Namakan Lakes study area.
- Prepare a final report.

2.0 FLOODING SOFTWARE DEVELOPMENT

Section 2.0 describes the theory of the algorithm, basic tool operation, description of a simulation approach, methods for structures with missing elevation data, and potential future upgrades for the tool.

2.1 Theory of Flooding Algorithm

The logic in this Excel flooding tool builds upon the logic first used in a similar tool inside the Flooding and Erosion Prediction System (FEPS) developed for the IJC Lake Ontario – St. Lawrence River regulation study (Baird, 2005). An earlier Excel based Flood Tool (Baird, 2012) was developed that only calculated flooding damages for a single user specified conditions (e.g., a single combination of water level and wave condition).

The Rainy Lake Excel Flood Tool utilizes time series water levels to estimate potential damage events over time (e.g. multiple years). The economic damages associated with flood inundation are based on a USACE report (2000).

2.2 Basic Operation

The Flood Tool is a Microsoft Excel macro-enabled spreadsheet coded in Visual Basic for Applications (VBA). It operates on the Rainy Database Excel spreadsheet to produce flooding event and summary information on worksheets within the tool workbook. The tool is controlled and executed via the Configuration worksheet. The main simulation controls are grouped as seen in Figure 2.1. These controls allow you to define and execute a simulation scenario.

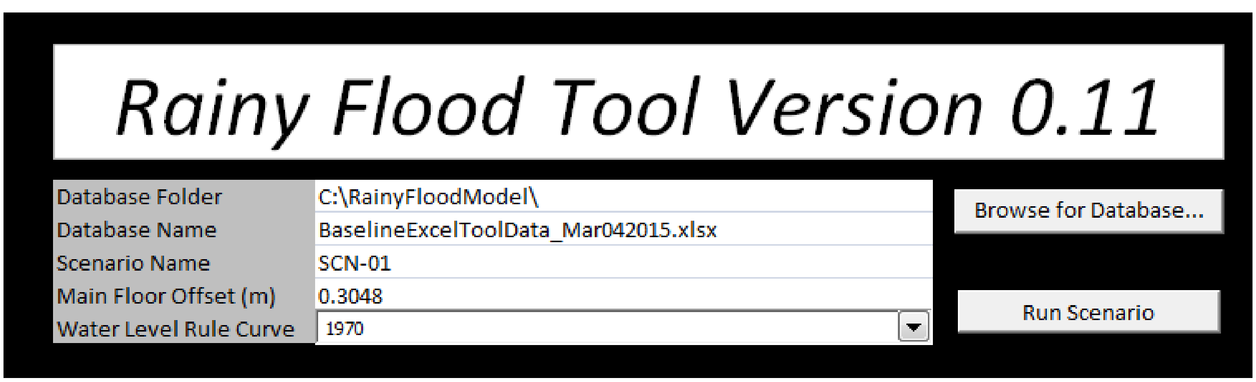

Figure 2.1 Control Menu for the Flood Tool

As a first step, the path to the database must be selected by using the "Browse for Database..." button, which is subsequently retained when the workbook is saved. Then a simulation scenario must be defined, which allows varying the input water levels, main floor offset (standard variable for all structures), and optional water level offsets by reach and stage-damage tables. The scenario is executed by pressing the "Run Scenario" button. Processing information will be written to the status bar as the simulation is in progress, and a message will pop up when the simulation is complete. The tool will generate output to four new worksheets prefixed with the scenario name.

The input database must provide quarter-monthly water levels for Rainy Lake and Namakan Lake on its worksheet named "RuleCurveWaterLevels". Two Rule Curve water level series are currently provided for each lake: 1970, and 2000. The tool is structured so that it can expand the number of water level time series or lakes with some minor modification. The water level time series can be extended into the future with no modifications of the tool.

The database defines three lake zones: Rainy, Namakan, and Crane. Figure 2.2 maps the regions encompassed by these zones. Kabetogama Lake is included in the Namakan Lake zone. Sand Point and Little Vermillion Lakes are included in the Crane Lake zone.

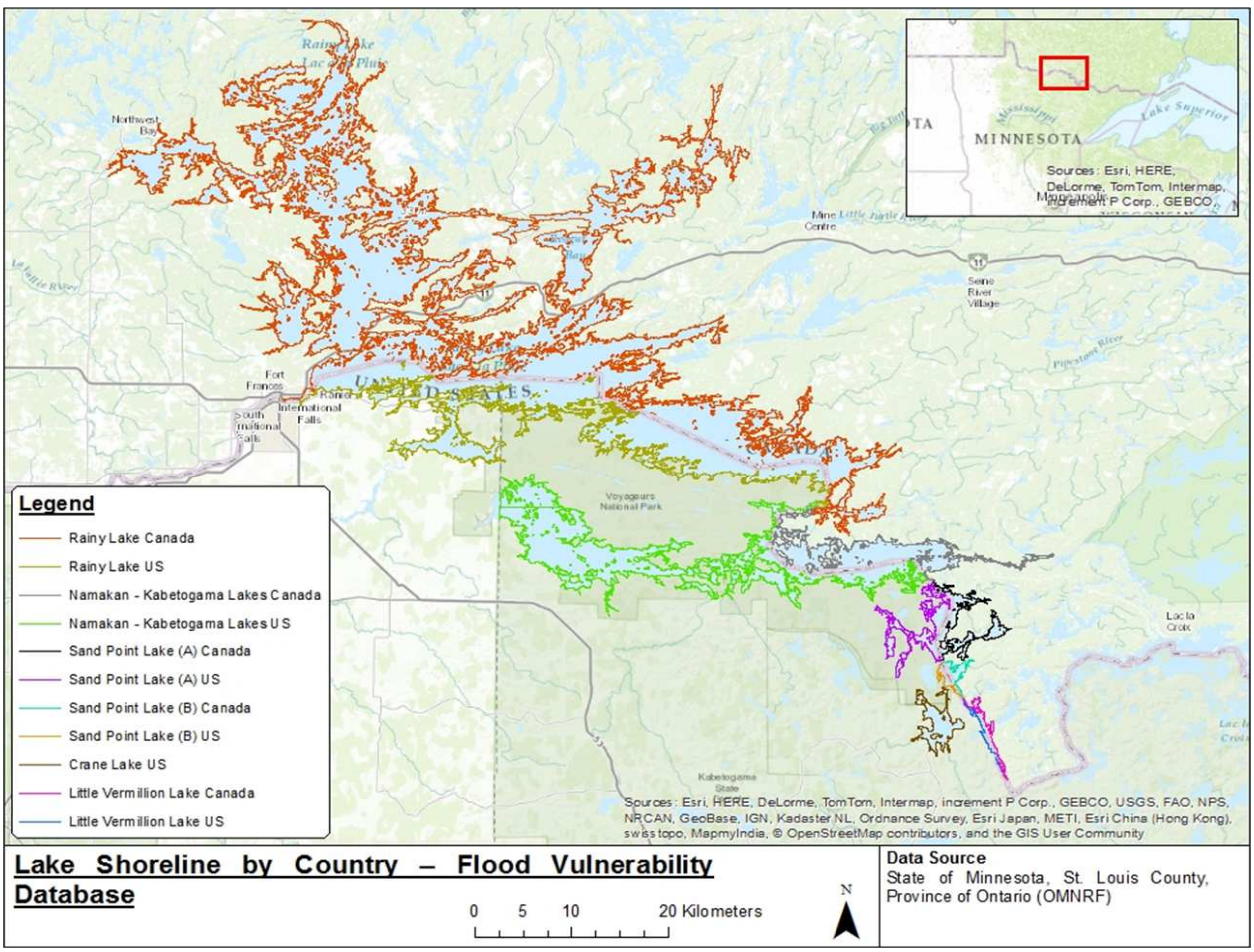

Figure 2.2 Three Lake Zones

The Crane Lake zone currently uses the water levels for Namakan Lake. Each zone is subdivided into reaches, which allows further adjusting the water levels by altering the offset value as seen in Table 2.1.

Water Level Offset by Reach (country code removed)			
Lake Zone	Shoreline Section	Code	Offset (m)
Rainy Lake	Lake shoreline	100	0.00
Rainy Lake	Rainy River between dam and lake outlet	101	0.00
Namakan/Kabetogama	Kabetogama Lake	200	0.00
Namakan/Kabetogama	Ash River	201	0.00
Namakan/Kabetogama	Namakan Lake	203	0.00
Crane Lake	Crane Lake above King William Narrows	300	0.10
Crane Lake	Little Vermillion above Little Vermillion narrow	301	0.05
Crane Lake	Sand Point Lake above Harrison Narrows	302	0.05
Crane Lake	Sand Point Lake above Namakan Narrows	303	0.05

Table 2.1 Offset Value per Lake

The database groups basic structures into buildings, boathouses, and docks. The tool extends these basic structure types based upon structure and design codes from the database to define structure types of interest: 1) lived-in buildings, 2) non lived-in buildings, 3) boathouses, 4) fixed/combination docks, and 5) floating docks. For each structure type, there is a corresponding stage-damage relationship as show in Table 2.2 that can be edited in the future.

Stage-damage for Lived-in Buildings, One Story, No Basement, Elevated Main Floor					
Inundation Depth (ft)	Inundation Depth (m)	Mean Damage to Structure (%)	Standard Deviation of Structure Damage	Mean Damage to Contents (%)	Standard Deviation of Content Damage
-2.00	-0.6096	0.0%	0.0%	0.0%	0.0%
-1.00	-0.3048	2.5%	2.7%	2.4%	2.1%
0.00	0.0000	13.4%	2.0%	8.1%	1.5%
1.00	0.3048	23.3%	1.6%	13.3%	1.2%
2.00	0.6096	32.1%	1.6%	17.9%	1.2%
3.00	0.9144	40.1%	1.8%	22.0%	1.4%
4.00	1.2192	47.1%	1.9%	25.7%	1.5%
5.00	1.5240	53.2%	2.0%	28.8%	1.6%
6.00	1.8288	58.6%	2.1%	31.5%	1.6%
7.00	2.1336	63.2%	2.2%	33.8%	1.7%
8.00	2.4384	67.2%	2.3%	35.7%	1.8%
9.00	2.7432	70.5%	2.4%	37.2%	1.9%
10.00	3.0480	73.2%	2.7%	38.4%	2.1%
11.00	3.3528	75.4%	3.0%	39.2%	2.3%
12.00	3.6576	77.2%	3.3%	39.7%	2.6%
13.00	3.9624	78.5%	3.7%	40.0%	2.9%
14.00	4.2672	79.5%	4.1%	40.0%	3.2%
15.00	4.5720	80.2%	4.5%	40.0%	3.5%
16.00	4.8768	80.7%	4.9%	40.0%	3.8%

Table 2.2 Stage-damage Curve Data (from USACE 2000)

2.3 Detailed Description of a Simulation

The database has worksheets that group structures based upon basic structure type, lake zone, country, and whether or not elevation estimates are available for the structure (designated as "Elev" or "NoElev"). Each of these worksheets represents a unique combination of these four criteria and must conform to a defined schema.

The tool processes the worksheets for structures with elevation estimates on a structure by structure basis in a time series loop, recording all flooding events, and outputting to three worksheets corresponding to the basic structure types. These worksheets are further sectioned horizontally by combination of lake zone, and country.

This approach allows calculation of the duration of inundation, as well as recording multiple flooding events in a year, which could be used to extend the tool in the future (e.g. combining subsequent events, or considering duration of inundation).

In order to define a flooding event, the water level in a given year must exceed the inundation depth that corresponds to damages as identified in the appropriate stage-damage curve for the specific type of structure. Table 2.2 provides an internal calculation for a lived-in building that was flooded and the estimated structure and content damage.

Structure Value ($$)	26,347
Main Floor Elevation (m)	338.21
Peak Flood Elevation (give date)	338.38
Structure Damage Estimate ($$)	4,900
Content Damage Estimate ($$)	2,900
Total Damage Estimate ($$)	7,500

Table 2.3 Example of Flooding Event and Damage Estimate (structure and content)

The damage due to an event is calculated by using the maximum depth of structure inundation as a lookup value to linearly interpolate mean structure and contents damage and standard deviations as a percentage of the structure's total cost using the appropriate stage-damage curve for the defined feature.

The depth of inundation is the water level minus the estimated ground elevation of the structure. For lived-in buildings, a main floor offset (user defined) is applied under the assumption of a raised main floor level. For each event, information is output as shown in Table 2.4.

YEAR	year of event
FID	feature ID for structure from database
RID	reach ID for structure from database
SC	structure code or design code from database
ST	structure type as defined by tool (1 to 5)
EID	event ID for the year, for the structure (1, 2, ...)
EMX	event annual maximum flag (Boolean 0/1)
QM	quarter month of start of event
DUR_QM	duration of event in quarter-months
DEP_M	maximum depth of inundation of event in metres
SD_MIN	structure damage minimum (mean minus two standard deviations)
SD_AVG	structure damage mean
SD_MAX	structure damage maximum (mean plus two standard deviations)
CD_MIN	contents damage minimum (mean minus two standard deviations)
CD_AVG	contents damage mean
CD_MAX	contents damage maximum (mean plus two standard deviations)

Table 2.4 Summary of Flood Events

The tool then creates a summary worksheet that processes the maximum annual flooding event for each year for each structure with elevation estimates, as well as calculating damage for structures without elevation estimates, and combining the results into a total including some degree of uncertainty as defined by total damage plus/minus two standard deviations where such uncertainty estimates are defined in the stage-damage curves.

The summary worksheet is sectioned horizontally by combination of lake zone, and country, and sectioned vertically by structure type. For structures with elevation estimates, information is output for each year as shown in Table 2.5. The estimates of uncertainty are retained for inclusion in the combined results.

Average Duration (d)	average duration of flooding events
Average Depth (m)	average depth of inundation of flooding events
Structures	number of structures flooded
Estimated Damage	total mean damage for all structures

Table 2.5 Saved Data for Structures with Missing Elevations

For structures without elevation estimates, a different approach is taken. Using the corresponding worksheet from the database for the basic structure type, damage is incrementally calculated and summed for 5 cm elevation bins until the maximum annual water level is reached. Different tables may be used as well as different or multiple columns in a table, all selected based upon structure type. Information is output for each year as shown in Table 2.6. The uncertainty calculation is retained for inclusion in the combined results.

Structures	number of structures flooded
Estimated Damage	total mean damage for all structures

Table 2.6 Summary Damage Table

The combined damage information for structures with and without elevation estimates is shown in Table 2.7.

Structures	total number of structures flooded
Estimated Damage	total of mean damage for all structures
Low End of Damage	total of mean damage minus two standard deviations for all structures
High End of Damage	total of mean damage plus two standard deviations for all structures

Table 2.7 Combined Damage Table

2.4 Estimating Damages for Features with No Elevation Data

Feature specific elevation estimates are only available for portions of the study area, primarily the U.S. shoreline where high resolution LIDAR data is available. Where feature specific elevation estimates are not available, individual features (e.g. individual lived-in buildings identified in the geospatial database) have been grouped together by feature category and geographic area and their distribution scaled relative to a comparable distribution developed using available elevation information. For example, there are 408 lived-in buildings and 409 non-lived-in buildings in the database for the U.S. shore of Rainy Lake with site specific elevation estimates. Figure 2.3 illustrates the cumulative distribution (based on count) of Rainy Lake buildings. The distributions are based on only U.S. features and a combination of all U.S. and Canadian features in the database (combined). Similar distributions of the percent of features at or below a particular elevation for specific portions of the dataset have been identified for various geographic regions (e.g. the shoreline of Rainy, Namakan/Kabetogama, and Sand Point/Crane/Little Vermillion Lakes on both the Canadian and U.S. side). Generally speaking, this has been done in 5 cm elevation bins.

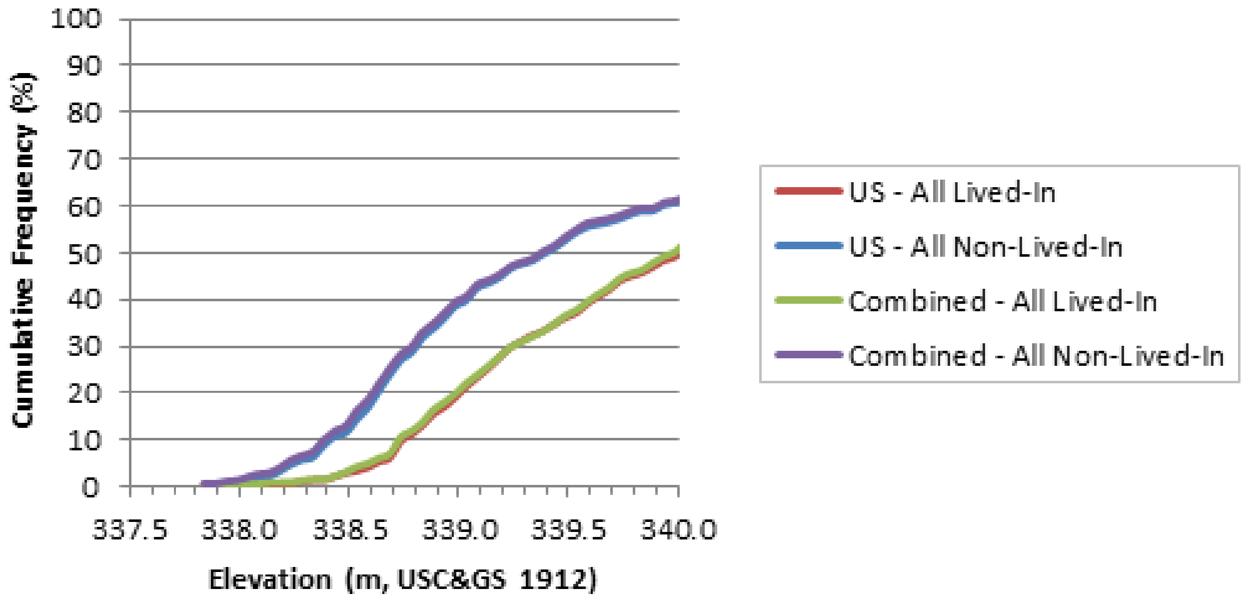

Figure 2.3 Cumulative frequency of lived-in and non-lived-in structures for Rainy Lake for US shoreline only and for combined US and Canadian structures

Using the distributions based on known elevations, it is possible to scale the number of buildings without an elevation estimate based on the percent that would be at or below a particular elevation where such estimates exist. For example, if 50% of the lived-in buildings in the database with elevation estimates on the U.S. shore of Rainy Lake have an elevation of 339.0 m or below, that percentage can be used to scale the features with missing elevation information. If there were an additional 200 features in the database for Rainy Lake without specific elevation information, 50% of that total (100) would be considered to have an elevation of 339.0 m or below. The same thing can be done for other elevation bins to come up with an estimated distribution of the count of the 200 features without elevation information. Similarly, the cumulative *area* of the buildings with known elevation can be used to scale the cumulative area of buildings without known elevation. The area estimates can then be converted to an economic value based on the economic characteristics assigned in the "SetupAndEconomics" tab of the input Excel spreadsheet used by the Flood Tool. Table 2.8 **Error! Reference source not found.**provides an example of how the input data is represented for features without site specific elevation estimates. A similar process has been generally applied in all cases where a known cumulative distribution is available and there are adjacent areas on the same lake where there are features with no elevation estimates. Each table has two elevation columns (USC&GS 1912 and NAVD88), the scaler for area and count, and the estimate of area and count based on the total amount of features in that category without an elevation estimate. The area estimates are multiplied by the m^2 values from the SetupAndEconomics table of the input database to show the total value, by elevation bin. The area and count estimates start only when the first full feature is considered flooded.

Rainy Lake - US (Non-Lived-In Structures)						
5 cm bins in USC&GS1912	5 cm bins in NAVD88	Scaler - Area	Scaler - Count	Non-Lived-In Area	Non-Lived-In Count	Value
				921.197251	32	
337.584	337.75	0	0	0.00	0	$0.00
337.634	337.8	0	0	0.00	0	$0.00
337.684	337.85	0	0	0.00	0	$0.00
337.734	337.9	0	0	0.00	0	$0.00
337.784	337.95	0	0	0.00	0	$0.00
337.834	338	0	0	0.00	0	$0.00
337.884	338.05	0	0	0.00	0	$0.00
337.934	338.1	0.002084	0.00463	0.00	0	$0.00
337.984	338.15	0.002432	0.006944	0.00	0	$0.00
338.034	338.2	0.010379	0.013889	0.00	0	$0.00
338.084	338.25	0.012097	0.020833	0.00	0	$0.00
338.134	338.3	0.012331	0.023148	0.00	0	$0.00
338.184	338.35	0.016654	0.034722	15.34	1	$2,914.83
338.234	338.4	0.023373	0.050926	21.53	2	$4,090.85
338.284	338.45	0.027021	0.060185	24.89	2	$4,729.34
338.334	338.5	0.037509	0.069444	34.55	2	$6,565.18
338.384	338.55	0.048959	0.094907	45.10	3	$8,569.10
338.434	338.6	0.056391	0.113426	51.95	4	$9,870.03
338.484	338.65	0.098552	0.125	90.79	4	$17,249.26
338.534	338.7	0.17413	0.157407	160.41	5	$30,477.45
338.584	338.75	0.18746	0.180556	172.69	6	$32,810.64
338.634	338.8	0.200029	0.215278	184.27	7	$35,010.56

Table 2.8 Cumulative frequency of non-lived-in structures for Rainy Lake for US shoreline only

In the Flood Tool, damage estimates for features without elevation information are calculated based on tables similar to the one shown in Table 2.8. Damages are reported based on the count of features impacted as well as the associated economic impacts. Flood damages are estimated on an annual basis based on the peak water level. For each year of the simulation, the Flood Tool identifies the peak quarter-monthly flood elevation based on the input water level time series being utilized for the simulation. For the count of impacted features, the peak water level falls within a given 5 cm elevation bin and the number of impacted features can be extracted directly from the table. For example, a peak annual flood elevation of 338.50 m would impact 4 non-lived-in buildings based on Table 2.8. The calculation of economic impacts follows a slightly different approach because the stage-damage relationships used to estimate flooding damages are based on a depth of inundation and it is not possible to simply pull a damage value from the table. Instead, the incremental feature value within each flooded 5 cm elevation bin is identified and the depth of inundation relative to the peak flood level determined for each bin. Damage estimates are obtained for each 5 cm bin using the appropriate stage-damage function as outlined on the "Configuration" Tab of the Flood Tool, the depth of inundation, and the incremental feature value. Damages for each 5 cm elevation bin are summed and reported on the summary tab of the Flood Tool associated with each simulation scenario, along with the number of features impacted. Damages are also reported as total damages for each year of the simulation by summing the total damages for features with and without an elevation estimate.

2.5 Future Updating and Upgrades to the Software

Potential future modifications to the tool can be grouped into updates and upgrades, as follows:

Updates:

- Attribute existing buildings with missing information, such as land elevation, main floor offset, and assessment data.
- Add new buildings to the database.

Upgrades:

- Improve the damage logic, such as considering duration of inundation and the effect of multiple events.
- Integrate wave forces into the damage logic for buildings. This was done previously in the FEPS and could be done in the Flood Tool with additional programming. Also, wave forces could be integrated into the damage logic for docks and boat houses, significantly improving the algorithm for those types of structures. Generally, this would involve the following tasks: 1) assembling local wind data, 2) developing a wave model for the lakes (shoreline and depths resolved), 3) hindcasting historical wave conditions (i.e., generate hourly wave height, period and direction around the lakes, 4) develop a new damage function that relates wave forces to structural damage for docks and boat houses, and 5) integrating the code for wave forces into the Excel tool.

3.0 REQUIREMENTS OF THE DATABASE

The Flood Tool finds information in the database by spreadsheet name, and by predetermined starting row indexes, and column indexes. If any of these factors change, then code adjustments must be made to variables, constants, enumerations, and a few key functions in the VBA module "modDatabase". In the case that VBA changes are required elsewhere, then the module will be specified.

Generally, more rows can be added to worksheets and columns can be renamed without any code changes required. Worksheets which contain multiple tables must be sectioned horizontally, with exactly three empty columns of separation. The number of columns of separation is set in VBA as the constant "SPACER". There are multiple sections for all the Crane Lake structure worksheets for the United States in order to support different reaches in the zone.

3.1 The Water Level Worksheet

The water level worksheet is named "RuleCurveWaterLevels" and the time series data must begin in cell "C2". The time series must contain only whole years of data (48 quarter-month entries per year), and all columns must have the same number of rows. Changing this table may require adjusting the named range "nrWaterLevelList" on the configuration worksheet as well as making changes to the VBA code.

If adding a new time series, the range "nrWaterLevelList" in hidden column I on the configuration worksheet will need to be extended in order to allow selection of the new series. In VBA, the function "db_wl_text()", and the "WL_IDX" enumeration will similarly need to be extended.

Other related elements in VBA are: the constant "g_wl_sheet", the constant "MIN_YR", and the function "db_wl()".

3.2 The Setup and Economics Worksheet

The setup and economics worksheet is named "SetupAndEconomics" and it must contain unit costs for lived-in buildings, non lived-in buildings, boathouses, and docks in the following named ranges:

- nrValueLivedIn
- nrValueNonLivedIn
- nrValueBoathouse

- nrValueDock

The same value is currently used for both fixed/combo and floating docks. Changing any of these items may require modifying the VBA constant "g_ec_sheet" as well as the function "db_str_value()".

3.3 Building Worksheets with Elevation Estimates

The building worksheets with elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:

- g_bd_sheet_rainy_US = "Rainy_US_build-Elev"
- g_bd_sheet_rainy_CA = "Rainy_Can_build-Elev"
- g_bd_sheet_namak_US = "NamKab_US_Build-ElevMN_NPS"
- g_bd_sheet_namak_CA = "NamKab_Can_build-Elev"
- g_bd_sheet_crane_US = "Crane_US_build-Elev"
- g_bd_sheet_crane_CA = "Crane_Can_build-Elev"

These worksheets can have columns added to the right, but if any of the key columns are moved, then the "BLD_FIELDS" enumeration must be adjusted in VBA. The key columns are as follows:

- column 02 - "FeatureID"
- column 08 - "StructureCode"
- column 09 - "Elev_Est"
- column 11 - "TotalCost"
- column 12 - "ReachID"

3.4 Boathouse Worksheets with Elevation Estimates

The boathouse worksheets with elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:.

- g_bh_sheet_rainy_US = "Rainy_US_BH-Elev"
- g_bh_sheet_rainy_CA = "Rainy_Can_BH-Elev"
- g_bh_sheet_namak_US = "NamKab_US_BH_MNandNPS-Elev"
- g_bh_sheet_namak_CA = ""
- g_bh_sheet_crane_US = "Crane_US_BH-Elev"
- g_bh_sheet_crane_CA = "Crane_Can_BH-Elev"

Note that there is no current worksheet for Namakan Lake for Canada. Should this sheet be added to the database, then supporting it merely requires filling in the name.

These worksheets can have columns added to the right, but if any of the key columns are moved, then the "BH_FIELDS" enumeration must be adjusted in VBA. The key columns are as follows:

- column 02 - "FeatureID"
- column 09 - "Elev_Est"
- column 10 - "DesignCode"
- column 11 - "ReachID"
- column 13 - "TotalCost"

3.5 Dock Worksheets with Elevation Estimates

The dock worksheets with elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:

- g_dk_sheet_rainy_US = "Rainy_US_Docks-Elev"
- g_dk_sheet_rainy_CA = "Rainy_Can_Docks-Elev"
- g_dk_sheet_namak_US = "NamKab_US_Docks-Elev"
- g_dk_sheet_namak_CA = "NamKab_Can_Docks-Elev"
- g_dk_sheet_crane_US = "Crane_US_Docks-Elev"
- g_dk_sheet_crane_CA = "Crane_Can_Docks-Elev"

These worksheets can have columns added to the right, but if any of key columns are moved, then the "DK_FIELDS" enumeration must be adjusted in VBA. The key columns are as follows:

- column 02 - "FeatureID"
- column 08 - "DesignCode"
- column 09 - "Elev_Est"
- column 11 - "TotalCost"
- column 12 - "ReachID"

3.6 Building Worksheets without Elevation Estimates

The building worksheets without elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:

- g_bd_sheet_rainy_US_ne = "Rainy_US_build-NoElev"
- g_bd_sheet_rainy_CA_ne = "Rainy_Can_build-NoElev"

- g_bd_sheet_namak_US_ne = ""
- g_bd_sheet_namak_CA_ne = "NamKab_Can_build-NoElev"
- g_bd_sheet_crane_US_ne = "Crane_US_build-noElev"
- g_bd_sheet_crane_CA_ne = "Crane_Can_build-noElev"

Note that there is no current worksheet for Namakan Lake for the United States as all building features in the database have an elevation estimate. Should this sheet be added to the database, then supporting it merely requires filling in the name.

These worksheets have two sections corresponding to lived-in, then non lived-in buildings. The table data for these worksheets must begin in row 4 and must not have any missing cells. The number of rows can be changed, but no column changes should be made without careful impact analysis of the VBA code, both in "modDatabase" and "modModel". The key columns are as follows:

- column 01 - "5 cm bins in USC&GS1912"
- column 06 - "Lived-In Count" or "Non- Lived-In Count"
- column 07 - "Value"

3.7 Boathouse Worksheets without Elevation Estimates

The building worksheets without elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:

- g_bh_sheet_rainy_US_ne = "Rainy_US_BH-NoElev"
- g_bh_sheet_rainy_CA_ne = "Rainy_Can_BH-NoElev"
- g_bh_sheet_namak_US_ne = "NamKab_US_BH_MNandNPS-NoElev"
- g_bh_sheet_namak_CA_ne = "NamKab_Can_BH-NoElev"
- g_bh_sheet_crane_US_ne = "Crane_US_BH-NoElev"
- g_bh_sheet_crane_CA_ne = ""

Note that there is no current worksheet for Crane Lake for Canada. Should this sheet be added to the database, then supporting it merely requires filling in the name.

The table data for these worksheets must begin in row 4 and must not have any missing cells. The number of rows can be changed, but no column changes should be made without careful impact analysis of the VBA code, both in "modDatabase" and "modModel". The key columns are as follows:

- column 01 - "5 cm bins in USC&GS1912"
- column 06 - "Boathouse Count - full structures (500)"
- column 07 - "Value - full structures"
- column 11- "Boathouse Count - part structures (600)"
- column 12 - "Value - part structures"

3.8 Dock Worksheets without Elevation Estimates

The dock worksheets without elevation data are identified in VBA as the following constants, which must be adjusted if the worksheet names change in the database:

- g_dk_sheet_rainy_US_ne = "Rainy_US_Docks-NoElev"
- g_dk_sheet_rainy_CA_ne = "Rainy_Can_Docks-NoElev"
- g_dk_sheet_namak_US_ne = "NamKab_US_Docks-NoElev"
- g_dk_sheet_namak_CA_ne = "NamKab_Can_Docks-NoElev"
- g_dk_sheet_crane_US_ne = "Crane_US_Docks-NoElev"
- g_dk_sheet_crane_CA_ne = "Crane_Can_Docks-NoElev"

The table data for these worksheets must begin in row 4 and must not have any missing cells. The number of rows can be changed, but no column changes should be made without careful impact analysis of the VBA code, both in "modDatabase" and "modModel". The key columns are as follows:

- column 01 - "5 cm bins in USC&GS1912"
- column 06 - "Dock Count - Combo"
- column 07 - "Value"
- column 11- "Dock Count - Fixed"
- column 12 - "Value"
- column 16- "Dock Count - Floating"
- column 17 - "Value"

4.0 BUILDING REPLACEMENT COSTS

Building replacement costs were generated for the following type of typical structures: cottage, floating dock, boat lift and unlived-in buildings (e.g., sheds and garages). Refer to 4.1 to 4.4 for typical pictures of these structure types. These costs were generated by reviewing product websites from Ontario and e-mail correspondence with distributors/builders. This limited approach was due to the budget available for this task, one day for a mid-level design engineer.

Where possible, a range of costing information was generated, from low to average to high. All costs are report in Table 4.1 as dollars/m^2, which is the structure description in the database. For structure variables that influence cost (e.g., manual or hydraulic boat lift), yet such details are not available in the database, the low end cost estimate represents the manual lift and the high end represents the hydraulic lift.

In the future, this table could be refined with additional effort to assemble the costs and further attribution of the buildings (e.g., single storey or two storey cottage).

Figure 4.1 Typical Cottage for Cost Estimate (*photo from Kenora Resource Consultants*)

Figure 4.2 Typical Floating Dock (*photo from Kenora Resource Consultants*)

Figure 4.3 Typical Boat Lift with Roof (*photo from Kenora Resource Consultants*)

Figure 4.4 Unlived-in Building (*photo from Kenora Resource Consultants*)

Source	Location	Low	Avg	High	Notes
LIVED-IN BUILDING					
Laclu Cottage	**Kenora, ON**	$1,561	$1,668	**$1,776**	
Comfort Homes	Woodstock, ON	**$1,126**	$1,173	$1,232	Low-end = w/o porch; High-end = w/ porch
Ontario Contractors	Ontario	$1,345	$1,399	$1,485	Low-end = 2-storey; High-end = bungalow
PIPE or FLOATING DOCK					
Docks & Lifts	**Kenora, ON**			**$700**	Pipe dock with steel frame
Dock in a Box**	Innisfil, ON	**$287**	$523	$675	Low-end = Lightduty+large; High-end = Superduty+small
BOAT LIFT (superstructure only, with lift)					
Docks & Lifts	**Kenora, ON**	**$762**		**$1,301**	Steel Frame, 5000 lb. lift Low-end = w/o roof; High-end = w/ roof
Dock in a Box**	Innisfil, ON	$827		$1,017	Aluminum frame, 1250-1500 lb. **"LIFT"**, manual/hydraulic
UNLIVED-IN BUILDING					
North American Lumber**	**Fort Frances, ON**	**$256**			Shed (9m^{2}x2.4m, siding, uninsulated), slab foundation est.
Tompkins Home Hardware	**Emo, ON**		$338		Shed (9m^{2}x2.4m, siding, uninsulated), slab foundation
Comfort Homes	Woodstock, ON			**$969**	Garage (roller door,roof truss, wood siding, eave troughs)

Table 4.1 Summary of Cost Information Collected for the Study

5.0 REFERENCES

Baird & Associates (2005). Flooding Performance Indicator: Methodology and Shared Vision Model Application. Prepared for the IJC Plan Formulation and Evaluation Group.

Baird & Associates (2012). IJC Flooding Sites Excel Tool. Prepared for the International Joint Commission.

USACE (2000). Economic Guidance Memorandum 01-03, Generic Depth-Damage Relationships. Prepared by the US Army Corps of Engineers.