**Final Report**

# Scoped Dam Safety Assessment
# Fourteen Island Lake Dam

**Township of South Frontenac, Ontario**

**D.M. Wills Project Number 20-5394**

**D.M. Wills Associates Limited**
Partners in Engineering, Planning and Environmental Services
Peterborough

**December 2022**

**Prepared for:**
**Fourteen Island and Mink Lakes Watershed Association**

## Summary of Revisions

| Rev. No. | Revision Title | Date | Summary of Revisions |
|---|---|---|---|
| 1 | Draft Report | 10/21/22 | Issued for Client Review |
| 2 | Final Report | 12/01/22 | Issues as Final |
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This report / proposal has been formatted considering the requirements of the Accessibility for Ontarians with Disabilities Act.

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# 1.0 Project Initiation, Data Collection and Site Inspection

## 1.1 Introduction

D.M. Wills Associates Limited (Wills) was retained by the Fourteen Island and Mink Lakes Watershed Association (FIMLA) to undertake a Scoped Dam Safety Assessment for the Fourteen Island Lake Dam located at the outlet of Fourteen Island Lake, east of the Town of Verona in the Township of South Frontenac, Ontario.

Wills inspected the Fourteen Island Lake Dam in 2020 to determine the condition of the dam. During this inspection, Wills noted that some sections of the dam, particularly the top slab and sluiceway walls, are in poor condition, while the remainder of the dam is in fair condition. Wills' recommendations were to repair and reface the upstream face of the dam, remove and replace the top slab and gains and sluice walls, and install drains in the downstream face.

A Dam Safety Review has not been completed for the Fourteen Island Lake Dam; therefore, the existing Hazard Potential Classification (HPC), Inflow Design Flood (IDF), hydraulic capacity and dam stability are unknown. In order to address the limited dam safety information for the Fourteen Island Lake Dam, Wills prepared a detailed scope of work and work plan. **Section 1.2** provides a general description of the scope of work for the project.

## 1.2 Scope of Work

Based on Wills' proposal, dated January 10, 2022, the scope of work for the Scoped Dam Safety Assessment includes the following activities:

- Hydrology Study.
- Prepare Hydraulic (HEC-RAS) Model.
- Simplified Dam Breach Assessment.
- Hazard Potential Classification and Inflow Design Flood Selection.
- Structural (Gravity Dam) Stability Assessment.

Upon completion of the Scoped Dam Safety Assessment, and approval from the FIMLA, Wills shall proceed with the development of detailed design drawings, specifications, and a cost estimate for the recommended rehabilitation measures.

## 1.3 Site Location

The Fourteen Island Lake Dam is located east of the Town of Verona in the Township of South Frontenac, Ontario. The location plan is provided in **Figure 1**. The Fourteen Island Lake Dam controls the water level in Fourteen Island Lake and Sigsworth Lake (Mink Lake), and outlets to an unnamed stream, which ultimately discharges to Hardwood Creek.

## 1.4 Guidelines

In August 2011, the Ministry of Natural Resources (MNR), now the Ministry of Natural Resources and Forestry (MNRF), replaced the 1999 (Draft) Ontario Dam Safety Guidelines (ODSG) with a series of Dam Safety Technical Bulletins under Sections 14 and 16 under the Lakes and Rivers Improvement Act (LRIA). Following the release of the 2011 Technical Bulletins by the MNR, the bulletins became the standard for the review and analysis of all dams in Ontario. Consequently, Wills has used the criteria within the August 2011 Technical Bulletins for this assignment. Where the information contained within the Technical Bulletins is not sufficient, Wills relied on the Canadian Dam Association (CDA) Dam Safety Guidelines and Technical Bulletins or other relevant documentation, as appropriate.

## 1.5 Site Reconnaissance

### 1.5.1 Introduction

Wills undertook a site inspection of the Fourteen Island Lake Dam on November 11, 2020. The purpose of the site visit was to review the dam and its operation with FIMLA members, and to undertake a detailed inspection of the dam, including its various components.

### 1.5.2 Record of Observations

A written record of the dam inspection is included in **Appendix A**. The locations of specific dam features are referenced looking downstream.

#### 1.5.2.1 Dam General Description


The construction date of Fourteen Island Lake Dam is unknown; however, previous inspections conducted at the site identified the year "1929" carved into the concrete on the left bank of the dam. The dam was constructed to maintain the water level of Fourteen Island Lake. Currently, the dam functions to provide recreational opportunities in Fourteen Island Lake. Fourteen Island Lake has a surface area of approximately 1.99 $km^2$.

The dam is a concrete gravity structure that is approximately 2 m high and 11 m long with a crest elevation of 142.60 m. The dam contains a spillway that is approximately 0.85 m wide with removable stoplogs.

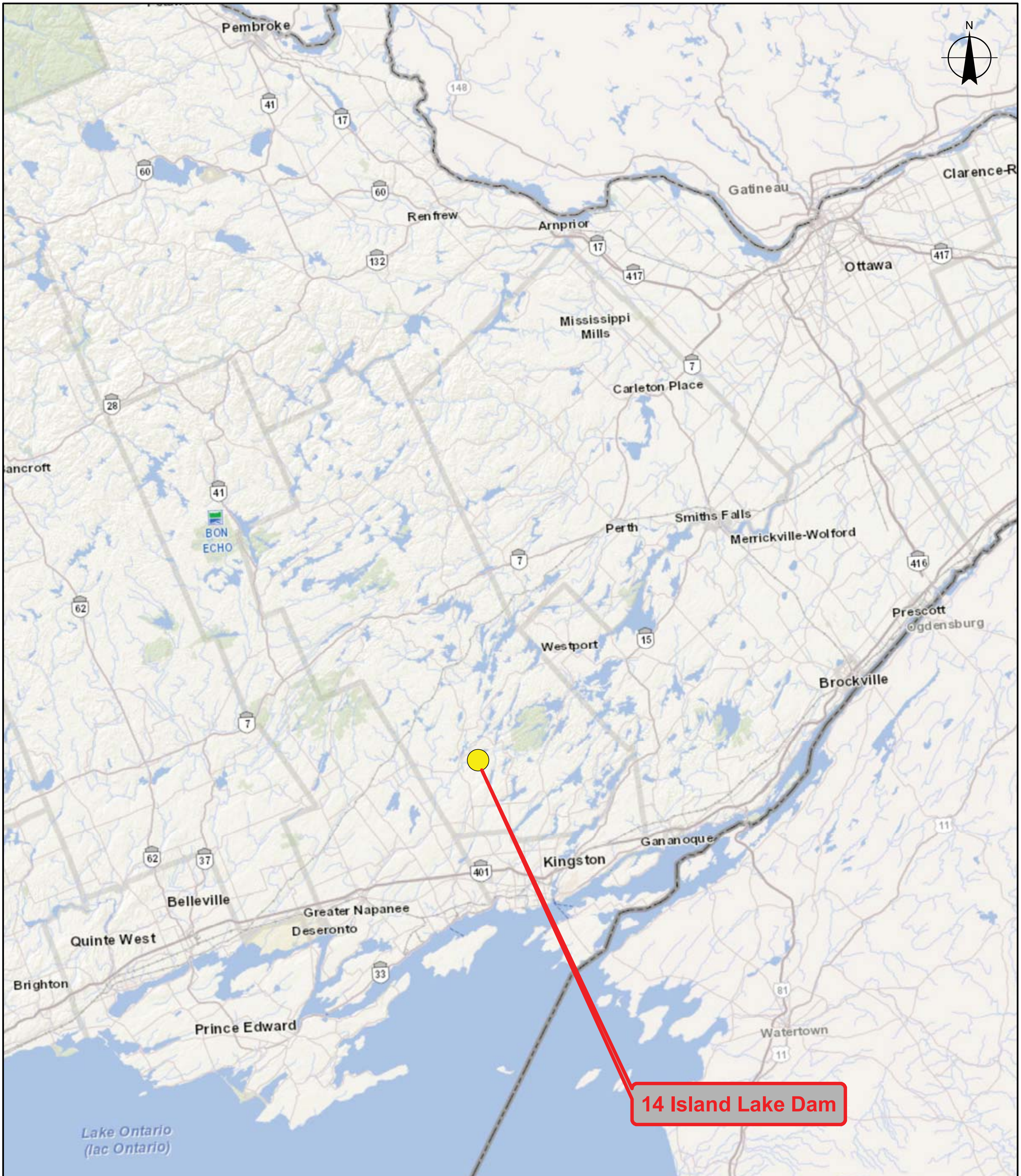


**Figure 1 - Location Plan**

NAD83 UTM Zone 18 North

0 5 10 20 30 40

Kilometers

W I L L S

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**Legend**

14 Island Lake Dam

| | |
|---|---|
| Drawn by: SO | Scale (Horz.) 1:1,000,000 |
| Checked by: DG | |
| Engineer: DG | Map Date 10/19/2022 |
| Project No. 20-5394 | Map File No. Figure 1 - 5394 |

#### 1.5.2.2 Dam General Condition

The following is a summary of the general condition of the dam. Additional details are provided in the FIMLA Dam Inspection Report, dated November 11, 2020, which is included in **Appendix A**.

**Earth Embankment**

There is no earth embankment at this site as it is a concrete dam founded on bedrock.

**Concrete Structures**

The dam appears to be of rock core construction with a concrete “skin”. The downstream face was sounded with a hammer and all concrete was in good condition with no delaminations or loose concrete. The top surface of the dam is “L” shaped and is set into/against solid bedrock on each bank. No significant leakage was noted along the dam/rock interfaces.

Significant deterioration was noted in the upstream half of the deck top on each “side” of the dam. It appears that the dam may have been refaced in the past as there is a distinct formed line approximately 200 mm (8”) back from the upstream edge of the dam top. The line is now an open crack (line) that defines the upstream face from the deck top. The deck top against this line is in poor condition.

**Upstream Face**

The upstream face of the dam is mostly submerged and could not be inspected. The upper portion of the face (above the water line) is in fair to good condition, with several large vertical cracks. These cracks would allow water to penetrate into the core of the dam; however, there was no obvious signs of water flowing through the dam structure.

**Metal Structures/Gains**

There are steel angles set into the concrete to form the operable gains for the dam. The steel angles are in generally good condition; however, the anchorage into the east portion of the dam is questionable. The concrete along the east side of the sluice (adjacent to and downstream of the gain) is in very poor condition. While no water was observed flowing from the core at the time of inspection, it is clear that water may build up in this area as ice in the winter and could cause significant damage.

**Gates and/or Stop Logs**

There are no gates located on site. Water depth in the upstream lake is controlled by timber boards contained within the gains. The upstream sediment levels are very high and a large pile of debris (stick, branches, etc.) has been cast to the downstream, east side of the dam. Dam operations and future inspections would significantly benefit from removal of sediment and debris.

## 1.6 Data Collection and Review

### 1.6.1 Background Data

The FIMLA provided Wills with background data related to the Fourteen Island Lake Dam. The information determined to be relevant to the current study is outlined in **Table 1.**

**Table 1 – Relevant Background Information**

| Title | Date | Author | Description of Contents |
|---|---|---|---|
| Dam Inspection Report | 2009 | Quinte Conservation | • Dam inspection report |
| Dam Inspection Report | 2019 | Quinte Conservation | • Dam inspection report |
| Dam Inspection Report | 2020 | Wills | • Dam inspection report |

### 1.6.2 Published Data

As well as the background data provided by the client, a large amount of the data used to perform the analyses for this report are published by federal or provincial government organizations. **Table 2** provides a list of data used and the corresponding source. The specific applications of this data to the analyses are further discussed in **Section 2.2** and **Section 3.2** of the report as they apply to the hydrologic and hydraulic assessments respectively.

**Table 2 – Sources of Published Data**

| Data Type | Source | Date of Publication |
|---|---|---|
| Rainfall Data | Ministry of Transportation Intensity Duration Frequency (MTO IDF) Curve Finder Version 3.0 | September 2016 |
| Land Cover Data | Ontario Land Cover Compilation, Land Information Ontario, Ministry of Natural Resources and Forestry | January 21, 2016 |
| Soil Data | Soil Survey Complex, Land Information Ontario, Ministry of Natural Resources and Forestry | November 20, 2015<br>Updated November 6, 2019 |
| Topographic Data | Ontario Digital Terrain Model (Lidar-Derived), Provincial Mapping Unit, Mapping and Information Resources Branch, Corporate Management and Information Division, Ministry of Natural Resource and Forestry | January 31, 2022 |

### 1.6.3 Topographic Survey

Wills' survey crew completed a topographic survey of the dam and surrounding area on November 11, 2020.

# 2.0 Hydrologic Assessment

## 2.1 Introduction

The hydrologic assessment was undertaken to provide an estimate of the 2-year to 100-year peak flows.

Since there are numerous methods for estimating peak flows, it was determined that a weight of evidence approach would be the most appropriate way to estimate peak flows for the 2-year to 100-year return period storms. This means that all of the credible methods of peak flow estimation available were reviewed, and based on the evidence, the most appropriate estimates were selected for further use in the study.

The following sections describe the background information used in the analyses, present the results of the various methods of peak flow estimation and identify the selected peak flows.

## 2.2 Available Data

### 2.2.1 Precipitation Data

#### 2.2.1.1 2-year to 100-year Design Storm Events and Distribution

The 2-year to 100-year total rainfall volumes are based on the Intensity Duration Frequency (IDF) parameters for the location of the Fourteen Island Lake Dam from the MTO IDF Curve Lookup Tool. The Intensity Duration Frequency parameters are provided in **Appendix B.**

The total rainfall volumes were distributed based on various synthetic storm distributions for use within the hydrologic model. The most appropriate synthetic storm distributions for this application are the 6-hour, 12-hour and 24-hour Soil Conservation Service (SCS) storm distributions. The results of the hydrologic model for each storm distribution are presented in **Section 2.6** and are compared to other methods of estimating the 2-year to 100-year peak flows in **Section 2.7**.

### 2.2.2 Land Cover and Soil Data

The Ontario Land Cover Compilation (OLCC) defined the land cover within the Fourteen Island Lake Dam watershed and was downloaded from the Ministry of Natural Resources and Forestry (MNRF) Land Information Ontario (LIO) database. The OLCC is a rationalized land cover product for the province of Ontario, combining (3) three separate land cover databases: Far North Land Cover, Southern Ontario Land Resources Information System and Provincial Land Cover. The Fourteen Island Lake Dam watershed is primarily comprised of wooded land with some agricultural areas, wetland, and residential / recreational areas. The land cover plan is included in **Figure 2.** Based on Wills' understanding of the area, it was assumed that only minimal development would occur within the study area over the next 10 to 15 years and that it would have no major effects on the hydrology.

Soils data was obtained from the Ontario Soil Survey Map No. 39, Soil Map of Frontenac County and Survey of Prince Edward County and the Soil Map of Prince Edward County prepared by the University of Guelph Ontario Agricultural College Department of Soil Science, and the Canada Department of Agriculture Research Branch. In 2015, the Ontario Ministry of Agriculture, Food and Rural Affairs and Agriculture (OMAFRA) and Agri-Food Canada, in cooperation with the Ministry of Natural Resources, compiled a geo-spatial soils database for Southern Ontario. The database consolidated the existing digital soil data, mapped on a county basis, into a digitally stitched and standardized product. The GIS data indicates that the majority of the watershed consists of Sandy Loam Rock. The soils plan is included in **Figure 3.**

### 2.2.3 Ontario Base Map Data

Ontario Base Map (OBM) data was downloaded from the MNRF Land Information Ontario (LIO) database. Key data used in this study included watercourses, waterbodies, wetlands, woods, roads and contours.

### 2.2.4 LiDAR Digital Elevation Model

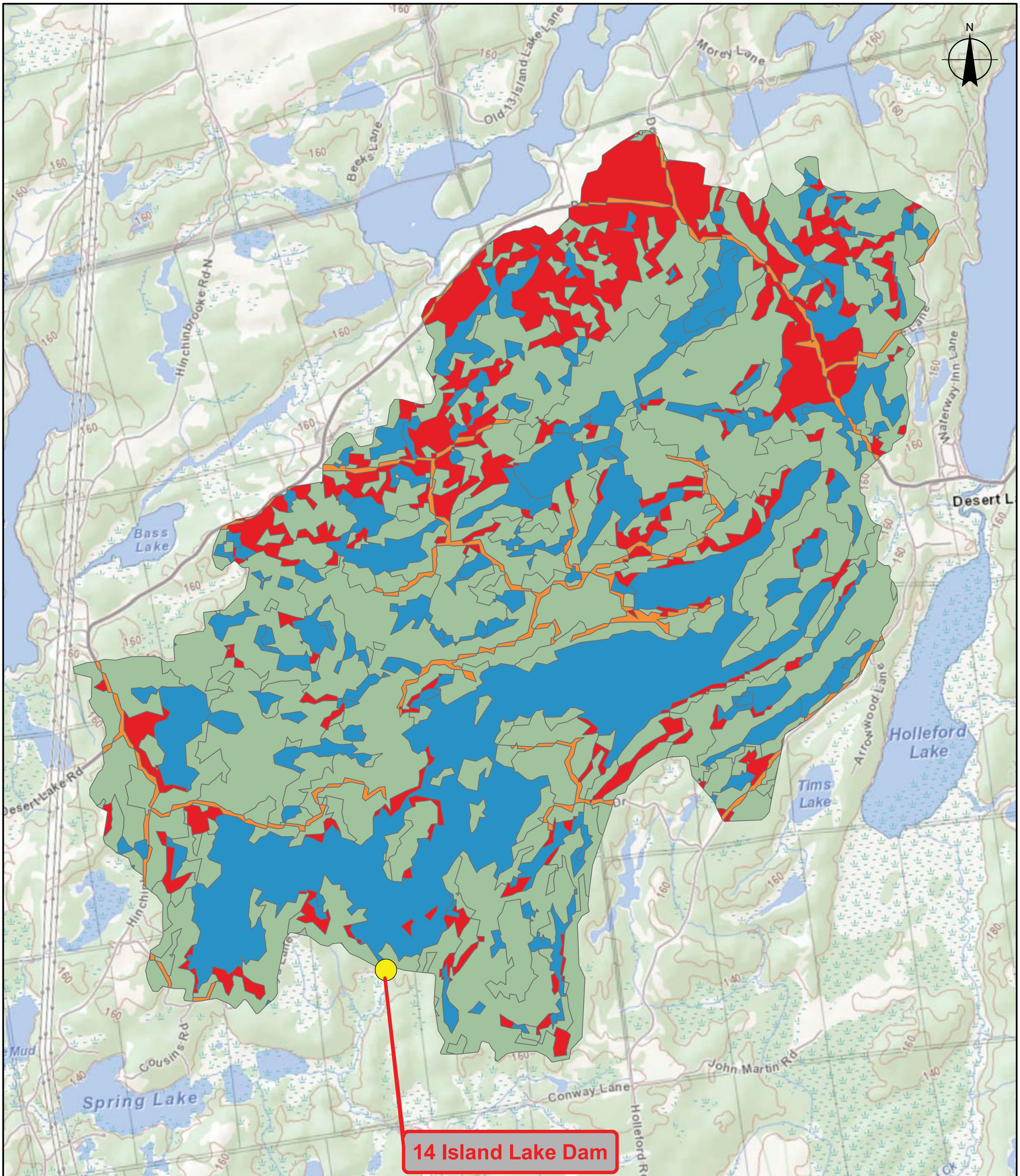
The primary source of topographic data for the hydrology study was the Ontario Digital Terrain Model (DTM) that was provided by the MNRF through LIO. This DTM was used to delineate the Fourteen Island Lake Dam catchment within ArcGIS.

## 2.3 Watershed Description

The Fourteen Island Lake dam is located within a watershed that outlets to an unnamed watercourse that is part of the Hardwood Creek watershed. The unnamed watercourse has a drainage area of approximately 16 $km^2$. It has a north-south orientation with a relatively constant width of approximately 3 km. The unnamed watercourse flows through a series of wetlands and lakes. The largest lakes are Little John Lake, Sigsworth Lake (also known as Mink Lake) and Fourteen Island Lake, which are approximately 27 ha, 23 ha and 199 ha in size, respectively. Two smaller lakes, Little John's Sister Lake and Buffy Lake are also part of this watershed. The Fourteen Island Lake Dam controls the water surface elevation in Fourteen Island Lake and Sigsworth Lake (Mink Lake). The watercourse enters Hardwood Creek approximately 400 m downstream of the Fourteen Island Lake Dam.

### 2.3.1 Catchment Delineation

As described previously, the Fourteen Island Lake Dam is located within a sub-watershed of the Hardwood Creek watershed. The drainage area for the unnamed watercourse was delineated starting at the Fourteen Island Lake Dam and is comprised of one catchment. The catchment was delineated in ArcGIS 10.7 using the LiDAR DTM. The drainage area plan showing the full catchment area of the dam and the areas downstream relevant for application to the hydraulic model are shown in **Figure 4**.




# Figure 2 - Land Cover Plan

NAD83 UTM Zone 18 North

0 0.2 0.4 0.8 1.2 1.6

Kilometers

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**Legend**

14 Island Lake Dam

**Landuse**

- Wetland
- Woods
- Impervious
- Developed
- Agriculture

| | |
|---|---|
| Drawn by: SO | Scale (Horz.) 1:30,000 |
| Checked by: DG | |
| Engineer: DG | Map Date 10/19/22 |
| Project No. 20-5394 | Map File No. Figure 2 - 5394 |

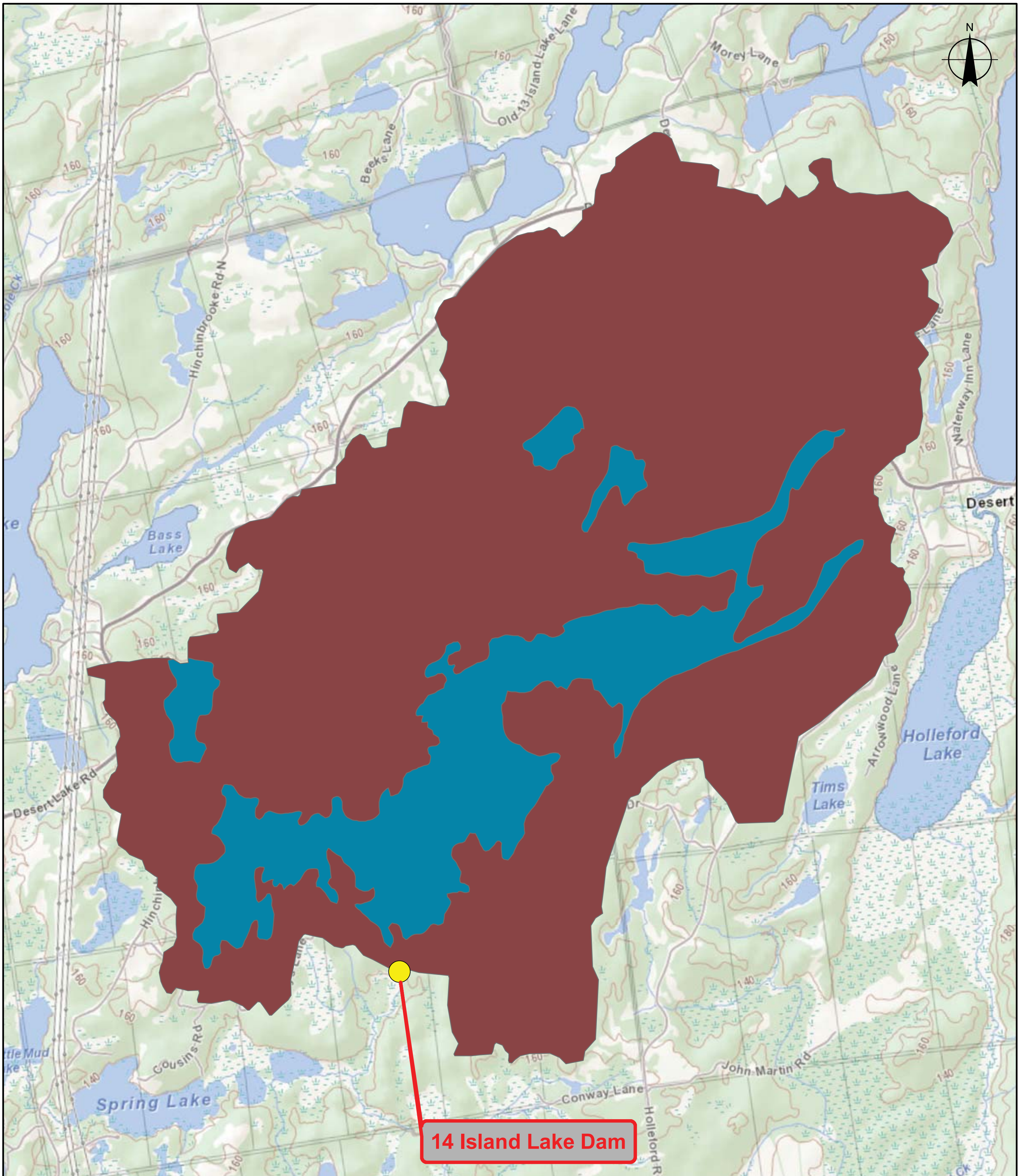


**Figure 3 - Soils Plan**

NAD83 UTM Zone 18 North

0 0.2 0.4 0.8 1.2 1.6

Kilometers

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**Legend**

14 Island Lake Dam

**Soil Type**

Msl-R

ZZ

| | |
|---|---|
| Drawn by: SO | Scale (Horz.) 1:30,000 |
| Checked by: DG | |
| Engineer: DG | Map Date 10/19/22 |
| Project No. 20-5394 | Map File No. Figure 3 - 5394 |

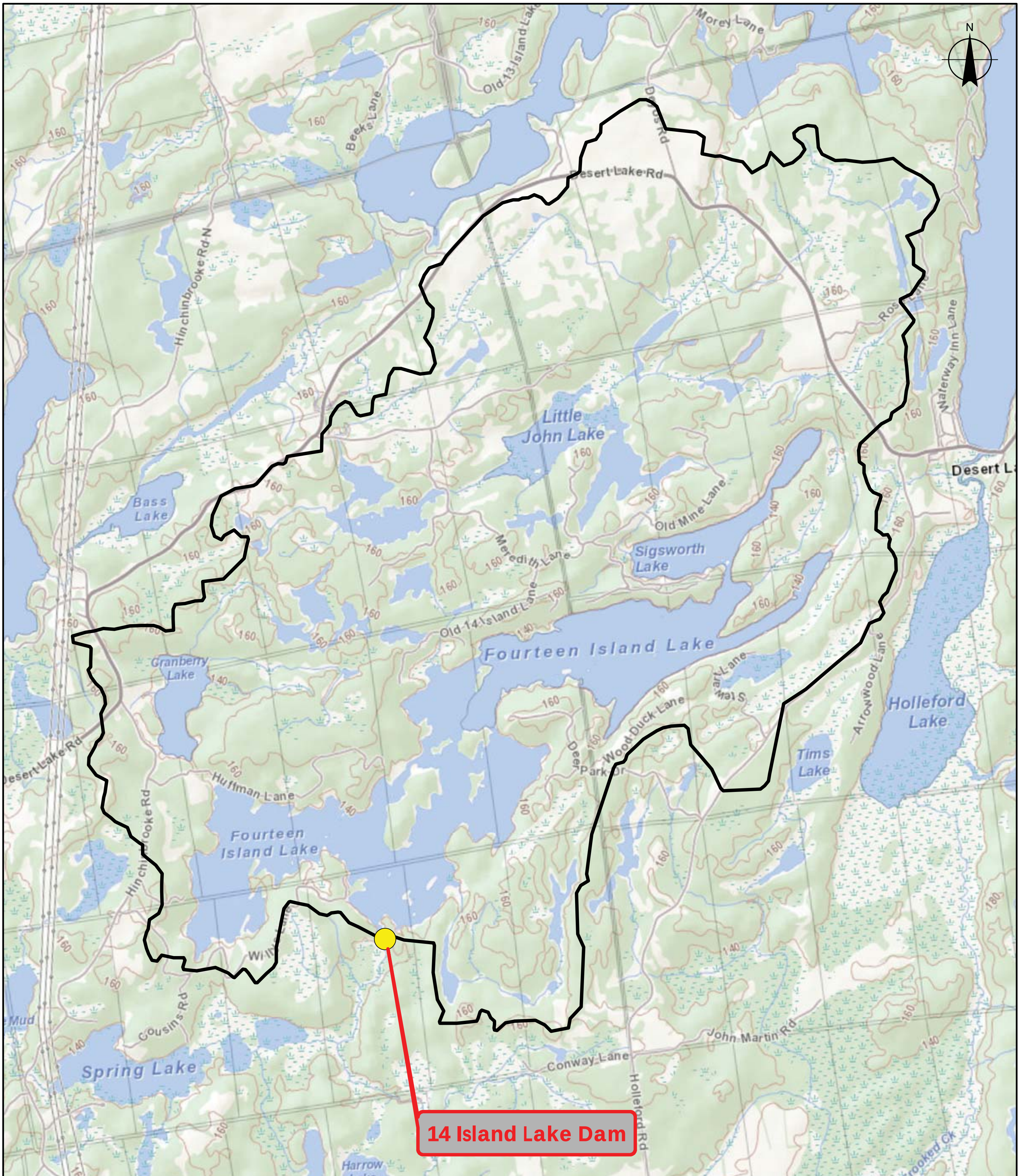


**Figure 4 - Catchment Area Plan**

NAD83 UTM Zone 18 North

0 0.2 0.4 0.8 1.2 1.6

Kilometers

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**Legend**

Catchment Area

| | |
|---|---|
| Drawn by: SO | Scale (Horz.) 1:30,000 |
| Checked by: DG | |
| Engineer: DG | Map Date 10/19/22 |
| Project No. 20-5394 | Map File No. Figure 4 - 5394 |

### 2.3.2 Hydrologic Parameters

The headwaters for unnamed watercourse originate east of the Town of Verona and flow southerly through the Buffy Lake, Little John's Sister Lake, Little John Lake, Sigsworth Lake (Mink Lake) and Fourteen Island Lake before discharging to a tributary to Hardwood Creek. The unnamed watercourse drains from northeast to southwest and is generally flat, with an average main channel slope is less than 0.5%. The contributing areas are primarily woods, wetlands and farmland; however, they also include parts of some developed areas.

A summary of the catchment area parameters is provided in **Table 3,** and the detailed hydrologic parameters are provided in **Appendix B**. The catchment area plan is provided in **Figure 4.**

**Table 3 – Catchment Parameters**

| Catchment ID | Area (ha) | Length (m) | Slope (%) | Impervious (%) | CN*[(1)] | Initial Abstraction (mm) | Time to Peak[1] (hr.) |
|---|---|---|---|---|---|---|---|
| CA-1 | 1613.7 | 5,304.0 | 0.5 | 1.0 | 62.7 | 9.3 | 3.22 |
| [(1)] CN* = Modified Curve Number | | | | | | | |

## 2.4 Regional Frequency Analysis

Several regional frequency analysis methods have been developed to estimate peak flows for ungauged watercourses throughout Ontario. Three regional frequency analysis methods were considered for this project. The background, methodology and application of each method is described below.

**MTO Unified Ontario Flood Method**

The Unified Ontario Flood Method (UFM) has been developed through a research project with the University of Toronto to provide instantaneous flow rates for large catchment areas within Ontario. This method provides a new approach to calculating the design flow rates based on up-to-date stream flow and rainfall information from Water Survey of Canada (2014). This method is developed for watersheds in this region having areas in excess of 13.16 $km^2$. The applicability of this method is detailed in Errata Sheet to Chapter 8, MTO Drainage Management Manual (1997), Issued March 31, 2016.

**MTO Northern Ontario Method**

The methodology was developed for MTO Northern Ontario Method (NOM) to provide flow rates across un-gauged streams with small to medium watershed areas (1 km2 < Area < 100 km2) in northern Ontario. This method is based on flood quantities estimated using probabilistic and statistical methods with data from 15 stream gauge stations across northern Ontario. This method becomes less reliable for drainage areas within the Canadian Shield that have a lake/wetland to drainage area ratio of under 6%.

**MNR Index Flood Method**

The MNR Index Flood Method (IFM) was developed by the MNR to provide flow rates in catchments where a limited number of years of data were available. A total of 238 gauging stations were analyzed to determine homogeneous regions with common hydrologic characteristics. Twelve regions were identified and a frequency curve was developed for each. This method is recommended for medium to large watersheds (3960 $km^2$ > Area > 86.0 $km^2$).

The results of the regional frequency analyses are provided in **Table 4** and the detailed calculations are provided in **Appendix B**.

**Table 4 – Regional Frequency Analysis Results**

| Return Period (Year) | Peak Flows ($m^3/s$) | | |
|---|---|---|---|
| | MTO UFM | MTO NOM | MNR IFM |
| 2 | 3.1 | 1.6 | 3.6 |
| 5 | 4.1 | 2.0 | 4.4 |
| 10 | 5.8 | 2.3 | 5.1 |
| 25 | 7.3 | 2.5 | 5.9 |
| 50 | 8.6 | 2.7 | 6.6 |
| 100 | 9.7 | 2.9 | 7.3 |

## 2.5 Hydrologic Model

The hydrologic modelling software Visual Otthymo Version 6.2 (VO6.2) was used to model the watershed area contributing to Fourteen Island Lake upstream of the Fourteen Island Lake Dam using parameters as described in **Section 2.3.** The layout of the hydrologic model is included in **Appendix B**.

### 2.5.1 Synthetic Storm Distributions

Various storm distributions were tested within the VO6.2 model to add to the weight of evidence. The results of the hydrologic model are provided in **Table 5.**

**Table 5 – Initial Hydrologic Model Results for Fourteen Island Lake Dam**

| Design Storm | Probability | Peak Flows ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | 12hr AES(1) | 6hr SCS(2) | 12hr SCS | 24hr SCS |
| 2-year | 0.5 | 4.41 | 2.92 | 4.10 | 5.22 |
| 5-year | 0.2 | 7.93 | 5.63 | 7.59 | 9.81 |
| 10-year | 0.1 | 10.62 | 7.80 | 10.30 | 13.19 |
| 25-year | 0.04 | 14.38 | 10.78 | 14.07 | 17.56 |
| 50-year | 0.02 | 17.28 | 13.23 | 16.96 | 20.78 |
| 100-year | 0.01 | 20.69 | 15.81 | 20.52 | 24.93 |

(1) AES = Atmospheric Environment Service
(2) SCS = Soil Conservation Service

### 2.5.2 Fourteen Island Lake Reservoir Routing

The development of the watershed boundary, hydrologic parameters, and regional methods, as detailed in **Section 2.1** to **Section 2.5**, is generally completed with the understanding that there have been no alterations within the catchment that would result in a significant change to the runoff response during extreme rainfall events. In keeping with the above, the following key assumptions were made:

- The watershed generally reflects the average characteristics of watersheds in the region, such that Regional Frequency Analyses are applicable.
- The storage within the watershed is reflected by the hydrologic parameters, such as initial abstraction and SCS curve number, which accounts for natural attenuation of lakes and wetlands.

In cases where watersheds have experienced significant development (urbanization) or in cases with unnatural peak flow attenuation (dams / reservoirs), the above assumptions may not be valid.

The active stage-storage relationship for Fourteen Island Lake was developed using an area time depth method and the stage-discharge relationship for Fourteen Island Lake was developed based on hydraulic calculations completed using the weir flow equation. Using the stage as a common variable, the stage-storage-discharge relationship was compiled as shown in **Table 6.**

**Table 6 – Stage-Storage-Discharge Fourteen Island Lake**

| Elev. (m) | Storage Depth (m) | Peak Flow ($m^3/s$) | Storage Volume (ha*m) |
|---|---|---|---|
| 142.27 | 0.00 | 0.00 | 0 |
| 142.44 | 0.17 | 0.91 | 32 |
| 142.62 | 0.35 | 2.95 | 68 |
| 142.70 | 0.43 | 4.12 | 84 |
| 142.79 | 0.52 | 5.45 | 104 |

The storage-discharge relationship was included as a route reservoir command in the hydrologic model (Visual Otthymo, NHYD 1). The significant storage volume in the lake, relative to the size of the catchment, appears to significantly attenuate (reduce) the peak flows. The resulting peak flow summary is included in **Table 7.**

**Table 7 – Attenuated Hydrologic Model Results for Fourteen Island Dam**

| Design Storm | Probability | Peak Flows ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | 12hr AES(1) | 6hr SCS(2) | 12hr SCS | 24hr SCS |
| 2-year | 0.5 | 0.29 | 0.18 | 0.29 | 0.44 |
| 5-year | 0.2 | 0.53 | 0.34 | 0.53 | 0.79 |
| 10-year | 0.1 | 0.72 | 0.47 | 0.72 | 1.19 |
| 25-year | 0.04 | 1.03 | 0.65 | 1.03 | 1.80 |
| 50-year | 0.02 | 1.41 | 0.80 | 1.40 | 2.25 |
| 100-year | 0.01 | 1.84 | 0.99 | 1.85 | 2.83 |

(1) AES = Atmospheric Environment Service
(2) SCS = Soil Conservation Service

In keeping with **Section 2.6.1**, the 24-hour SCS storm duration appears to be the most appropriate distribution given the catchment size and time of concentration.

The stage-storage relationship shown in **Table 6** only represents water stored above the crest of the dam. It is assumed that the elevation of the lake is level with the crest of the dam at the beginning of the storm. The dam breach analyses described in **Section 3.4** include more storage than that shown in **Table 6** because in the dam breach analyses, the storage between the crest of the weir and the bottom of the breach become relevant to the analysis (i.e. a wave of water is released downstream).

## 2.6 Peak Discharge Summary and Selection

As discussed in **Section 2.1,** given the range of different methods available to apply to the hydrologic assessment, a weight of evidence approach was taken. The various methodologies have been laid out above and this section discusses the final selections for application to the hydraulic model.

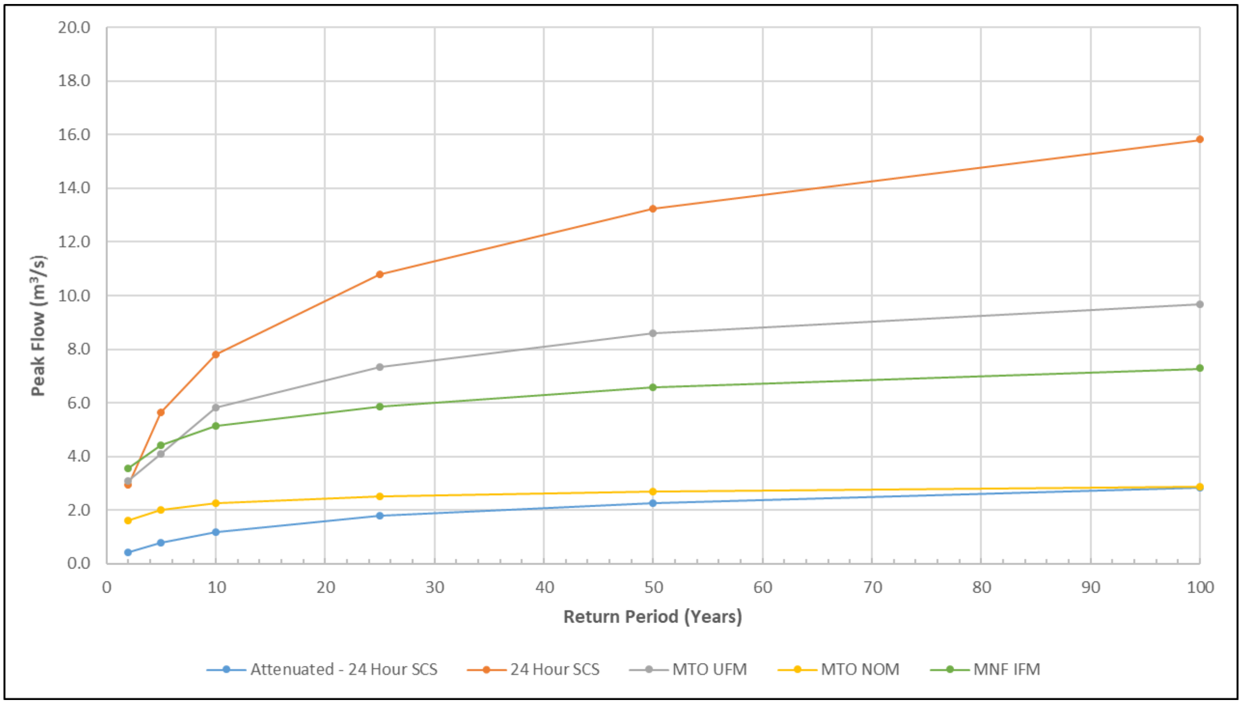
### 2.6.1 Sunny Day Flow

The sunny day flow was estimated as 0.22 $m^3/s$. No flow data was available for review; therefore, the sunny day flow was estimated to be half of the 2-Year peak flow. While this sunny day flow may be indicative of the base flow in the river, a detailed baseflow separation was not conducted as part of this study. This value will only be used to provide a base flow within the HEC-RAS model during the sunny day dam breach scenario to ensure a stable model run.

### 2.6.2 2-Year to 100-Year Return Period Peak Flows

The methodologies utilized to estimate the 2-year to 100-year return period peak flows included regional frequency analysis and hydrologic modelling. The results from the hydrologic model (24-hour SCS) produced peak flows that were relatively consistent with the regional frequency analysis results and were used as the basis for the peak flows for the 2-year to 100-year peak flows. In a post-calibration process, the peak flows were modelled with consideration to the significant attenuation which occurs within Fourteen Island Lake. **Figure 5** shows a plot comparing the different methods used to estimate the 2-year to 100-year peak flows. The selected peak flows are included in **Table 8**.

**Figure 5 – 2-Year to 100-Year Peak Flow Comparison**




## 2.7 Summary of Selected Peak Flows

The summary of selected peak flows is provided in **Table 8.** These peak flows will be utilized when completing the hydraulic model as well as the Hazard Potential Classification (HPC), and Inflow Design Flood (IDF) selection.

**Table 8 – Summary of Selected Peak Flows**

| Flood Event | Peak Flow ($m^3/s$) | Methodology |
|---|---|---|
| Sunny Day | 0.22 | Assumed |
| 2-Year | 0.44 | Hydrologic Model 24-hour SCS |
| 5-Year | 0.79 | Hydrologic Model 24-hour SCS |
| 10-Year | 1.19 | Hydrologic Model 24-hour SCS |
| 25-Year | 1.80 | Hydrologic Model 24-hour SCS |
| 50-Year | 2.25 | Hydrologic Model 24-hour SCS |
| 100-Year | 2.83 | Hydrologic Model 24-hour SCS |

# 3.0 Hydraulic Assessment

## 3.1 Introduction

A simplified approach to the dam breach assessment was undertaken in order to gain a general understanding of the expected Hazard Potential Classification (HPC) and subsequently the Inflow Design Flood (IDF) of the dam. The dam breach assessment uses the flows presented in **Section 2.8** and a HEC-RAS model run under steady flow conditions to evaluate a number of different dam failure scenarios (sunny day and a range of flood scenarios). The results of the hydraulic modelling are used to estimate the potential incremental losses that would result from a dam failure.

## 3.2 Available Data

### 3.2.1 Topographic Data

The primary source of topographic data for this project was the Ontario Digital Elevation Model (DEM) (Imagery Derived) that was obtained from the MNRF through Ontario GeoHub. The Ontario DEM (Imagery Derived) is 2-m raster elevation product that provides a generalized representation of both surface and ground features based on a pixel-autocorrelation process using aerial photography. The User Guide, Ontario Digital Elevation Model (Imagery Derived) (MNRF, 2022), identifies the coordinate reference systems used as:

- The horizontal coordinate system of the Ontario Digital Elevation Model (Imagery Derived) is Universal Transverse Mercator (UTM), Zone 18 North. The horizontal datum of the product is the North American Datum of 1983 Canadian Spatial Reference System epoch 2010 (NAD83 (CSRS)). The horizontal unit of measure (coordinate system axis units) for all raster grid cells is meters (m).
- The vertical coordinate system of the study area is CGVD28. The vertical unit of measure (coordinate system axis units) for all raster grid cells in the products is meters (m). One single vertical elevation value represents each raster grid cell in the DEM. For more information on Canadian vertical datums see the Height Reference System Modernization of Natural Resources Canada (https://www.nrcan.gc.ca/height-reference-system-modernization/9054#_Canadian_ Geodetic_Vertical_1).

With the aid of GIS software, the DEM was used to create the overbank portions of cross-sections for input into the hydraulic model.

### 3.2.2 Structural Drawings

The general arrangement drawing prepared by Wills using the collected topographic survey data was used as the basis for the dam geometry and dimensions for the Fourteen Island Lake Dam.

## 3.3 Hydraulic Model Development

GeoHEC-RAS was used to model the Fourteen Island Lake Dam and perform the hydraulic analysis of the river system. GeoHEC-RAS is a proprietary software program developed by CivilGEO Engineering Software that integrates the one dimensional HEC-RAS Version 5.07 hydraulic model, developed by the U.S. Army Corps of Engineers, Arc-GIS and AutoCAD Civil 3D.

The model was created using multiple reaches to represent the watercourse from the Fourteen Island Lake Dam to Verona Lake. The geometry and flow files are based on the following:

**Cross-Section Data**

The model cross sections were defined based on the described DEM.

**Manning's Roughness**

Manning's roughness ("n") coefficients for the channel were estimated from field inspection and literature review. The selected Manning's roughness values are indicative of a clean, winding river with some weeds, pools and stones for the main channel and medium to dense brush in summer for floodplain areas. Manning's roughness ("n") coefficients for the overbanks were assigned based on the OLCC data. A Manning's roughness value was chosen to correspond with each of the units in that database based on the reference material for OLCC and GeoHEC-RAS.

**Boundary Conditions**

When using a subcritical flow regime, GeoHEC-RAS requires downstream boundary conditions. The boundary conditions can be based on critical depth, normal depth, a rating curve, or a known hydraulic control. In this case, the downstream boundary condition is based on normal depth.

**Downstream Bridges/Culverts**

The culverts in the downstream area were modelled based on aerial imagery and GIS measurements. The DEM data was used to define the roadway sections. In total, one roadway culvert was identified downstream of the dam at Hinchinbrooke Road.

**Peak Flows**

The peak flows used in the analysis are those that are discussed and outlined in **Section 2.7**, resulting from the hydrologic assessment.

## 3.4 Simplified Dam Breach Assessment

The simplified dam breach assessment was completed using the steady flow GeoHEC-RAS model with the purpose of attaining a high level understanding of the potential incremental effects resulting from a dam breach during the Sunny Day and Flood dam breach scenarios. Once the potential incremental effects are understood, the Hazard Potential Classification (HPC) and Inflow Design Flood (IDF) can be selected. Typically, if the HPC were Moderate, High or Very High, a detailed dam breach study using an unsteady flow HEC-RAS model would be recommended in order to provide a detailed understanding of the impacts of the dam breach and corresponding incremental losses.

### 3.4.1 Dam Breach Parameters

When undertaking a simplified dam breach analysis, the key dam breach parameters to be considered are the breach bottom elevation, breach bottom width and incremental flow resulting from the dam breach.

The selection of the breach bottom elevation is typically based on the natural ground elevation at the dam. Using Wills' 2020 survey data, Wills has assumed a normal operating water level of 142.27 m and a breach bottom elevation of 140.38 m. These elevations represent the summer water level and the approximate natural ground at the base of the dam, respectively. This study assumes that all stoplogs are installed during all failure scenarios.

There are multiple methodologies available for estimating the dam breach bottom width and peak flow rate. The key inputs include the reservoir volume at the time of breach, the height of the breach and the breach bottom elevation. Wills prepared a Microsoft Excel spreadsheet to estimate the dam breach parameters. The breach bottom width was calculated based on the OPG method for assessing breach bottom width for concrete gravity structures and dam breach peak flow rates were calculated using the US Army Corps of Engineers (USACE, 1997) methodology. The estimated dam breach parameters are included in **Table 9** and the dam breach estimates are included in **Appendix C**. It is noted that the sunny day failure represents a failure of just the stoplogs whereas the flood failure represents the sliding or overturning of the entire dam structure.

**Table 9 – Dam Breach Parameters**

| Failure Scenario | Estimated Breach Bottom Width (m) | Dam Breach Incremental Flow ($m^3/s$) |
|---|---|---|
| Sunny Day | 0.9 | 2.4 |
| 25-Year | 7.2 | 23.1 |
| 50-Year | 7.2 | 24.1 |
| 100-Year | 7.2 | 25.6 |

### 3.4.2 Dam Breach Results

As described previously, the steady flow GeoHEC-RAS model was used to complete the simplified dam beach analysis. A summary of the flows, incremental flows and depths due to the dam breach for all scenarios is provided in **Table 10**. The detailed model results are included in **Appendix C.**

**Table 10 – Summary of Model Results**

| Flood Event | Dam Condition | Peak Flow Rate ($m^3/s$) | Max. Incremental Flow ($m^3/s$) | Max. Incremental Depth (m) |
|---|---|---|---|---|
| Sunny Day | No Failure | 0.22 | 2.18 | 0.49 |
| | Dam Failure | 2.40 | | |
| 25-Year | No Failure | 1.80 | 21.30 | 0.49 |
| | Dam Failure | 23.10 | | |
| 50-Year | No Failure | 2.25 | 21.85 | 1.31 |
| | Dam Failure | 24.10 | | |
| 100-Year | No Failure | 2.83 | 22.77 | 1.37 |
| | Dam Failure | 25.60 | | |

## 3.5 Hazard Potential Classification and Inflow Design Flood

### 3.5.1 Hazard Potential Classification

The Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011), outlines the requirements for the classification of dams. In Ontario, dams are classified using the Hazard Potential Classification (HPC) system, which categorizes dams according to the potential hazards presented by the dam. The HPC is an assessment of the consequences of dam failure, not the risk of dam failure, based on its current condition. The HPC is determined through an assessment of the greatest incremental losses that could result from an uncontrolled release of the reservoir due to the failure of a dam. Potential incremental losses are assessed with respect to life, property, the environment and cultural-built heritage sites at the dam site, upstream and downstream. **Table 11** outlines the four (4) classification categories and describes how the potential incremental losses are assessed for each potential hazard. Dams are classified according to the highest potential incremental hazard. Incremental losses refer to losses from a dam failure that are above and beyond those which may be expected to occur under the same natural conditions with the dam in place but without failure of the dam.

Dams require two (2) HPCs, one based on dam failure during normal (sunny day) conditions and a second based on dam failure under flood conditions. To determine the HPC for the normal (sunny day) and flood scenarios, the GeoHEC-RAS model results were reviewed.

**Table 11 – Hazard Potential Classification**

| Hazard Potential | Life Safety[2] | Property Losses | Environmental Losses | Cultural-Built Heritage Losses[3] |
|---|---|---|---|---|
| **Low** | No expected loss of life | Very low damage to property < $300,000 | Minimal loss of habitat with high capability of restoration | Reversible damage to municipally designated cultural heritage sites |
| **Moderate** | No expected loss of life | Moderate damage < $3 million | Moderate loss of habitat with moderate capability of restoration | Irreversible damage to municipally designated cultural heritage sites |
| **High** | Expected loss of life 1-10 persons | Appreciable damage < $30 million | Appreciable loss of habitat - reversible damage to habitat | Irreversible damage to provincially or nationally designated cultural heritage sites |
| **Very High** | Expected loss of life 11 or more persons | Extensive damage > $30 million | Extensive loss of habitat with no feasibility of recovery | |

Note: 1. Abbreviated Table 1 - Hazard Potential Classification (Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011).
2. Life Safety is assessed using the "2 by 2 Rule" as outlined in the Technical Guide River and Stream Systems: Flooding Hazard Limit. For dam failures under flood conditions, the potential for loss of life is assessed based on permanent dwellings (including habitable buildings and trailer parks) only. For dam failures under normal (sunny day) conditions, the potential for loss of life is assessed based on both permanent dwellings (including habitable buildings, trailer parks and seasonal campgrounds) and transient persons.
3. Cultural-Built Heritage Losses are assessed with respect to sites designated under the Ontario Heritage Act or nationally recognized heritage sites.

### 3.5.2 Sunny Day Failure

During a sunny day dam failure, the water level of the lake will be at approximately the top of the stoplogs, meaning that there is a significant amount of storage within the lake. A failure of the stoplogs under this scenario would result in a flood wave peak of approximately 2.40 $m^3/s$, which is an increment of 2.18 $m^3/s$ over the non-breach peak flow.

**Life Safety Assessment**

In the case of the sunny day dam failure, the incremental water level due to the dam failure is expected to be outside of the main channel of the watercourse; however, the overbank velocities are expected to be low, resulting in limited potential for incremental loss of life.

**Property Losses**

In the case of the sunny day dam failure, there is incremental inundation of some structures; however, the incremental property losses are expected to be less than $300,000.

**Environmental Losses**

In the case of the sunny day dam failure, Fourteen Island Lake will almost completely drain, resulting in a moderate temporary loss of aquatic habitat. It is understood that once the dam is re-built, the aquatic habitat within the lake could be restored. Downstream of the dam, the incremental water level due to the dam failure is not expected to cause any significant incremental environmental losses.

**Cultural / Built Heritage Losses**

In the case of the sunny day dam failure, the incremental water level due to the dam failure is not expected to have any measurable effect on cultural or built heritage resources.

**Based on the above assessment, the HPC for the sunny day dam breach scenario is assessed as being Low.**

### 3.5.3 Flood Failure

During a dam failure in a flood scenario (i.e. 25-year, 50-year, and 100-year), Fourteen Island Lake is expected to be at full flood stage; therefore, the failure of the overflow weir will result in a wave of water being released downstream, which could result in incremental losses within the overbank areas.

**Life Safety Assessment**

In the case of the dam failure during the flood scenario, the water level is expected to be outside of the main channel; however, the overbank velocities are expected to be low in areas where people may be present. Therefore, it is anticipated that there is low potential for incremental loss of life as a result of a dam failure during a flood scenario.

**Property Losses**

In all cases of flood failure, there is incremental inundation of some structures; however, the incremental property losses are expected to be less than $300,000.

In addition, in all cases of flood failure, it is expected that the dam break flows will overtop Hinchinbrooke Road, which would likely result in incremental damage to the culvert/roadway.

**Environmental Losses**

In all cases of flood failure, Fourteen Island Lake will almost completely drain, resulting in a moderate temporary loss of aquatic habitat. It is understood that once the dam is re-built, the aquatic habitat within the Lake could be restored. Downstream of the dam, the incremental water level due to the dam failure is not expected to cause any significant incremental environmental losses.

**Cultural / Built Heritage Losses**

In the case of the flood failure scenarios, the incremental water level due to the dam failure is not expected to have any measurable effect on cultural or built heritage resources.

**Based on the above assessment, the HPC for flood dam breach scenario is assessed as being Low.**

### 3.5.4 Inflow Design Flood

The Inflow Design Flood (IDF) is the most severe inflow flood for which a dam and its associated facilities are designed. Two methods can be used to determine the IDF. The IDF is typically selected using Table 2 in the Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011); however, the Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011) also makes allowance for the use of an incremental analysis for cases where the dam owner wishes to explore the possibility of selecting a lower magnitude IDF. The incremental analysis is discussed in more detail in the Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011); however, Wills' does not believe it would provide a benefit in this case.

**Table 12 – Range of Minimum Inflow Design Floods[1]**

<table>
<tr><th rowspan="2">Hazard Potential</th><th colspan="4">Range of Minimum Inflow Design Floods</th></tr>
<tr><th colspan="2">Life Safety</th><th>Property and Environment</th><th>Cultural-Built Heritage</th></tr>
<tr><td>Low</td><td colspan="4">25-year flood to 100-year flood</td></tr>
<tr><td>Moderate</td><td colspan="4">100-year flood to 1000-year flood or Regulatory flood (whichever is greater)</td></tr>
<tr><td>High</td><td>1-10</td><td>1/3 between the 1000-year flood and the PMF.</td><td>1000-year flood or Regulatory flood (whichever is greater) to 1/3 between the 1000-year flood and PMF.</td><td>1000-year flood or Regulatory flood (whichever is greater).</td></tr>
<tr><td rowspan="2">Very High</td><td>11-100</td><td>2/3 between the 1000-year flood and the PMF.</td><td rowspan="2">1/3 between the 1000-year flood and PMF to PMF.</td><td rowspan="2"></td></tr>
<tr><td>Greater than 100</td><td>PMF</td></tr>
</table>

Note: 1. Abbreviated Table 2 - Range of Minimum Inflow Design Floods (Technical Bulletin for Classification and Inflow Design Flood Criteria (MNR, 2011).

**Table 8** outlines the peak flows estimated for Unnamed Creek at the Fourteen Island Lake Dam and **Table 12** outlines the range of minimum Inflow Design Floods for the various HPCs. With reference to **Table 8**, and given the Low HPC for the flood scenario, the IDF should be selected as a value between the 25-year flood and the 100-year flood.

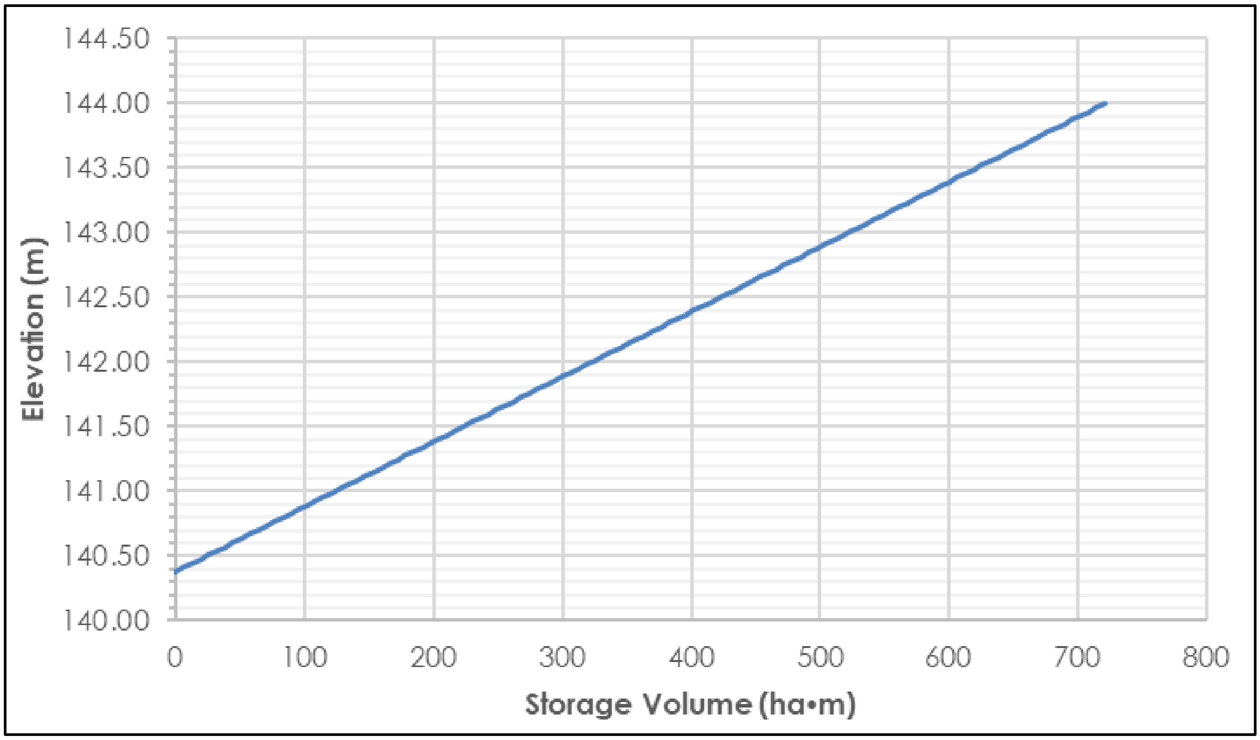
**The peak flow of 2.83 m$^3$/s, 100-year flood, was selected as the IDF peak flow.**

## 3.6 Spillway Capacity and Freeboard Assessment

### 3.6.1 Stage-Storage Curve

The stage-storage curve for the reservoir is based on the area of the reservoir times the depth of water above the base of the overflow weir (140.38 m). The stage-storage relationship for the dam is provided in **Figure 6**.

**Figure 6 – Stage-Storage Curve**



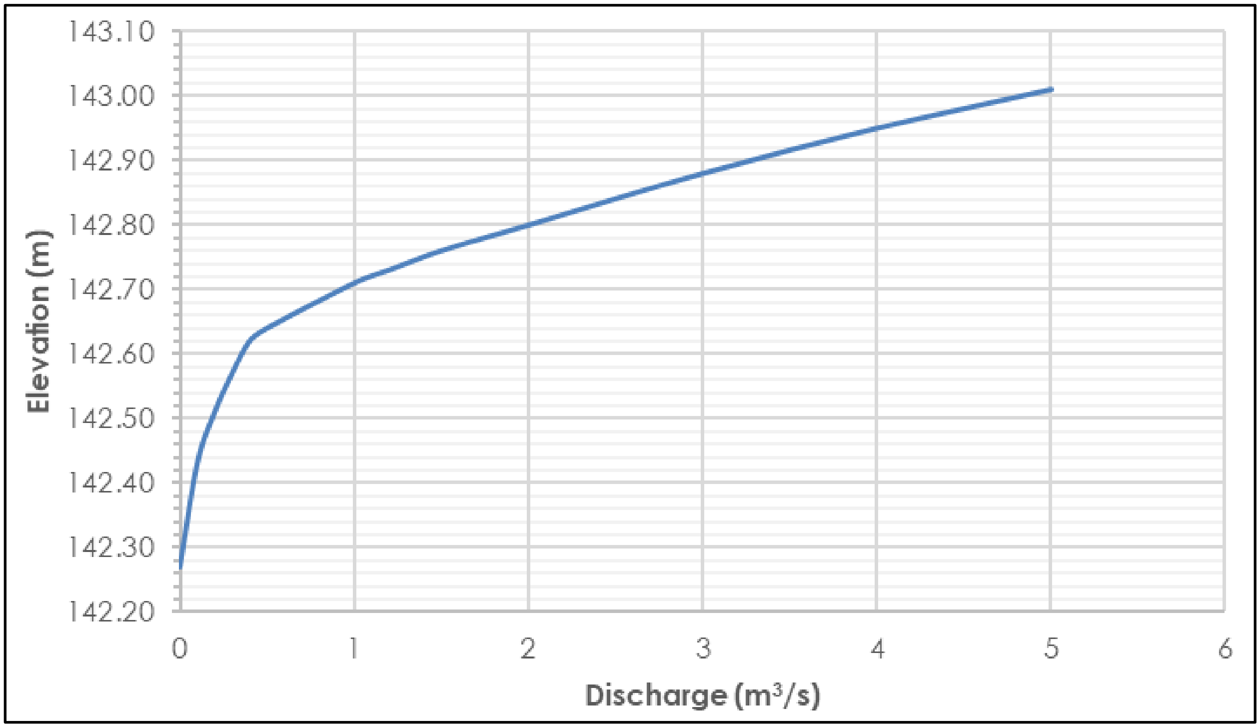

### 3.6.2 Discharge Capacity

The discharge facilities at the dam consist of the following:

- One 0.85 m wide stoplog sluiceway with a sill elevation of 142.27 m.
- An overflow weir with a 4.65 m long section on one side of the stoplog sluiceway and a 3.60 m long section on the other side of the stoplog sluiceway. The crest elevation of the overflow weir is 142.60 m.

The stage-discharge curve was developed using the results of a hydraulic model. **Figure 7** shows the stage-discharge curve. The estimated water surface elevation during the IDF (2.83 m$^3$/s) is 142.87 m, which is 0.27 m above the crest of the weir. Therefore, the existing dam configuration provides sufficient capacity to convey the IDF.

**Figure 7 – Stage-Discharge Curve for Overflow Spillway**




# 4.0 Structural Stability Assessment

## 4.1 Introduction

The structural stability assessment was completed in accordance with the Technical Bulletin for Structural Design and Factors of Safety (MNR, 2011). The purpose of the structural stability assessment was to assess the stability of the concrete gravity dam section with respect to sliding, overturning and overstressing of the concrete dam or foundation.

The structural stability assessment was completed for one (1) typical section, the overflow weir. The typical cross-section was selected based on the topographic survey that was previously completed by Wills.

The methodology and the results of the structural stability assessment are presented herein, and the detailed calculations are provided in **Appendix E**.

## 4.2 Methodology

The analysis was based on a rigid body limit equilibrium method with the various load combinations treated as static because of the relatively sustained nature of the loads involved. The following loads were considered in the assessment of the concrete structures:

- Dead loads of permanent structures, rock or soil backfill, silt deposited against the structure and any significant equipment loads.
- Hydrostatic loads, including the normal summer, normal winter and IDF headwater levels, with corresponding tailwater levels.
- Internal water pressure and foundation uplift.
- Ice load.
- Earthquake load.

Seismic analyses are performed at different levels of sophistication. Since there is low earthquake potential in central Ontario, a pseudo-static method of analysis was used to assess the earthquake loading on the concrete gravity dam sections.

The position of the resultant force, the normal stresses at the heel and toe and the calculated sliding and overturning factors were reviewed and compared to the requirements of the Technical Bulletin for Structural Design and Factors of Safety (MNR, 2011).

In accordance with the Technical Bulletin for Structural Design and Factors of Safety (MNR, 2011), the following loading combinations were considered:

1. Usual Load (Summer) includes the following loads acting in combination: Dead load; Hydrostatic Load (maximum normal operating level); Soil Load; and Uplift.
2. Usual Load (Winter) includes the following loads acting in combination: Dead load; Hydrostatic Load (winter operating level); Ice Load; Soil Load; and Uplift.
3. Unusual Load (Flood) includes the following loads acting in combination: Dead Load; Hydrostatic Load (IDF flood level); Soil Load; and Uplift Load.
4. Earthquake loading includes the following loads acting in combination; Maximum Design Earthquake, Dead loads, Hydrostatic Load (maximum normal operating level); Soil Load; and Uplift.

## 4.3 Loading Data

Wills determined the loading data to be used in the analysis based on the identified loading combinations and the existing information. The loading data is summarized in **Table 13**.

**Table 13 – Loading Data**

| Loading Case | Water Level (m) | | Ice Load (kN/m) | Seismic Coefficient (%g) |
|---|---|---|---|---|
| | Headwater | Tailwater | | |
| 1. Usual Load (Summer) | 142.27 | 140.86 | 0 | - |
| 2. Usual Load (Winter) | 142.27 | 140.86 | 75 | - |
| 3. Unusual Load (Flood) | 142.87 | 140.86 | 0 | - |
| 4. Extreme Load (Earthquake) | 142.27 | 140.86 | 0 | 4.0 |

## 4.4 Results

As described in **Section 4.1**, the stability analysis was completed for one (1) typical section, the overflow weir. The results of the structural stability assessment are summarized in **Table 14** and the detailed calculations and results are provided in **Appendix E**.

The typical weir section meets the minimum factors of safety for all loading conditions, with the exception of the winter loading condition. The factors of safety for the Usual Winter (sliding and overturning) are below the 1.0. This indicates that the dam would be expected to fail if the anticipated ice loads were applied. While a factor of safety of less than 1.0 for the winter loading condition is concerning, the dam hasn't failed or shown signs of stress due to ice loading since its construction. This may be because the dam has not experienced the ice loading conditions specified in the Technical Bulletin for Structural Design and Factors of Safety (MNR, 2011) or because there are other forces acting on the dam (i.e. friction to the adjoining bedrock) that help resist the ice loading forces. The FIMLA has indicated the small bay upstream of the dam is sheltered and has either thin ice or no ice due to the concentration of the flow of water at the dam.

**Table 14 – Structural Stability Assessment Results**

| Loading Case | FOS Sliding | | FOS Overturning | | Position of Resultant from Toe (m) | Location of Resultant | Foundation Bearing Stress at Toe (kPa) | |
|---|---|---|---|---|---|---|---|---|
| | Required | Computed | Required | Computed | | | Allowable | Computed |
| 1. Usual Load (Summer) | 1.5 | 2.3 | 1.5 | 2.2 | 1.32 | Inside Middle Third | 500 | 42 |
| 2. Usual Load (Winter) | 1.5 | **0.5** | 1.5 | **1.0** | -0.11 | **Outside Middle Third** | 500 | 114 |
| 3. Unusual Load (Flood) | 1.3 | 1.4 | 1.3 | 2.2 | 1.39 | Inside Middle Third | 500 | 37 |
| 4. Extreme Load (Earthquake) | 1.1 | 1.8 | 1.1 | 2.0 | 1.25 | Inside Middle Third | 500 | 44 |

FOS = Factor of Safety

# 5.0 Conclusions

This section summarizes and concludes the findings of the Scoped Dam Safety Assessment for the Fourteen Island Lake Dam.

## 5.1 Hydrotechnical

- The sunny day peak flow for the Fourteen Island Lake Dam was assumed to be 0.22 $m^3/s$.
- The 100-year flood peak flow for the Fourteen Island Lake Dam was estimated as 2.83 $m^3/s$, as determined by the hydrologic model.
- The Fourteen Island Lake Dam is classified as a Low hazard dam for normal (sunny day) dam breach scenario.
- The Fourteen Island Lake Dam is classified as a Low hazard dam for the flood dam breach scenario.
- The Inflow Design Flood (IDF) for the Fourteen Island Lake Dam is 2.83 $m^3/s$, which is the 100-year flood.
- The headwater elevation for the IDF (2.83 $m^3/s$) is 142.87 m.
- The existing discharge facilities have sufficient capacity to convey the IDF.

## 5.2 Civil / Structural

- The results of the structural stability assessment indicate that the dam meets the required factors of safety for the Summer, Flood and Earthquake loading conditions but not for the Winter loading condition. The factors of safety for the Usual Winter (sliding and overturning) are below 1.0; however, the dam hasn't failed or shown signs of stress due to ice loading since its construction. This may be because the dam has not experienced the ice loading conditions specified in the Technical Bulletin for Structural Design and Factors of Safety (MNR, 2011) or because there are other forces acting on the dam (i.e. friction to the adjoining bedrock) that help resist the ice loading forces. The FIMLA has indicated the small bay upstream of the dam is sheltered and has either thin ice or no ice due to the concentration of the flow of water at the dam.

# 6.0 Recommendations

Based on the results of the Scoped Dam Safety Assessment, it is recommended that the Fourteen Island and Mink Lakes Watershed Association move forward with the rehabilitation of the Fourteen Island Lake Dam as outlined in Wills' November 2020 dam inspection report. Subject to MNRF approval, modifications to the dam to improve the factor of safety for the winter loading condition are not recommended at this time and instead a monitoring and inspection program should be implemented.

# 7.0 Closure

We appreciate the opportunity to provide Professional Engineering Services to the Fourteen Island and Mink Lakes Watershed Association. Should you have any questions regarding any of the material contained herein, please do not hesitate to contact the undersigned.

Respectfully submitted,



David Green, P.Eng.
Assistant Manager,
Water Resources Engineering

Sarah Ormel, P.Eng.
Water Resources Engineer

DG/SO

# Appendix A

## Site Inspection

November 11, 2020 **Inspection Date**

Fourteen Island and Mink Lakes Watershed Association
P.O. Box 105
Hartington, ON
K0H 1W0

***Attention: Mary Rae, Director and President***

Dear Ms. Rae:

**Re: FIMLWA Dam Inspection**
**D.M. Wills Associates Project No. 5394**

D.M. Wills Associates ("Wills") was retained to complete a structural inspection of the concrete gravity dam located at the outlet (tributary to Hardwood Creek and the Napanee River) of Fourteen Island Lake in the Township of South Frontenac. The inspection was completed by Mr. David Bonsall, P.Eng. on November 11, 2020.

A Photo Report is attached to this letter for reference.

A General Arrangement Drawing has also been prepared and is attached to this letter for reference.

The dam appears to be of rock core construction with a concrete "skin"; refer to Photo #1 and #2 for illustration of the downstream face of the dam (west and east "sides", respectively). The downstream face was sounded with a hammer and all concrete was in good condition with no delaminations or loose concrete.

The top surface of the dam, refer to Photo#3 and #4, is "L" shaped and is set into/against solid bedrock on each bank. No significant leakage was noted along the dam/rock interfaces. Significant deterioration was noted in the upstream half of the deck top in each "side" of the dam; refer to Photo #5 & #6. It appears that the dam may have been refaced in the past as there is a distinct formed line approx. 200mm (8") back from the upstream edge of the dam top. The line is now an open crack (line) that defines the upstream face from the deck top. The deck top against this line is in poor condition.

The upstream face of the dam is mostly submerged and could not be inspected. The upper portion of the face (above the water line) is in fair to good condition, with several large vertical cracks. These cracks would allow water to penetrate into the core of the dam; however there was no obvious sign of water flowing through the dam structure. The cracks can be seen in Photos #5 and #6.

There are steel angles set into the concrete to form the operable gains for the dam; refer to Photos #7 and #8. The steel angles are in generally good condition; however the anchorage into the east portion of the dam is questionable. The concrete along the east side of the sluice (adjacent to and downstream of the gain) is in very poor condition. While no water was observed flowing from the core at the time of inspection, it is clear that water may build up in this area as ice in the winter and could cause significant damage.

Water depth in the upstream lake is controlled by timber boards contained within the gains. The timbers can be seen in Photo #1. The upstream sediment levels are very high and a large pile of debris (stick, branches, etc.) has been cast to the downstream, east side of the dam. Dam operations and future inspections would significantly benefit from removal of sediment and debris.

Based upon the inspection, it is recommended that the dam be rehabilitated in the near future to include:

- Crack Injection (Repair) and Refacing of the Upstream Face;
- Removal and Replacement of the Top Slab;
- Removal and Replacement of the Gains and Sluice Walls;
- Installation of Drains in the Downstream Face.

Completion of the above noted work will significantly increase the service life of the dam. It is estimated that without rehabilitation, the dam may exhibit failure (loss of concrete and unwanted leakage/spill) within 5 years. Rehabilitation would increase the life of the dam by 15 to 20 years.

Please note that global stability and dam safety review should be completed prior to any rehabilitation design or construction. This Inspection Report may be used to document condition at the time of inspection, but should not be used to imply or conclude dam safety in terms of water control and/or overall dam failure.

Based upon the dam inspection, current access and provisions for cofferdams, we have estimated construction costs to be $141,000 plus HST for the necessary rehabilitation needs of the dam. This work should be planned for completion within 5 years, as the current condition of the dam will present operational concerns if rehabilitation measures are not completed. A Cost estimate breakdown is attached.

The above noted information is provided based upon visual inspection and access available on November 11, 2020.

We trust this letter is adequate for your interim use and discussions. Should you require anything further, please contact the undersigned.

David Bonsall, P.Eng.
*Manager, Structural Engineering*

LICENSED PROFESSIONAL ENGINEER
D. S. BONSALL
24-Dec-2020
PROVINCE OF ONTARIO

**PHOTO#1 – Downstream Face (West Half)**

**PHOTO#2 – Downstream Face (East Half)**

**PHOTO#3 – Top of Dam (looking East)**

**PHOTO#4 – Top of Dam (looking West)**

**PHOTO#5 – Deck Top**

**PHOTO#6 – Deck Top**

**PHOTO#7 – East Gain**

**PHOTO#8 – West Gain**

## Attachment - Preliminary Cost Estimate

**December 2020**

| Item No. | Description | Unit | Quantity | Est. Unit Price | Extension |
|---|---|---|---|---|---|
| 1 | Environmental / Watercourse Protection | Lump Sum | 1 | $2,500 | $2,500 |
| 2 | Access Improvements (Clearing, Grubbing, Road Const.) | Lump Sum | 1 | $10,000 | $10,000 |
| 3 | Cofferdam / Dewatering (AquaDam, Pumps, Flow Bypass) | Lump Sum | 1 | $30,000 | $30,000 |
| | Sediment / Debris Removals | Lump Sum | 1 | $30,000 | $30,000 |
| 4 | Concrete Removals | Lump Sum | 1 | $10,000 | $10,000 |
| 5 | New Concrete (Refacing - Upstream and Deck Top) | Lump Sum | 1 | $20,000 | $20,000 |
| 6 | New Gains (Concrete & Steel Forming) | Lump Sum | 1 | $5,000 | $5,000 |
| 7 | Dam Safety Features (Signs, Railing, etc.) | Lump Sum | 1 | $5,000 | $5,000 |
| 8 | Site Cleanup / Demobalization | Lump Sum | 1 | $5,000 | $5,000 |
| | | | **Sub-Total** | | $117,500 |
| | | Contingency (20%) | | | $23,500 |
| | | **TOTAL ESTIMATED COST** | | | **$141,000** |

**METRIC**
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

# TOWNSHIP OF SOUTH FRONTENAC

FOURTEEN ISLAND LAKE DAM

EXISTING GENERAL ARRANGEMENT

SHEET SK–01


D.M. Wills Associates Limited
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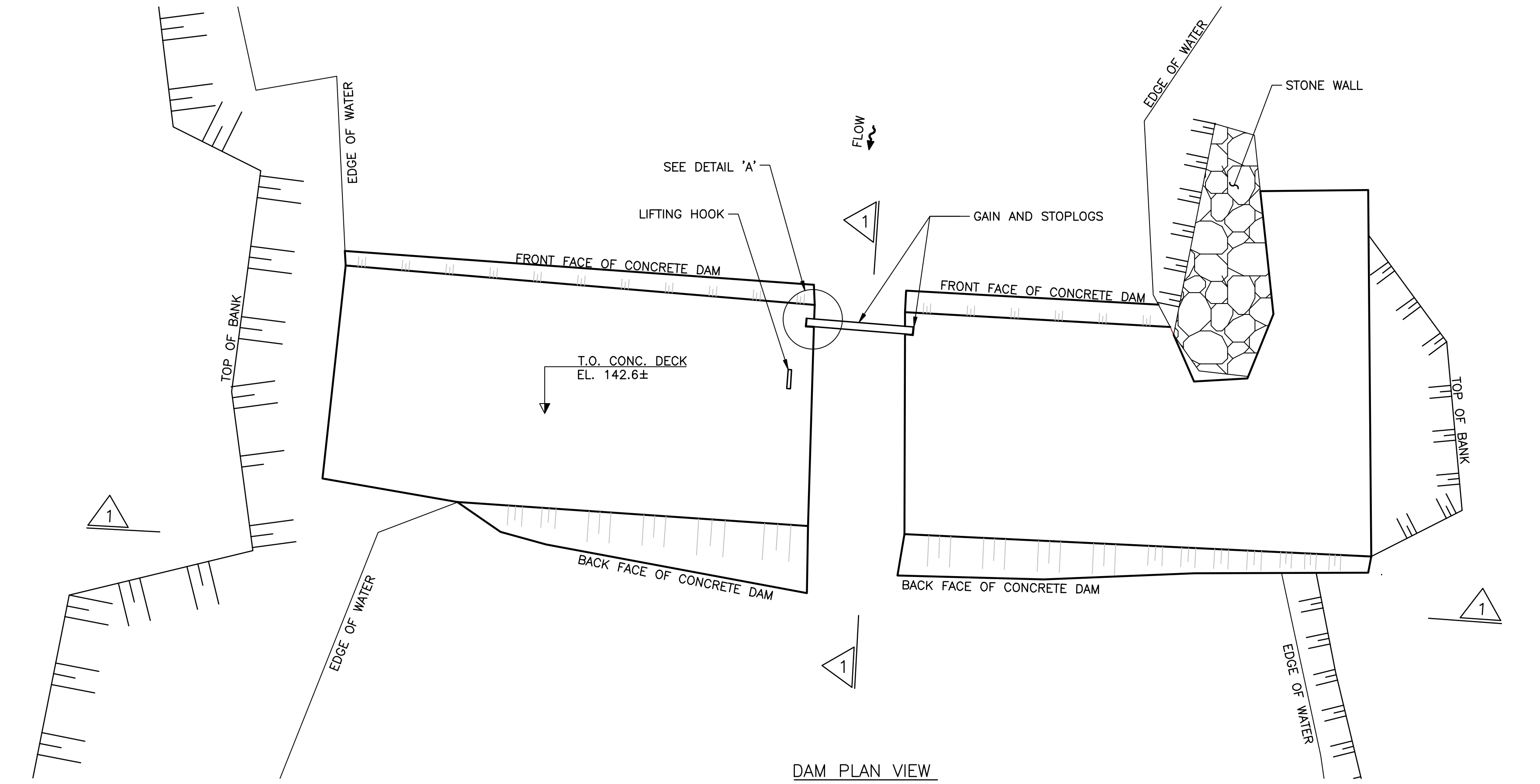
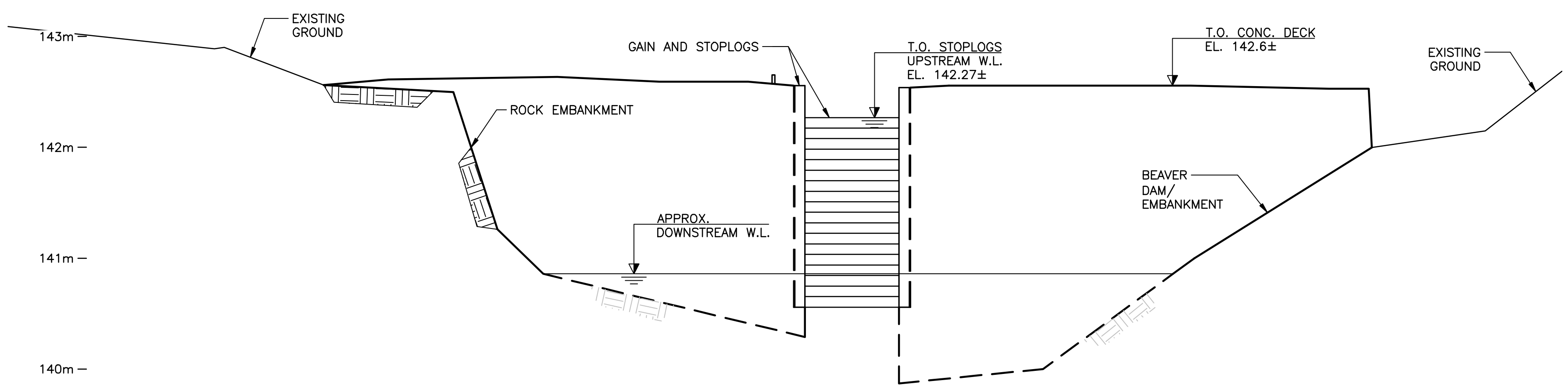
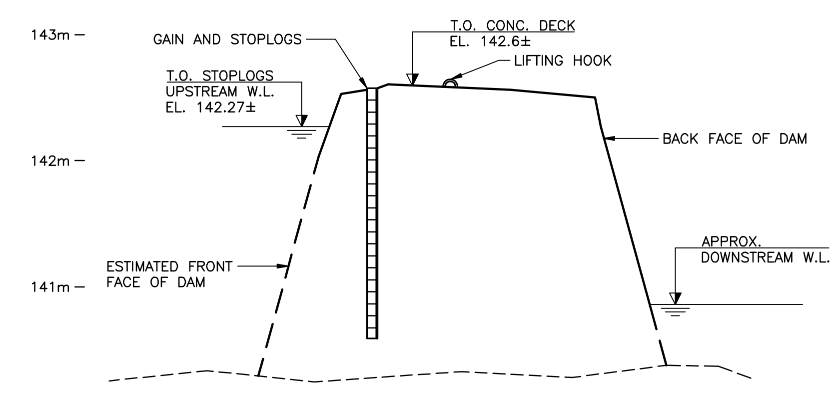
F. 705.748.9944
E. wills@dmwills.com

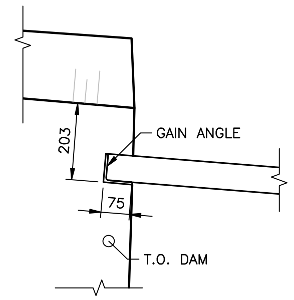

DAM PLAN VIEW
SCALE 1:30




1 DAM ELEVATION VIEW
SCALE 1:30




1 DAM SECTION VIEW
SCALE 1:30




A TYPICAL DETAIL AT GAIN
SCALE 1:10

| REVISIONS | | |
|---|---|---|
| DATE | BY | DESCRIPTION |

| DESIGN | DSB | CHK | | DATE | DEC 2020 |
|---|---|---|---|---|---|
| DRAWN | AO | CHK | | DWG | SK–01 |

2019-11
ANSI-B
D.M. WILLS ASSOCIATES LIMITED

FILE NAME: U:\5300-5399\5394 - FIMLA 14 Island Lake Dam\02 Drawings\Current Drawings\5394 - 14 Island Lake Dam - GA Sketch.dwg
CREATED: 2020-12-08 MODIFIED: 2020-12-08 15:55

# Appendix B

## Hydrologic Assessment

# Active coordinate

44° 29' 15" N, 76° 38' 45" W (44.487500,-76.645833)

Retrieved: Mon, 11 Jul 2022 17:49:52 GMT


## Location summary

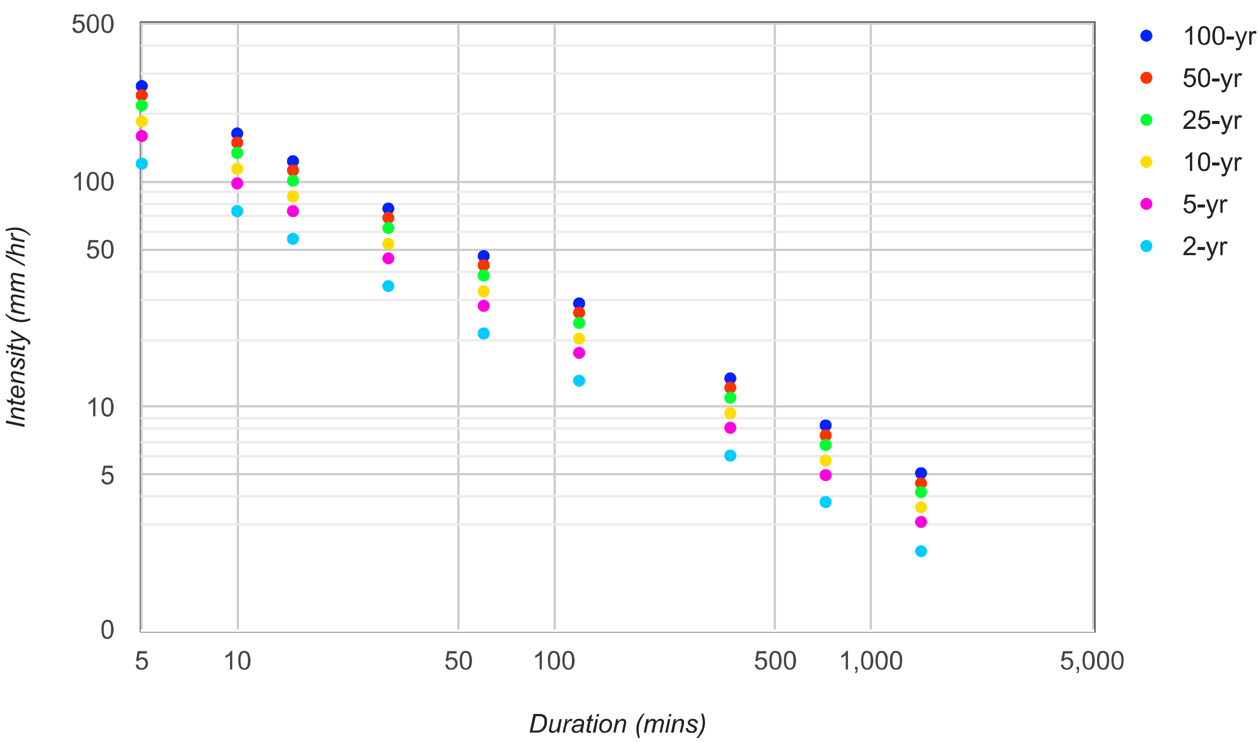
These are the locations in the selection.

**IDF Curve:** 44° 29' 15" N, 76° 38' 45" W (44.487500,-76.645833)

## Results

An IDF curve was found.

**Coordinate: 44.487500, -76.645833**
**IDF curve year: 2022**



## Coefficient summary

**IDF Curve:** 44° 29' 15" N, 76° 38' 45" W (44.487500,-76.645833)

Retrieved: Mon, 11 Jul 2022 17:49:52 GMT

**Data year:** 2010
**IDF curve year:** 2022

## Statistics

### Rainfall intensity (mm $hr^{-1}$)

| Duration | 5-min | 10-min | 15-min | 30-min | 1-hr | 2-hr | 6-hr | 12-hr | 24-hr |
|---|---|---|---|---|---|---|---|---|---|
| 2-yr | 119.9 | 73.9 | 55.7 | 34.4 | 21.2 | 13.1 | 6.1 | 3.8 | 2.3 |
| 5-yr | 159.0 | 98.1 | 73.9 | 45.6 | 28.1 | 17.4 | 8.1 | 5.0 | 3.1 |
| 10-yr | 184.6 | 113.8 | 85.8 | 52.9 | 32.6 | 20.1 | 9.4 | 5.8 | 3.6 |
| 25-yr | 217.0 | 133.8 | 100.8 | 62.2 | 38.3 | 23.6 | 11.0 | 6.8 | 4.2 |
| 50-yr | 240.8 | 148.5 | 111.9 | 69.0 | 42.5 | 26.2 | 12.2 | 7.5 | 4.6 |
| 100-yr | 264.7 | 163.2 | 122.9 | 75.8 | 46.7 | 28.8 | 13.4 | 8.3 | 5.1 |

### Rainfall depth (mm)

| Duration | 5-min | 10-min | 15-min | 30-min | 1-hr | 2-hr | 6-hr | 12-hr | 24-hr |
|---|---|---|---|---|---|---|---|---|---|
| 2-yr | 10.0 | 12.3 | 13.9 | 17.2 | 21.2 | 26.2 | 36.6 | 45.6 | 55.2 |
| 5-yr | 13.2 | 16.4 | 18.5 | 22.8 | 28.1 | 34.8 | 48.6 | 60.0 | 74.4 |
| 10-yr | 15.4 | 19.0 | 21.4 | 26.4 | 32.6 | 40.2 | 56.4 | 69.6 | 86.4 |
| 25-yr | 18.1 | 22.3 | 25.2 | 31.1 | 38.3 | 47.2 | 66.0 | 81.6 | 100.8 |
| 50-yr | 20.1 | 24.8 | 28.0 | 34.5 | 42.5 | 52.4 | 73.2 | 90.0 | 110.4 |
| 100-yr | 22.1 | 27.2 | 30.7 | 37.9 | 46.7 | 57.6 | 80.4 | 99.6 | 122.4 |

## Terms of Use

| Hydrologic Parameters for CA-1 | Sheet 1 of 7 |
|---|---|

WILLS

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

**Land Use**

| | | | |
|---|---|---|---|
| Agriculture | 209.10 | 14.23 | ha |
| Range | 0.00 | 0.00 | ha |
| Grass | 20.78 | 6.55 | ha |
| Woods | 791.83 | 103.49 | ha |
| Wetland | 302.66 | 149.65 | ha |
| Gravel | 0.00 | 0.00 | ha |
| Impervious | 13.87 | 1.64 | ha |
| **SUM** | **1338.24** | **275.55** | |
| **Hydrologic Soil Group[1]** | B | D | |
| **Soil Type** | 0 | 0 | |
| **C** | 0.11 | 0.08 | |
| **CN (Nashyd)** | 59.2 | 63.0 | |

**Rainfall Data**

| | | |
|---|---|---|
| **Gauging Station =** | | |
| **12 hr, 100 Yr Rainfall =** | 99.3 | mm |
| **Drainage Area** | ########### | ha |
| **Impervious Area** | **15.50** | ha |
| **Percent Impervious** | **1.0%** | |
| Connected Impervious | 1.0% | |

**Pervious**

| | | |
|---|---|---|
| **Length** | 5304 | m |
| **US Elev** | 169.0 | m |
| **DS Elev** | 140.0 | m |
| **Slope** | 0.5 | % |
| | Flat | |

| Parameter | Soil Group | Land Use | | | | | | | Weighted Value | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Range | Grass | Woods | Wetland | Gravel | Imperv. | Incl. Imperv. NASHYD | Not Incl. Imperv. STANDHYD |
| Runoff Coefficient[2], C | B | 0.26 | 0.14 | 0.08 | 0.08 | 0.05 | 0.76 | 0.90 | 0.11 | n.a. |
| | D | 0.26 | 0.14 | 0.08 | 0.08 | 0.05 | 0.76 | 0.90 | 0.08 | |
| | | 0.26 | 0.14 | 0.08 | 0.08 | 0.05 | 0.76 | 0.90 | | |
| | | 0.26 | 0.14 | 0.08 | 0.08 | 0.05 | 0.76 | 0.90 | | |
| SCS Curve No.[3], CN | B | 74 | 65 | 61 | 58 | 50 | 85 | 98 | 59.2 | 58.7 |
| | D | 86 | 81 | 80 | 77 | 50 | 91 | 98 | 63.0 | 62.8 |
| Initial Abstraction[5], mm | | 6.0 | 8.0 | 5.0 | 10.0 | 10.0 | 2.5 | 2.0 | 9.3 | 9.4 |

**Time of Concentration[6]**

| | | |
|---|---|---|
| **Total Length** | 5304 | m |
| **Average Slope** | 0.5 | % |
| **Airport** | **288.5** | min. |
| **Bransby - Williams** | 163.0 | min. |
| **Applicable Minimum[7]** | 10.0 | min. |
| **Time to Peak** | 193.3 | min. |
| | **3.22** | **hr.** |

Flat: 0-2% Slopes
Rolling: 2-6% Slopes
Hilly: >6% Slopes

**Composite Parameters**

| | | |
|---|---|---|
| **Drainage Area** | **1613.79 ha** | |
| **Runoff Coefficient** | **0.10** | |
| **SCS Curve No.** | 59.8 | 59.4 |
| **Modified Curve No.[4], CN*** | **62.7** | 62.5 |
| **Initial Abstraction.** | **9.3** | 9.4 |

**Notes:**

1. Hydrologic Soil Group obtained from Design Chart H2-6A, M.T.O. Drainage Manual, 1980.
2. Runoff coefficient obtained from M.T.O. Design Chart 1.07, M.T.O. Drainage Management Manual, 1997, Hydrologic Analysis and Design, McCuen 2004 and New Jersey Technical Manual for Stream Encroachment, 1984.
3. SCS Curve No. obtained from M.T.O. Design Chart 1.09, M.T.O. Drainage Management Manual, 1997, and Table 2-2a, TR-55, page 2-5.
4. The modified curve number is adjusted as per Paul Wisner & Associates (1982) and represents anticedent moisture conditions Type II
5. Initial Abstraction values taken from the Environmental and Engineering Services Department, The Corporation of the City of London, Dec 2005
6. Use Airport Equation to calculate time of concentration for C <= 0.4, and Bransby-Williams for C > 0.4.
7. Minimum Time of Concentration for use in the Rational Method and Hydrologic Model has been set to 10 minutes
8. All impervious areas have been assumed to be directly connected.

# Rational Method for CA-1

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| | | | |
|---|---|---|---|
| **Drainage Area** | **A =** | **1613.79** | ha |
| **Percent Impervious** | **% Imp =** | **1.0** | % |
| **Slope** | **S =** | **0.5** | % |

**Gauging Station =**

**IDF Parameters**

| | **2-Year** | **5-Year** | **10-Year** | **25-Year** | **50-Year** | **100-Year** |
|---|---|---|---|---|---|---|
| **a =** | 367.361 | 485.992 | 563.962 | 665.283 | 743.229 | 812.429 |
| **b =** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **c =** | 0.696 | 0.695 | 0.696 | 0.697 | 0.699 | 0.697 |

| **Return Period (Years)** | **Area (ha)** | **C-value** | **Tc (min)** | **Int. (mm/hr)** | **Flow ($m^3/s$)** |
|---|---|---|---|---|---|
| **25 mm** | 1613.79 | 0.10 | 288 | 5.4 | **2.5** |
| **2** | 1613.79 | 0.10 | 288 | 7.1 | **3.3** |
| **5** | 1613.79 | 0.10 | 288 | 9.5 | **4.4** |
| **10** | 1613.79 | 0.10 | 288 | 11.0 | **5.1** |
| **25** | 1613.79 | 0.11 | 288 | 12.8 | **6.6** |
| **50** | 1613.79 | 0.13 | 288 | 14.2 | **8.0** |
| **100** | 1613.79 | 0.13 | 288 | 15.7 | **9.2** |

**Notes :**

1. Rainfall intensity rainfall data obtained for
2. For storms having return period of more than 10 years the runoff coefficient was increased as follows to a maximum value of 0.95.
   25 yr: add 10%
   50 yr: add 20%
   100 yr: add 25%
3. IDF parameters for the 25 mm storm:
   a: 405
   b: 3.0
   c: 0.76

| Visual Otthymo Model for CA-1 | Sheet 3 of 7 |
|---|---|

WILLS

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| Design Storm (yr) | 24hr SCS | 12hr SCS | 6hr SCS | 1hr AES | 12hr AES | 1hr Chic | 4hr Chic | 6 hr Chic |
|---|---|---|---|---|---|---|---|---|
| 2 | 0.4 | 0.3 | 0.2 | | 0.3 | | | |
| 5 | 0.8 | 0.5 | 0.3 | | 0.5 | | | |
| 10 | 1.2 | 0.7 | 0.5 | | 0.7 | | | |
| 25 | 1.8 | 1.0 | 0.6 | | 1.0 | | | |
| 50 | 2.2 | 1.4 | 0.8 | | 1.4 | | | |
| 100 | 2.8 | 1.8 | 1.0 | | 1.8 | | | |
| Regional | 7.7 | | | | | | | |

**Notes:**

1. Storm used to determine peak flow values **24hr SCS**

| NASHYD | |
|---|---|
| DT (min) | 5.0 |
| Area (ha) | 1613.79 |
| DWF (m3/s) - Default [0.0] | 0.0 |
| CN* | 62.7 |
| IA (mm) | 9.3 |
| N - Default [3.0] | 3 |
| TP (hr) | 3.22 |

| MTO Unified Ontario Flood Method for CA-1<br>(Errata April 2016 to Chapter 8, M.T.O. Drainage Management Manual) | Sheet 4 of 7 |
|---|---|

WILLS

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| | | |
|---|---|---|
| **Drainage Area** | **A = 16.14** | $km^2$ |
| **Lake and Wetland Area** | **Ad = 4.52** | $km^2$ |
| **Area Ratio** | **Ad/A = 0.28** | |

| | | | |
|---|---|---|---|
| **1.** | **Lake Attenuation Index**[1] | **LI = 1.280** | |
| **2.** | **Mean Annual Precipitation**[2] | **P = 960** | **mm** |
| **3.** | **Stepwise Regression Constant**[3] | **$K_R$ = as below** | |
| **4.** | **Constants: Boreal Shield**[4] | | |

| **Return Period (years)** | **x** | **a** | **b** | **c** | **$K_R$** |
|---|---|---|---|---|---|
| 2 | -10.870 | 0.839 | -4.633 | 3.583 | 1.3E-11 |
| 5 | - | - | - | - | - |
| 10 | -8.583 | 0.795 | -4.522 | 2.917 | 2.6E-09 |
| 25 | -7.834 | 0.779 | -4.510 | 2.703 | 1.5E-08 |
| 50 | -7.371 | 0.769 | -4.520 | 2.572 | 4.3E-08 |
| 100 | -6.967 | 0.759 | -4.541 | 2.457 | 1.1E-07 |

| **Return Period (years)** | **$Q_{UOFM}$ ($m^3/s$)** | **Lower Limit of $Q_{UOFM}$ ($m^3/s$)** | **Upper Limit of $Q_{UOFM}$ ($m^3/s$)** |
|---|---|---|---|
| 2 | **2.1** | 1.5 | 3.1 |
| 5[5] | **2.8** | 1.9 | 4.1 |
| 10 | **3.9** | 2.6 | 5.8 |
| 25 | **4.8** | 3.2 | 7.3 |
| 50 | **5.5** | 3.6 | 8.6 |
| 100 | **6.2** | 3.9 | 9.7 |

**Notes:**

1. Taken as (1+WA / A) where WA is the area of the Lakes and Wetlands; and A is area (dimensionless)
2. Figure 2: IsoHyetal Map; Design and Contract Standards Office #2016-03; Appendix A March 3, 2106
3. Taken as $10^x$ (value of contstant obtained from the output of the stepwise regression)
4. Table 1: Coefficients; Design and Contract Standards Office #2016-03; Appendix A March 3, 2106
5. Interpolated from 2 year and 10 year results

# M.T.O. Modified Index Flood Method for CA-1

(Chapter 8, M.T.O. Drainage Management Manual)

WILLS

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| | | | |
|---|---|---|---|
| **Region** | | **Southern** | (Design Chart 1.14)[1] |
| **Watershed Area** | **A =** | **16.14** | **$km^2$** |
| **Storage Area from Lakes & Swamps** | **Ad =** | **4.52** | **$km^2$** |
| **Watershed Slope** | **S =** | **0.55** | **%** |

| | | | | |
|---|---|---|---|---|
| **1.** | **Percent Storage** | **Ad/A =** | **28.0** | **%** |
| **2.** | **Watershed Base Class** | **WCb =** | **5.8** | (Design Chart 1.16 or 1.17, based on lakes & wetland curve)[2] |
| **3a.** | **Base Adjustment in Northern Basin** | | | |
| | 1. Storage mostly in upper 1/3 of the Watershed | Adjust = | 0.5 | |
| | 2. Storage well distributed or within the middle 1/3 | Adjust = | 0.0 | |
| | 3. Storage mostly in lower 1/3 of the Watershed | Adjust = | -0.5 | |
| | **Storage is mostly located within the lower portion** | **Adjust =** | **0.0** | |
| **3b.** | **Base Adjustment in Southern Basin** | | | |
| | 1. Slope Adjustment | Adjust = | 0.3 | (Design Chart 1.18)[3] |
| | 2. Detention Adjustment | Adjust = | -3.2 | (Design Chart 1.19)[4] |
| | | **Adjust =** | **-2.9** | |
| **4.** | **Adjusted Watershed Class** | **WCa =** | **2.9** | |
| **5.** | **Class Coefficient** | **C =** | **0.30** | (Design Chart 1.15)[5] |
| **6.** | **25 Year Flow** (Equation 8.20)[6] | **$Q_{25}$ =** | **2.41** | **$m^3/s$** |
| **7.** | **Return Period Flows** | | | |

| Return Period (year) | Frequency Conversion Factor[7] | Peak flow ($m^3/s$) |
|---|---|---|
| 2 | 0.50 | **1.2** |
| 5 | 0.67 | **1.616** |
| 10 | 0.82 | **1.977** |
| 25 | 1.00 | **2.411** |
| 50 | 1.13 | **2.725** |
| 100 | 1.27 | **3.062** |

**Notes:**

1. Design Chart 1.14: Hydrologic Regions and Precipitation Index, from MTO Drainage Management Manual, Part 4
2. Design Chart 1.16 : Base Class Chart Determination: Northern Basins, from MTO Drainage Management Manual, Part 4
3. Design Chart 1.18: Base Class Adjustment for Slope - Southern Basins
4. Design Chart 1.19: Base Class Adjustment for Detention - Southern Basins
5. Design Chart 1.15: Typical Watershed Classes, from MTO Drainage Management Manual, Part 4
6. Equation 8.20 from MTO Drainage Management Manual, Chapter 8: Hydrology, Hydraulics & Stormwater Quality
7. Frequency conversion factors from Chart H5-9, Chapter H, M.T.O. Drainage Manual

# MNR Index Flood Method for CA-1

(Appendix 5, M.N.R. Flood Plain Management in Ontario)

WILLS

**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| | | |
|---|---|---|
| **Area** | **A = 16.1379014** | $km^2$ |
| **Region** | **1a** | (Figure 1)[1] |
| | | 1a refers to A<60$km^2$ |
| **Constant** | **C = 0.22** | (Table 8)[2] |
| **Exponent** | **n = 1.000** | (Table 8) |

**1. Index Flood**

$Q_2$ = CAn
$Q_2$ = 3.55 $m^3/s$

**2. Flood Discharge, Qf**

| Return Period (years) | Ratio to Index Flood Rf[3] | Flood Discharge ($m^3/s$) |
|---|---|---|
| 2 | 1.00 | **3.6** |
| 5 | 1.25 | **4.4** |
| 10 | 1.45 | **5.1** |
| 25 | 1.65 | **5.9** |
| 50 | 1.85 | **6.6** |
| 100 | 2.05 | **7.3** |

**Notes:**

1. Flood Frequency Regions Index Method, Figure 1
2. Table 8 from Regional Regression Equation Coefficients, M.N.E. Flood Plain Management in Ontario, Appendix 5
3. Rf factor from Regional Frequency Curve, Figure 2A for Region 1a

## Peak Flow Comparison for CA-1



**Project No:** 22-5394
**Project Name:** FIMLA 14 Island Lake Dam
**Designed/Checked By:** SO/DG
**Date:** 11-Jul-22

| Return Period (Year) | Rational Method | Visual Otthymo | MTO Unified Flood Method (Upper Limit) | MTO Northern Ontario | MTO Modified Index Flood | MNR Index Flood | Average Values |
|---|---|---|---|---|---|---|---|
| 2 | 3.3 | **0.4** | 3.1 | | 1.2 | 3.6 | 2.3 |
| 5 | 4.4 | **0.8** | 4.1 | | 1.6 | 4.4 | 3.1 |
| 10 | 5.1 | **1.2** | 5.8 | | 2.0 | 5.1 | 3.9 |
| 25 | 6.6 | **1.8** | 7.3 | | 2.4 | 5.9 | 4.8 |
| 50 | 8.0 | **2.2** | 8.6 | | 2.7 | 6.6 | 5.6 |
| 100 | 9.2 | **2.8** | 9.7 | | 3.1 | 7.3 | 6.4 |
| | | 0.0 | | | | | |
| Regional Event | **-** | - | - | | - | - | - |

Method used to determine the peak flows values **Visual Otthymo**

**Notes:**

1. Not Used
2. Not Used
3. Not Used

# Appendix C

## Hydraulic Assessment

# Concrete Dam Breach Estimates Report Output for 14 Island Lake Dam

WILLS

**Project No:** 21-5394
**Project Name:** 14 Island Lake Dam - DSR
**Designed/Checked By:** SO / DG
**Date:** October 19, 2022

**Simplified Dam Breach Analysis (Steady Flow GeoHEC-RAS Model)**

| Failure Scenario | Breach Bottom Elevation (m) | Estiamted Breach Bottom Width (m) | Dam Breach Incremental Flow ($m^3/s$) | Total Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| Sunny Day | 140.38 | 0.9 | 2.1 | 2.4 |
| 2-Year | 140.38 | 7.2 | 18.6 | 19.0 |
| 5-Year | 140.38 | 7.2 | 19.6 | 20.4 |
| 10-Year | 140.38 | 7.2 | 20.3 | 21.5 |
| 25-Year | 140.38 | 7.2 | 21.3 | 23.1 |
| 50-Year | 140.38 | 7.2 | 21.9 | 24.1 |
| 100-Year | 140.38 | 7.2 | 22.8 | 25.6 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Whitney Dam HEC-RAS Model Results
Steady Flow Scenarios

## Life Safety Assessment

Sheet 1 of 1

**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Depth (m) | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | | |
| | | | | | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | |
| 5669 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.29 | 0.18 | 0.21 | 0.06 | 0.03 | 0.04 | 0.02 | 0.01 | 0.01 | 137.49 | 0.60 | 0.49 | 0.52 | 0.24 | 0.15 | 0.18 | 0.14 | 0.07 | 0.09 | 0.31 | 0.18 | 0.12 | 0.14 | 0.13 | 0.07 | 0.09 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.35 | 0.24 | 0.27 | 0.09 | 0.05 | 0.07 | 0.03 | 0.01 | 0.02 | 138.53 | 1.64 | 1.53 | 1.56 | 0.46 | 0.28 | 0.25 | 0.75 | 0.43 | 0.39 | 1.29 | 0.37 | 0.23 | 0.18 | 0.72 | 0.42 | 0.37 | Safe to Not Safe | Safe to Not Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.26 | 0.37 | 0.26 | 0.29 | 0.14 | 0.09 | 0.12 | 0.05 | 0.02 | 0.03 | 138.59 | 1.70 | 1.59 | 1.62 | 0.46 | 0.29 | 0.25 | 0.78 | 0.46 | 0.41 | 1.33 | 0.32 | 0.20 | 0.13 | 0.73 | 0.44 | 0.37 | Safe to Not Safe | Safe to Not Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.34 | 0.45 | 0.34 | 0.37 | 0.17 | 0.11 | 0.14 | 0.08 | 0.04 | 0.05 | 138.64 | 1.75 | 1.64 | 1.67 | 0.47 | 0.30 | 0.26 | 0.82 | 0.49 | 0.43 | 1.30 | 0.30 | 0.19 | 0.12 | 0.75 | 0.45 | 0.38 | Safe to Not Safe | Safe to Not Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.43 | 0.54 | 0.43 | 0.46 | 0.21 | 0.13 | 0.16 | 0.11 | 0.06 | 0.07 | 138.71 | 1.82 | 1.71 | 1.74 | 0.47 | 0.30 | 0.26 | 0.86 | 0.51 | 0.45 | 1.28 | 0.26 | 0.17 | 0.10 | 0.74 | 0.46 | 0.38 | Safe to Not Safe | Safe to Not Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.48 | 0.59 | 0.48 | 0.51 | 0.23 | 0.14 | 0.18 | 0.14 | 0.07 | 0.09 | 138.75 | 1.86 | 1.75 | 1.78 | 0.47 | 0.31 | 0.26 | 0.87 | 0.54 | 0.46 | 1.27 | 0.24 | 0.17 | 0.08 | 0.74 | 0.48 | 0.37 | Safe to Not Safe | Safe to Not Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.53 | 0.64 | 0.53 | 0.56 | 0.26 | 0.16 | 0.19 | 0.17 | 0.08 | 0.11 | 138.82 | 1.93 | 1.82 | 1.85 | 0.48 | 0.32 | 0.26 | 0.93 | 0.58 | 0.48 | 1.29 | 0.22 | 0.16 | 0.07 | 0.76 | 0.50 | 0.37 | Safe to Not Safe | Safe to Not Safe |
| 5568 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.44 | 0.24 | 0.20 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 137.49 | 0.75 | 0.55 | 0.51 | 0.07 | 0.04 | 0.05 | 0.05 | 0.02 | 0.03 | 0.31 | 0.05 | 0.03 | 0.04 | 0.04 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.50 | 0.30 | 0.26 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.52 | 1.78 | 1.58 | 1.54 | 0.13 | 0.08 | 0.12 | 0.23 | 0.13 | 0.18 | 1.28 | 0.10 | 0.06 | 0.10 | 0.22 | 0.12 | 0.18 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.26 | 0.52 | 0.32 | 0.28 | 0.05 | 0.02 | 0.03 | 0.03 | 0.01 | 0.01 | 138.59 | 1.85 | 1.65 | 1.61 | 0.13 | 0.08 | 0.12 | 0.24 | 0.13 | 0.19 | 1.33 | 0.08 | 0.06 | 0.09 | 0.21 | 0.13 | 0.18 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.33 | 0.59 | 0.39 | 0.35 | 0.06 | 0.03 | 0.04 | 0.04 | 0.01 | 0.01 | 138.64 | 1.90 | 1.70 | 1.66 | 0.14 | 0.08 | 0.12 | 0.27 | 0.14 | 0.20 | 1.31 | 0.08 | 0.05 | 0.08 | 0.23 | 0.12 | 0.19 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.42 | 0.68 | 0.48 | 0.44 | 0.06 | 0.04 | 0.04 | 0.04 | 0.02 | 0.02 | 138.71 | 1.97 | 1.77 | 1.73 | 0.14 | 0.08 | 0.12 | 0.28 | 0.14 | 0.21 | 1.29 | 0.08 | 0.04 | 0.08 | 0.24 | 0.12 | 0.19 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.47 | 0.73 | 0.53 | 0.49 | 0.07 | 0.04 | 0.05 | 0.05 | 0.02 | 0.02 | 138.75 | 2.01 | 1.81 | 1.77 | 0.14 | 0.08 | 0.13 | 0.28 | 0.14 | 0.23 | 1.28 | 0.07 | 0.04 | 0.08 | 0.23 | 0.12 | 0.21 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.53 | 0.79 | 0.59 | 0.55 | 0.08 | 0.04 | 0.06 | 0.06 | 0.02 | 0.03 | 138.82 | 2.08 | 1.88 | 1.84 | 0.14 | 0.08 | 0.13 | 0.29 | 0.15 | 0.24 | 1.29 | 0.06 | 0.04 | 0.07 | 0.23 | 0.13 | 0.21 | Safe | Safe |
| 5480 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.49 | 0.35 | 0.34 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.48 | 0.79 | 0.65 | 0.64 | 0.06 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 0.30 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.55 | 0.41 | 0.40 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.52 | 1.83 | 1.69 | 1.68 | 0.15 | 0.13 | 0.14 | 0.27 | 0.22 | 0.24 | 1.28 | 0.13 | 0.11 | 0.12 | 0.26 | 0.21 | 0.23 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.26 | 0.57 | 0.43 | 0.42 | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 138.58 | 1.89 | 1.75 | 1.74 | 0.15 | 0.13 | 0.15 | 0.28 | 0.23 | 0.26 | 1.32 | 0.11 | 0.10 | 0.12 | 0.26 | 0.21 | 0.25 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.33 | 0.64 | 0.50 | 0.49 | 0.05 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 138.63 | 1.94 | 1.80 | 1.79 | 0.16 | 0.14 | 0.15 | 0.31 | 0.25 | 0.27 | 1.30 | 0.11 | 0.11 | 0.11 | 0.28 | 0.24 | 0.25 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.42 | 0.73 | 0.59 | 0.58 | 0.06 | 0.04 | 0.05 | 0.04 | 0.02 | 0.03 | 138.71 | 2.02 | 1.88 | 1.87 | 0.16 | 0.14 | 0.15 | 0.32 | 0.26 | 0.28 | 1.29 | 0.10 | 0.10 | 0.10 | 0.28 | 0.24 | 0.25 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.47 | 0.78 | 0.64 | 0.63 | 0.06 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 138.75 | 2.06 | 1.92 | 1.91 | 0.17 | 0.14 | 0.16 | 0.35 | 0.27 | 0.31 | 1.28 | 0.11 | 0.09 | 0.11 | 0.30 | 0.24 | 0.27 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.52 | 0.83 | 0.69 | 0.68 | 0.07 | 0.05 | 0.06 | 0.06 | 0.03 | 0.04 | 138.81 | 2.12 | 1.98 | 1.97 | 0.17 | 0.14 | 0.16 | 0.36 | 0.28 | 0.32 | 1.29 | 0.10 | 0.09 | 0.10 | 0.30 | 0.24 | 0.27 | Safe | Safe |
| 5365 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.35 | | | 0.09 | | | 0.03 | | | 137.47 | 0.64 | 0.07 | | 0.38 | 0.07 | 0.00 | 0.24 | 0.00 | | 0.29 | 0.29 | 0.07 | 0.00 | 0.21 | 0.00 | 0.00 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.41 | | | 0.14 | | | 0.06 | | | 138.50 | 1.67 | 1.10 | 1.02 | 0.52 | 0.30 | 0.21 | 0.87 | 0.33 | 0.21 | 1.26 | 0.38 | 0.30 | 0.21 | 0.81 | 0.33 | 0.21 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.25 | 0.42 | | | 0.23 | | | 0.10 | | | 138.56 | 1.73 | 1.16 | 1.08 | 0.51 | 0.30 | 0.21 | 0.88 | 0.35 | 0.23 | 1.31 | 0.28 | 0.30 | 0.21 | 0.79 | 0.35 | 0.23 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.32 | 0.49 | | | 0.28 | | | 0.14 | | | 138.62 | 1.79 | 1.22 | 1.14 | 0.51 | 0.30 | 0.22 | 0.91 | 0.37 | 0.25 | 1.30 | 0.23 | 0.30 | 0.22 | 0.78 | 0.37 | 0.25 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.40 | 0.57 | | | 0.33 | | | 0.19 | | | 138.69 | 1.86 | 1.29 | 1.21 | 0.50 | 0.29 | 0.22 | 0.93 | 0.37 | 0.27 | 1.29 | 0.17 | 0.29 | 0.22 | 0.74 | 0.37 | 0.27 | Safe to Not Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.45 | 0.62 | 0.05 | | 0.37 | 0.05 | | 0.23 | 0.00 | | 138.73 | 1.90 | 1.33 | 1.25 | 0.50 | 0.29 | 0.22 | 0.95 | 0.39 | 0.28 | 1.28 | 0.13 | 0.24 | 0.22 | 0.72 | 0.38 | 0.28 | Safe to Not Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.51 | 0.68 | 0.11 | 0.03 | 0.41 | 0.10 | 0.03 | 0.28 | 0.01 | 0.00 | 138.80 | 1.97 | 1.40 | 1.32 | 0.50 | 0.28 | 0.22 | 0.98 | 0.39 | 0.29 | 1.29 | 0.09 | 0.18 | 0.19 | 0.71 | 0.38 | 0.29 | Safe to Not Safe | Safe |
| 5285 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.74 | 0.23 | 0.31 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 137.47 | 1.03 | 0.52 | 0.60 | 0.05 | 0.04 | 0.04 | 0.05 | 0.02 | 0.02 | 0.29 | 0.04 | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.80 | 0.29 | 0.37 | 0.02 | 0.01 | 0.01 | 0.02 | 0.00 | 0.00 | 138.50 | 2.06 | 1.55 | 1.63 | 0.13 | 0.12 | 0.11 | 0.27 | 0.19 | 0.18 | 1.26 | 0.11 | 0.11 | 0.10 | 0.25 | 0.18 | 0.18 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.25 | 0.81 | 0.30 | 0.38 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.56 | 2.12 | 1.61 | 1.69 | 0.13 | 0.12 | 0.12 | 0.28 | 0.19 | 0.20 | 1.31 | 0.10 | 0.10 | 0.10 | 0.25 | 0.19 | 0.20 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.32 | 0.88 | 0.37 | 0.45 | 0.04 | 0.03 | 0.02 | 0.04 | 0.01 | 0.01 | 138.61 | 2.17 | 1.66 | 1.74 | 0.13 | 0.13 | 0.12 | 0.28 | 0.22 | 0.21 | 1.29 | 0.09 | 0.10 | 0.10 | 0.25 | 0.20 | 0.20 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.40 | 0.96 | 0.45 | 0.53 | 0.05 | 0.04 | 0.03 | 0.05 | 0.02 | 0.02 | 138.69 | 2.25 | 1.74 | 1.82 | 0.14 | 0.13 | 0.12 | 0.32 | 0.23 | 0.22 | 1.29 | 0.09 | 0.09 | 0.09 | 0.27 | 0.21 | 0.20 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.45 | 1.01 | 0.50 | 0.58 | 0.05 | 0.04 | 0.04 | 0.05 | 0.02 | 0.02 | 138.73 | 2.29 | 1.78 | 1.86 | 0.14 | 0.13 | 0.12 | 0.32 | 0.23 | 0.22 | 1.28 | 0.09 | 0.09 | 0.08 | 0.27 | 0.21 | 0.20 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.51 | 1.07 | 0.56 | 0.64 | 0.06 | 0.05 | 0.04 | 0.06 | 0.03 | 0.03 | 138.80 | 2.36 | 1.85 | 1.93 | 0.14 | 0.14 | 0.13 | 0.33 | 0.26 | 0.25 | 1.29 | 0.08 | 0.09 | 0.09 | 0.27 | 0.23 | 0.23 | Safe | Safe |
| 5195 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.40 | 0.08 | 0.33 | 0.02 | | 0.02 | 0.01 | | 0.01 | 137.47 | 0.69 | 0.37 | 0.62 | 0.09 | 0.04 | 0.08 | 0.06 | 0.01 | 0.05 | 0.29 | 0.07 | 0.04 | 0.06 | 0.05 | 0.01 | 0.04 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.46 | 0.14 | 0.39 | 0.03 | 0.01 | 0.03 | 0.01 | 0.00 | 0.01 | 138.49 | 1.71 | 1.39 | 1.64 | 0.23 | 0.14 | 0.21 | 0.39 | 0.19 | 0.34 | 1.25 | 0.20 | 0.13 | 0.18 | 0.38 | 0.19 | 0.33 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.25 | 0.47 | 0.15 | 0.40 | 0.05 | 0.02 | 0.04 | 0.02 | 0.00 | 0.02 | 138.56 | 1.78 | 1.46 | 1.71 | 0.23 | 0.14 | 0.22 | 0.41 | 0.20 | 0.38 | 1.31 | 0.18 | 0.12 | 0.18 | 0.39 | 0.20 | 0.36 | Safe | Safe to Not Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.32 | 0.54 | 0.22 | 0.47 | 0.06 | 0.02 | 0.06 | 0.03 | 0.00 | 0.03 | 138.61 | 1.83 | 1.51 | 1.76 | 0.24 | 0.14 | 0.22 | 0.44 | 0.21 | 0.39 | 1.29 | 0.18 | 0.12 | 0.16 | 0.41 | 0.21 | 0.36 | Safe | Safe to Not Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.40 | 0.62 | 0.30 | 0.55 | 0.08 | 0.03 | 0.07 | 0.05 | 0.01 | 0.04 | 138.68 | 1.90 | 1.58 | 1.83 | 0.25 | 0.14 | 0.23 | 0.48 | 0.22 | 0.42 | 1.28 | 0.17 | 0.11 | 0.16 | 0.43 | 0.21 | 0.38 | Safe | Safe to Not Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.45 | 0.67 | 0.35 | 0.60 | 0.09 | 0.04 | 0.08 | 0.06 | 0.01 | 0.05 | 138.72 | 1.94 | 1.62 | 1.87 | 0.25 | 0.15 | 0.23 | 0.48 | 0.24 | 0.43 | 1.27 | 0.16 | 0.11 | 0.15 | 0.42 | 0.23 | 0.38 | Safe | Safe to Not Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.50 | 0.72 | 0.40 | 0.65 | 0.10 | 0.05 | 0.09 | 0.07 | 0.02 | 0.06 | 138.79 | 2.01 | 1.69 | 1.94 | 0.25 | 0.15 | 0.23 | 0.50 | 0.25 | 0.45 | 1.29 | 0.15 | 0.10 | 0.14 | 0.43 | 0.23 | 0.39 | Safe | Safe to Not Safe |
| 5132 | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.38 | 0.33 | 0.32 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 137.46 | 0.66 | 0.61 | 0.60 | 0.10 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 | 0.28 | 0.08 | 0.07 | 0.07 | 0.06 | 0.05 | 0.04 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.44 | 0.39 | 0.38 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 138.49 | 1.69 | 1.64 | 1.63 | 0.25 | 0.24 | 0.22 | 0.42 | 0.39 | 0.36 | 1.25 | 0.22 | 0.21 | 0.20 | 0.41 | 0.38 | 0.35 | Safe to Not Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.25 | 0.45 | 0.40 | 0.39 | 0.05 | 0.05 | 0.04 | 0.02 | 0.02 | 0.02 | 138.55 | 1.75 | 1.70 | 1.69 | 0.26 | 0.25 | 0.23 | 0.46 | 0.43 | 0.39 | 1.30 | 0.21 | 0.20 | 0.19 | 0.43 | 0.41 | 0.37 | Safe to Not Safe | Safe to Not Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.32 | 0.52 | 0.47 | 0.46 | 0.07 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 138.60 | 1.80 | 1.75 | 1.74 | 0.27 | 0.25 | 0.23 | 0.49 | 0.44 | 0.40 | 1.28 | 0.20 | 0.19 | 0.18 | 0.45 | 0.41 | 0.38 | Safe to Not Safe | Safe to Not Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.40 | 0.60 | 0.55 | 0.54 | 0.08 | 0.08 | 0.07 | 0.05 | 0.04 | 0.04 | 138.67 | 1.87 | 1.82 | 1.81 | 0.27 | 0.26 | 0.24 | 0.50 | 0.47 | 0.43 | 1.27 | 0.19 | 0.18 | 0.17 | 0.46 | 0.43 | 0.40 | Safe to Not Safe | Safe to Not Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.45 | 0.65 | 0.60 | 0.59 | 0.09 | 0.09 | 0.08 | 0.06 | 0.05 | 0.05 | 138.71 | 1.91 | 1.86 | 1.85 | 0.28 | 0.26 | 0.24 | 0.53 | 0.48 | 0.44 | 1.26 | 0.19 | 0.17 | 0.16 | 0.48 | 0.43 | 0.40 | Safe to Not Safe | Safe to Not Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.50 | 0.70 | 0.65 | 0.64 | 0.11 | 0.10 | 0.09 | 0.08 | 0.07 | 0.06 | 138.78 | 1.98 | 1.93 | 1.92 | 0.28 | 0.27 | 0.25 | 0.55 | 0.52 | 0.48 | 1.28 | 0.17 | 0.17 | 0.16 | 0.48 | 0.46 | 0.42 | Safe to Not Safe | Safe to Not Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.41 | 0.39 | 0.37 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.46 | 0.69 | 0.67 | 0.65 | 0.06 | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 | 0.28 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | Safe | Safe |

**Whitney Dam HEC-RAS Model Results**
**Steady Flow Scenarios**

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Depth (m) | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | | |
| | | | | | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | |
| | 0.44 | 2 | 19.00 | 19 | 137.24 | 0.47 | 0.45 | 0.43 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.48 | **1.71** | **1.69** | **1.67** | 0.16 | 0.14 | 0.15 | 0.27 | 0.24 | 0.25 | 1.24 | 0.14 | 0.12 | 0.13 | 0.26 | 0.23 | 0.24 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.47 | 0.45 | 0.43 | 0.03 | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 138.55 | **1.78** | **1.76** | **1.74** | 0.17 | 0.14 | 0.16 | 0.30 | 0.25 | 0.28 | 1.31 | 0.14 | 0.11 | 0.13 | 0.29 | 0.23 | 0.27 | Safe | Safe |
| 5060 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.54 | 0.52 | 0.50 | 0.04 | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 138.60 | **1.83** | **1.81** | **1.79** | 0.17 | 0.14 | 0.16 | 0.31 | 0.25 | 0.29 | 1.29 | 0.13 | 0.11 | 0.12 | 0.29 | 0.24 | 0.27 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.40 | 0.63 | 0.61 | 0.59 | 0.05 | 0.04 | 0.05 | 0.03 | 0.02 | 0.03 | 138.67 | **1.90** | **1.88** | **1.86** | 0.17 | 0.15 | 0.16 | 0.32 | 0.28 | 0.30 | 1.27 | 0.12 | 0.11 | 0.11 | 0.29 | 0.26 | 0.27 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.67 | 0.65 | 0.63 | 0.06 | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 | 138.71 | **1.94** | **1.92** | **1.90** | 0.18 | 0.15 | 0.17 | 0.35 | 0.29 | 0.32 | 1.27 | 0.12 | 0.10 | 0.12 | 0.31 | 0.26 | 0.29 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.50 | 0.73 | 0.71 | 0.69 | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 | 0.04 | 138.78 | **2.01** | **1.99** | **1.97** | 0.18 | 0.15 | 0.17 | 0.36 | 0.30 | 0.33 | 1.28 | 0.11 | 0.09 | 0.11 | 0.31 | 0.26 | 0.29 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.46 | 0.42 | 0.43 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.46 | 0.74 | 0.70 | 0.71 | 0.07 | 0.05 | 0.06 | 0.05 | 0.04 | 0.04 | 0.28 | 0.06 | 0.04 | 0.05 | 0.05 | 0.03 | 0.04 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.51 | 0.47 | 0.48 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 138.48 | **1.76** | **1.72** | **1.73** | 0.16 | 0.11 | 0.14 | 0.28 | 0.19 | 0.24 | 1.25 | 0.14 | 0.10 | 0.12 | 0.27 | 0.18 | 0.23 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.52 | 0.48 | 0.49 | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 138.54 | **1.82** | **1.78** | **1.79** | 0.16 | 0.12 | 0.14 | 0.29 | 0.21 | 0.25 | 1.30 | 0.13 | 0.09 | 0.11 | 0.28 | 0.20 | 0.24 | Safe | Safe |
| 4939 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.59 | 0.55 | 0.56 | 0.04 | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 138.59 | **1.87** | **1.83** | **1.84** | 0.16 | 0.12 | 0.14 | 0.30 | 0.22 | 0.26 | 1.28 | 0.12 | 0.09 | 0.10 | 0.28 | 0.20 | 0.24 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.67 | 0.63 | 0.64 | 0.06 | 0.04 | 0.05 | 0.04 | 0.03 | 0.03 | 138.67 | **1.95** | **1.91** | **1.92** | 0.17 | 0.12 | 0.15 | 0.33 | 0.23 | 0.29 | 1.28 | 0.11 | 0.08 | 0.10 | 0.29 | 0.20 | 0.26 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.72 | 0.68 | 0.69 | 0.07 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 138.71 | **1.99** | **1.95** | **1.96** | 0.17 | 0.13 | 0.15 | 0.34 | 0.25 | 0.29 | 1.27 | 0.10 | 0.08 | 0.10 | 0.29 | 0.22 | 0.26 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.77 | 0.73 | 0.74 | 0.07 | 0.05 | 0.06 | 0.05 | 0.04 | 0.04 | 138.77 | **2.05** | **2.01** | **2.02** | 0.17 | 0.13 | 0.15 | 0.35 | 0.26 | 0.30 | 1.28 | 0.10 | 0.08 | 0.09 | 0.29 | 0.22 | 0.26 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.49 | 0.41 | 0.45 | 0.01 | | | 0.00 | | | 137.46 | 0.77 | 0.69 | 0.73 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.28 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.54 | 0.46 | 0.50 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.48 | **1.79** | **1.71** | **1.75** | 0.06 | 0.06 | 0.06 | 0.11 | 0.10 | 0.11 | 1.25 | 0.05 | 0.05 | 0.05 | 0.10 | 0.10 | 0.10 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.55 | 0.47 | 0.51 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.54 | **1.85** | **1.77** | **1.81** | 0.07 | 0.06 | 0.06 | 0.13 | 0.11 | 0.11 | 1.30 | 0.05 | 0.05 | 0.05 | 0.12 | 0.10 | 0.10 | Safe | Safe |
| 4812 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.62 | 0.54 | 0.58 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 138.59 | **1.90** | **1.82** | **1.86** | 0.07 | 0.06 | 0.06 | 0.13 | 0.11 | 0.11 | 1.28 | 0.05 | 0.05 | 0.04 | 0.12 | 0.10 | 0.10 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.70 | 0.62 | 0.66 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.66 | **1.97** | **1.89** | **1.93** | 0.07 | 0.06 | 0.06 | 0.14 | 0.11 | 0.12 | 1.27 | 0.05 | 0.04 | 0.04 | 0.12 | 0.10 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.75 | 0.67 | 0.71 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.70 | **2.01** | **1.93** | **1.97** | 0.07 | 0.06 | 0.07 | 0.14 | 0.12 | 0.14 | 1.26 | 0.04 | 0.04 | 0.05 | 0.12 | 0.10 | 0.12 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.80 | 0.72 | 0.76 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 138.77 | **2.08** | **2.00** | **2.04** | 0.07 | 0.06 | 0.07 | 0.15 | 0.12 | 0.14 | 1.28 | 0.04 | 0.04 | 0.05 | 0.12 | 0.11 | 0.13 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.49 | 0.34 | 0.35 | 0.01 | | 0.01 | 0.00 | | 0.00 | 137.46 | 0.77 | 0.62 | 0.63 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.28 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.54 | 0.39 | 0.40 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 138.47 | **1.78** | **1.63** | **1.64** | 0.09 | 0.08 | 0.08 | 0.16 | 0.13 | 0.13 | 1.24 | 0.08 | 0.07 | 0.07 | 0.15 | 0.13 | 0.13 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.55 | 0.40 | 0.41 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 138.54 | **1.85** | **1.70** | **1.71** | 0.09 | 0.08 | 0.08 | 0.17 | 0.14 | 0.14 | 1.30 | 0.07 | 0.07 | 0.06 | 0.16 | 0.13 | 0.13 | Safe | Safe |
| 4721 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.62 | 0.47 | 0.48 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.59 | **1.90** | **1.75** | **1.76** | 0.09 | 0.08 | 0.09 | 0.17 | 0.14 | 0.16 | 1.28 | 0.07 | 0.06 | 0.07 | 0.16 | 0.13 | 0.15 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.70 | 0.55 | 0.56 | 0.03 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 | 138.66 | **1.97** | **1.82** | **1.83** | 0.09 | 0.09 | 0.09 | 0.18 | 0.16 | 0.16 | 1.27 | 0.06 | 0.07 | 0.06 | 0.16 | 0.15 | 0.15 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.75 | 0.60 | 0.61 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 138.70 | **2.01** | **1.86** | **1.87** | 0.10 | 0.09 | 0.09 | 0.20 | 0.17 | 0.17 | 1.26 | 0.07 | 0.06 | 0.06 | 0.18 | 0.15 | 0.15 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.80 | 0.65 | 0.66 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 138.77 | **2.08** | **1.93** | **1.94** | 0.10 | 0.09 | 0.09 | 0.21 | 0.17 | 0.17 | 1.28 | 0.06 | 0.06 | 0.06 | 0.18 | 0.15 | 0.15 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.64 | 0.32 | 0.62 | 0.00 | | | | | | 137.46 | **0.92** | 0.60 | **0.90** | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 0.28 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.69 | 0.37 | 0.67 | 0.01 | | 0.01 | 0.01 | | 0.01 | 138.47 | **1.93** | **1.61** | **1.91** | 0.07 | 0.07 | 0.08 | 0.14 | 0.11 | 0.15 | 1.24 | 0.06 | 0.07 | 0.07 | 0.13 | 0.11 | 0.15 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.70 | 0.38 | 0.68 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.54 | **2.00** | **1.68** | **1.98** | 0.08 | 0.07 | 0.08 | 0.16 | 0.12 | 0.16 | 1.30 | 0.07 | 0.06 | 0.07 | 0.15 | 0.11 | 0.15 | Safe | Safe |
| 4607 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.77 | 0.45 | 0.75 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 0.02 | 138.59 | **2.05** | **1.73** | **2.03** | 0.08 | 0.07 | 0.08 | 0.16 | 0.12 | 0.16 | 1.28 | 0.07 | 0.06 | 0.06 | 0.16 | 0.12 | 0.15 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | **0.85** | 0.53 | **0.83** | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 138.66 | **2.12** | **1.80** | **2.10** | 0.08 | 0.08 | 0.09 | 0.17 | 0.14 | 0.19 | 1.27 | 0.06 | 0.07 | 0.07 | 0.15 | 0.14 | 0.17 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | **0.90** | 0.58 | **0.88** | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 138.70 | **2.16** | **1.84** | **2.14** | 0.08 | 0.08 | 0.09 | 0.17 | 0.15 | 0.19 | 1.26 | 0.06 | 0.06 | 0.06 | 0.15 | 0.14 | 0.17 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | **0.95** | 0.63 | **0.93** | 0.03 | 0.02 | 0.03 | 0.03 | 0.01 | 0.03 | 138.77 | **2.23** | **1.91** | **2.21** | 0.09 | 0.08 | 0.09 | 0.20 | 0.15 | 0.20 | 1.28 | 0.06 | 0.06 | 0.06 | 0.17 | 0.14 | 0.17 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | **1.00** | 0.79 | **0.99** | 0.00 | | | | | | 137.46 | **1.28** | **1.07** | **1.27** | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.28 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | **1.05** | **0.84** | **1.04** | 0.01 | | 0.01 | 0.01 | | 0.01 | 138.47 | **2.29** | **2.08** | **2.28** | 0.08 | 0.06 | 0.07 | 0.18 | 0.12 | 0.16 | 1.24 | 0.07 | 0.06 | 0.06 | 0.17 | 0.12 | 0.15 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | **1.06** | **0.85** | **1.05** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.54 | **2.36** | **2.15** | **2.35** | 0.08 | 0.06 | 0.07 | 0.19 | 0.13 | 0.16 | 1.30 | 0.07 | 0.05 | 0.06 | 0.18 | 0.12 | 0.15 | Safe | Safe |
| 4511 | 1.19 | 10 | 21.50 | 20 | 137.31 | **1.13** | **0.92** | **1.12** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.59 | **2.41** | **2.20** | **2.40** | 0.08 | 0.06 | 0.08 | 0.19 | 0.13 | 0.19 | 1.28 | 0.07 | 0.05 | 0.07 | 0.18 | 0.12 | 0.18 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | **1.21** | **1.00** | **1.20** | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 138.66 | **2.48** | **2.27** | **2.47** | 0.08 | 0.07 | 0.08 | 0.20 | 0.16 | 0.20 | 1.27 | 0.06 | 0.06 | 0.06 | 0.17 | 0.15 | 0.17 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | **1.26** | **1.05** | **1.25** | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 138.70 | **2.52** | **2.31** | **2.51** | 0.08 | 0.07 | 0.08 | 0.20 | 0.16 | 0.20 | 1.26 | 0.06 | 0.05 | 0.06 | 0.18 | 0.14 | 0.18 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | **1.31** | **1.10** | **1.30** | 0.03 | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 | 138.77 | **2.59** | **2.38** | **2.58** | 0.09 | 0.07 | 0.08 | 0.23 | 0.17 | 0.21 | 1.28 | 0.06 | 0.05 | 0.06 | 0.19 | 0.14 | 0.18 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | **1.30** | **1.21** | **1.28** | 0.00 | | | | | | 137.46 | **1.58** | **1.49** | **1.56** | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.28 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | **1.35** | **1.26** | **1.33** | | | | | | | 138.47 | **2.59** | **2.50** | **2.57** | 0.04 | 0.03 | 0.04 | 0.10 | 0.08 | 0.10 | 1.24 | 0.04 | 0.03 | 0.04 | 0.10 | 0.08 | 0.10 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | **1.36** | **1.27** | **1.34** | | | | | | | 138.54 | **2.66** | **2.57** | **2.64** | 0.04 | 0.04 | 0.04 | 0.11 | 0.10 | 0.11 | 1.30 | 0.04 | 0.04 | 0.04 | 0.11 | 0.10 | 0.11 | Safe | Safe |
| 4400 | 1.19 | 10 | 21.50 | 20 | 137.31 | **1.43** | **1.34** | **1.41** | 0.01 | | 0.01 | 0.01 | | 0.01 | 138.59 | **2.71** | **2.62** | **2.69** | 0.04 | 0.04 | 0.04 | 0.11 | 0.10 | 0.11 | 1.28 | 0.03 | 0.04 | 0.03 | 0.09 | 0.10 | 0.09 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | **1.51** | **1.42** | **1.49** | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.66 | **2.78** | **2.69** | **2.76** | 0.05 | 0.04 | 0.04 | 0.14 | 0.11 | 0.11 | 1.27 | 0.04 | 0.03 | 0.03 | 0.12 | 0.09 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | **1.56** | **1.47** | **1.54** | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 138.70 | **2.82** | **2.73** | **2.80** | 0.05 | 0.04 | 0.04 | 0.14 | 0.11 | 0.11 | 1.26 | 0.04 | 0.03 | 0.03 | 0.13 | 0.09 | 0.10 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | **1.61** | **1.52** | **1.59** | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.77 | **2.89** | **2.80** | **2.87** | 0.05 | 0.04 | 0.05 | 0.14 | 0.11 | 0.14 | 1.28 | 0.04 | 0.03 | 0.04 | 0.13 | 0.10 | 0.13 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.30 | 0.26 | 0.30 | 0.00 | | | | | | 137.46 | 0.58 | 0.54 | 0.58 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.28 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.35 | 0.31 | 0.35 | | | | | | | 138.47 | **1.59** | **1.55** | **1.59** | 0.04 | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 | 1.24 | 0.04 | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.36 | 0.32 | 0.36 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.54 | **1.66** | **1.62** | **1.66** | 0.04 | 0.04 | 0.04 | 0.07 | 0.06 | 0.07 | 1.30 | 0.03 | 0.03 | 0.03 | 0.06 | 0.06 | 0.06 | Safe | Safe |
| 4280 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.43 | 0.39 | 0.43 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.59 | **1.71** | **1.67** | **1.71** | 0.04 | 0.04 | 0.04 | 0.07 | 0.07 | 0.07 | 1.28 | 0.03 | 0.03 | 0.03 | 0.06 | 0.06 | 0.06 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.51 | 0.47 | 0.51 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.66 | **1.78** | **1.74** | **1.78** | 0.04 | 0.04 | 0.04 | 0.07 | 0.07 | 0.07 | 1.27 | 0.03 | 0.03 | 0.03 | 0.07 | 0.06 | 0.07 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.56 | 0.52 | 0.56 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.70 | **1.82** | **1.78** | **1.82** | 0.05 | 0.04 | 0.04 | 0.09 | 0.07 | 0.07 | 1.26 | 0.04 | 0.03 | 0.03 | 0.09 | 0.07 | 0.07 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.61 | 0.57 | 0.61 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 138.77 | **1.89** | **1.85** | **1.89** | 0.05 | 0.04 | 0.04 | 0.09 | 0.07 | 0.08 | 1.28 | 0.03 | 0.03 | 0.02 | 0.08 | 0.07 | 0.06 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.79 | 0.46 | 0.43 | 0.01 | | | 0.01 | | | 137.46 | **1.07** | 0.74 | 0.71 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.28 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | **0.84** | 0.51 | 0.48 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 138.47 | **2.08** | **1.75** | **1.72** | 0.06 | 0.03 | 0.05 | 0.12 | 0.05 | 0.09 | 1.24 | 0.05 | 0.02 | 0.04 | 0.12 | 0.05 | 0.08 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | **0.85** | 0.52 | 0.49 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 138.54 | **2.15** | **1.82** | **1.79** | 0.06 | 0.03 | 0.05 | 0.13 | 0.05 | 0.09 | 1.30 | 0.04 | 0.02 | 0.04 | 0.11 | 0.05 | 0.08 | Safe | Safe |

**Whitney Dam HEC-RAS Model Results**
**Steady Flow Scenarios**

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) Channel | Water Depth (m) L. Overbank | Water Depth (m) R. Overbank | Velocity (m/s) Channel | Velocity (m/s) L. Overbank | Velocity (m/s) R. Overbank | Hazard Rating (2x2 Rule) Channel | Hazard Rating (2x2 Rule) L. Overbank | Hazard Rating (2x2 Rule) R. Overbank | Water Level (m) | Water Depth (m) Channel | Water Depth (m) L. Overbank | Water Depth (m) R. Overbank | Velocity (m/s) Channel | Velocity (m/s) L. Overbank | Velocity (m/s) R. Overbank | Hazard Rating (2x2 Rule) Channel | Hazard Rating (2x2 Rule) L. Overbank | Hazard Rating (2x2 Rule) R. Overbank | Water Depth (m) | Velocity (m/s) Channel | Velocity (m/s) L. Overbank | Velocity (m/s) R. Overbank | Hazard Rating (2x2 Rule) Channel | Hazard Rating (2x2 Rule) L. Overbank | Hazard Rating (2x2 Rule) R. Overbank | | |
| 4194 | 1.19 | 10 | 21.50 | 20 | 137.31 | **0.92** | 0.59 | 0.56 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 138.59 | **2.20** | **1.87** | **1.84** | 0.06 | 0.03 | 0.05 | 0.13 | 0.06 | 0.09 | 1.28 | 0.04 | 0.01 | 0.04 | 0.11 | 0.04 | 0.09 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | **1.00** | 0.67 | 0.64 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 138.66 | **2.27** | **1.94** | **1.91** | 0.06 | 0.03 | 0.06 | 0.14 | 0.06 | 0.11 | 1.27 | 0.03 | 0.01 | 0.04 | 0.11 | 0.04 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | **1.05** | 0.72 | 0.69 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 138.70 | **2.31** | **1.98** | **1.95** | 0.07 | 0.03 | 0.06 | 0.16 | 0.06 | 0.12 | 1.26 | 0.04 | 0.01 | 0.04 | 0.13 | 0.04 | 0.10 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | **1.10** | 0.77 | 0.74 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 138.77 | **2.38** | **2.05** | **2.02** | 0.07 | 0.03 | 0.06 | 0.17 | 0.06 | 0.12 | 1.28 | 0.04 | 0.01 | 0.04 | 0.13 | 0.05 | 0.11 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.33 | 0.32 | 0.30 | 0.01 | 0.01 | | 0.00 | 0.00 | | 137.46 | 0.61 | 0.60 | 0.58 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.28 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.38 | 0.37 | 0.35 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.47 | **1.62** | **1.61** | **1.59** | 0.06 | 0.05 | 0.06 | 0.10 | 0.08 | 0.10 | 1.24 | 0.05 | 0.04 | 0.05 | 0.09 | 0.08 | 0.09 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.39 | 0.38 | 0.36 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 138.54 | **1.69** | **1.68** | **1.66** | 0.06 | 0.06 | 0.06 | 0.10 | 0.10 | 0.10 | 1.30 | 0.04 | 0.05 | 0.05 | 0.09 | 0.10 | 0.10 | Safe | Safe |
| 4076 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.46 | 0.45 | 0.43 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.59 | **1.74** | **1.73** | **1.71** | 0.06 | 0.06 | 0.06 | 0.10 | 0.10 | 0.10 | 1.28 | 0.04 | 0.04 | 0.04 | 0.10 | 0.09 | 0.09 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.54 | 0.53 | 0.51 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.66 | **1.81** | **1.80** | **1.78** | 0.06 | 0.06 | 0.06 | 0.11 | 0.11 | 0.11 | 1.27 | 0.04 | 0.04 | 0.04 | 0.10 | 0.10 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.59 | 0.58 | 0.56 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.70 | **1.85** | **1.84** | **1.82** | 0.07 | 0.06 | 0.06 | 0.13 | 0.11 | 0.11 | 1.26 | 0.04 | 0.04 | 0.04 | 0.11 | 0.10 | 0.10 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.64 | 0.63 | 0.61 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 138.77 | **1.92** | **1.91** | **1.89** | 0.07 | 0.06 | 0.06 | 0.13 | 0.11 | 0.11 | 1.28 | 0.04 | 0.03 | 0.03 | 0.12 | 0.10 | 0.10 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.18 | 0.27 | 0.27 | 0.23 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 137.45 | 0.54 | 0.54 | 0.50 | 0.07 | 0.06 | 0.06 | 0.04 | 0.03 | 0.03 | 0.27 | 0.05 | 0.04 | 0.05 | 0.03 | 0.03 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.32 | 0.32 | 0.28 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.47 | **1.56** | **1.56** | **1.52** | 0.12 | 0.09 | 0.10 | 0.19 | 0.14 | 0.15 | 1.24 | 0.09 | 0.07 | 0.08 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.24 | 0.33 | 0.33 | 0.29 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 138.53 | **1.62** | **1.62** | **1.58** | 0.12 | 0.09 | 0.10 | 0.19 | 0.15 | 0.16 | 1.29 | 0.07 | 0.05 | 0.07 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| 4002 | 1.19 | 10 | 21.50 | 20 | 137.31 | 0.40 | 0.40 | 0.36 | 0.05 | 0.05 | 0.04 | 0.02 | 0.02 | 0.01 | 138.58 | **1.67** | **1.67** | **1.63** | 0.12 | 0.09 | 0.10 | 0.20 | 0.15 | 0.16 | 1.27 | 0.07 | 0.04 | 0.06 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.39 | 0.48 | 0.48 | 0.44 | 0.06 | 0.06 | 0.05 | 0.03 | 0.03 | 0.02 | 138.66 | **1.75** | **1.75** | **1.71** | 0.12 | 0.09 | 0.10 | 0.21 | 0.16 | 0.17 | 1.27 | 0.06 | 0.03 | 0.05 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.44 | 0.53 | 0.53 | 0.49 | 0.07 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 138.70 | **1.79** | **1.79** | **1.75** | 0.12 | 0.09 | 0.10 | 0.21 | 0.16 | 0.18 | 1.26 | 0.05 | 0.03 | 0.05 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.49 | 0.58 | 0.58 | 0.54 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.03 | 138.77 | **1.86** | **1.86** | **1.82** | 0.12 | 0.09 | 0.10 | 0.22 | 0.17 | 0.18 | 1.28 | 0.04 | 0.02 | 0.04 | 0.18 | 0.13 | 0.15 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.34 | 0.09 | 0.11 | 0.04 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 137.45 | 0.62 | 0.37 | 0.39 | 0.09 | 0.06 | 0.06 | 0.06 | 0.02 | 0.02 | 0.28 | 0.05 | 0.03 | 0.04 | 0.04 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.40 | 0.15 | 0.17 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 138.47 | **1.64** | **1.39** | **1.41** | 0.11 | 0.09 | 0.10 | 0.18 | 0.13 | 0.14 | 1.24 | 0.06 | 0.05 | 0.07 | 0.16 | 0.12 | 0.14 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.40 | 0.15 | 0.17 | 0.09 | 0.06 | 0.05 | 0.04 | 0.01 | 0.01 | 138.53 | **1.70** | **1.45** | **1.47** | 0.11 | 0.09 | 0.10 | 0.19 | 0.13 | 0.15 | 1.30 | 0.02 | 0.03 | 0.05 | 0.15 | 0.12 | 0.14 | Safe | Safe |
| 3879 | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.47 | 0.22 | 0.24 | 0.08 | 0.06 | 0.05 | 0.04 | 0.01 | 0.01 | 138.58 | **1.75** | **1.50** | **1.52** | 0.11 | 0.09 | 0.10 | 0.19 | 0.14 | 0.15 | 1.28 | 0.03 | 0.03 | 0.05 | 0.15 | 0.12 | 0.14 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.55 | 0.30 | 0.32 | 0.08 | 0.06 | 0.06 | 0.04 | 0.02 | 0.02 | 138.65 | **1.82** | **1.57** | **1.59** | 0.12 | 0.09 | 0.10 | 0.22 | 0.14 | 0.16 | 1.27 | 0.04 | 0.03 | 0.04 | 0.17 | 0.12 | 0.14 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.60 | 0.35 | 0.37 | 0.09 | 0.06 | 0.06 | 0.05 | 0.02 | 0.02 | 138.69 | **1.86** | **1.61** | **1.63** | 0.12 | 0.09 | 0.11 | 0.22 | 0.14 | 0.18 | 1.26 | 0.03 | 0.03 | 0.05 | 0.17 | 0.12 | 0.16 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.65 | 0.40 | 0.42 | 0.09 | 0.06 | 0.06 | 0.06 | 0.02 | 0.03 | 138.76 | **1.93** | **1.68** | **1.70** | 0.12 | 0.09 | 0.11 | 0.23 | 0.15 | 0.19 | 1.28 | 0.03 | 0.03 | 0.05 | 0.17 | 0.13 | 0.16 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.78 | 0.66 | 0.56 | 0.00 | | | | | | 137.45 | **1.06** | **0.94** | **0.84** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.28 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | **0.84** | 0.72 | 0.62 | | | | | | | 138.46 | **2.07** | **1.95** | **1.85** | 0.05 | 0.05 | 0.04 | 0.10 | 0.10 | 0.07 | 1.23 | 0.05 | 0.05 | 0.04 | 0.10 | 0.10 | 0.07 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | **0.84** | 0.72 | 0.62 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.53 | **2.14** | **2.02** | **1.92** | 0.05 | 0.05 | 0.04 | 0.11 | 0.10 | 0.08 | 1.30 | 0.04 | 0.04 | 0.03 | 0.10 | 0.09 | 0.07 | Safe | Safe |
| 3753 | 1.19 | 10 | 21.50 | 20 | 137.30 | **0.91** | 0.79 | 0.69 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.58 | **2.19** | **2.07** | **1.97** | 0.05 | 0.05 | 0.05 | 0.11 | 0.10 | 0.10 | 1.28 | 0.04 | 0.04 | 0.04 | 0.10 | 0.10 | 0.09 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | **0.99** | **0.87** | 0.77 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.65 | **2.26** | **2.14** | **2.04** | 0.06 | 0.05 | 0.05 | 0.14 | 0.11 | 0.10 | 1.27 | 0.05 | 0.04 | 0.04 | 0.13 | 0.10 | 0.09 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | **1.04** | **0.92** | **0.82** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.69 | **2.30** | **2.18** | **2.08** | 0.06 | 0.06 | 0.05 | 0.14 | 0.13 | 0.10 | 1.26 | 0.05 | 0.05 | 0.04 | 0.13 | 0.12 | 0.10 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | **1.09** | **0.97** | **0.87** | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 138.76 | **2.37** | **2.25** | **2.15** | 0.06 | 0.06 | 0.05 | 0.14 | 0.14 | 0.11 | 1.28 | 0.04 | 0.04 | 0.04 | 0.12 | 0.12 | 0.10 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.55 | 0.55 | 0.55 | 0.00 | | | | | | 137.45 | **0.83** | **0.83** | **0.83** | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.28 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.61 | 0.61 | 0.61 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.46 | **1.84** | **1.84** | **1.84** | 0.09 | 0.10 | 0.06 | 0.17 | 0.18 | 0.11 | 1.23 | 0.08 | 0.09 | 0.05 | 0.16 | 0.18 | 0.10 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.61 | 0.61 | 0.61 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.53 | **1.91** | **1.91** | **1.91** | 0.09 | 0.10 | 0.07 | 0.17 | 0.19 | 0.13 | 1.30 | 0.08 | 0.09 | 0.06 | 0.17 | 0.18 | 0.13 | Safe | Safe |
| 3562 | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.68 | 0.68 | 0.68 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 138.58 | **1.96** | **1.96** | **1.96** | 0.09 | 0.10 | 0.07 | 0.18 | 0.20 | 0.14 | 1.28 | 0.08 | 0.08 | 0.06 | 0.17 | 0.18 | 0.13 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.76 | 0.76 | 0.76 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 138.65 | **2.03** | **2.03** | **2.03** | 0.10 | 0.10 | 0.07 | 0.20 | 0.20 | 0.14 | 1.27 | 0.08 | 0.07 | 0.05 | 0.19 | 0.18 | 0.13 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | **0.81** | **0.81** | **0.81** | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 138.69 | **2.07** | **2.07** | **2.07** | 0.10 | 0.10 | 0.07 | 0.21 | 0.21 | 0.14 | 1.26 | 0.08 | 0.07 | 0.05 | 0.19 | 0.18 | 0.13 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | **0.86** | **0.86** | **0.86** | 0.03 | 0.04 | 0.02 | 0.03 | 0.03 | 0.02 | 138.76 | **2.14** | **2.14** | **2.14** | 0.10 | 0.10 | 0.08 | 0.21 | 0.21 | 0.17 | 1.28 | 0.07 | 0.06 | 0.06 | 0.19 | 0.18 | 0.15 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.33 | | | 0.02 | 0.02 | | 0.01 | | | 137.45 | 0.61 | 0.12 | 0.22 | 0.08 | 0.08 | 0.03 | 0.05 | 0.01 | 0.01 | 0.28 | 0.06 | 0.06 | 0.03 | 0.04 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.39 | | | 0.02 | 0.03 | | 0.01 | | | 138.46 | **1.62** | **1.13** | **1.23** | 0.16 | 0.16 | 0.08 | 0.26 | 0.18 | 0.10 | 1.23 | 0.14 | 0.13 | 0.08 | 0.25 | 0.18 | 0.10 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.39 | | | 0.04 | 0.05 | | 0.02 | | | 138.53 | **1.69** | **1.20** | **1.30** | 0.16 | 0.16 | 0.09 | 0.27 | 0.19 | 0.12 | 1.30 | 0.12 | 0.11 | 0.09 | 0.25 | 0.20 | 0.12 | Safe | Safe |
| 3476 | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.46 | | 0.07 | 0.05 | 0.06 | 0.01 | 0.02 | | 0.00 | 138.58 | **1.74** | **1.25** | **1.35** | 0.16 | 0.16 | 0.09 | 0.28 | 0.20 | 0.12 | 1.28 | 0.11 | 0.10 | 0.08 | 0.26 | 0.20 | 0.12 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.54 | 0.05 | 0.15 | 0.07 | 0.07 | 0.02 | 0.04 | 0.00 | 0.00 | 138.65 | **1.81** | **1.32** | **1.42** | 0.17 | 0.16 | 0.10 | 0.31 | 0.21 | 0.14 | 1.27 | 0.10 | 0.09 | 0.08 | 0.27 | 0.21 | 0.14 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.59 | 0.10 | 0.20 | 0.07 | 0.08 | 0.03 | 0.04 | 0.01 | 0.01 | 138.69 | **1.85** | **1.36** | **1.46** | 0.17 | 0.16 | 0.10 | 0.31 | 0.22 | 0.15 | 1.26 | 0.10 | 0.08 | 0.07 | 0.27 | 0.21 | 0.14 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.64 | 0.15 | 0.25 | 0.08 | 0.09 | 0.03 | 0.05 | 0.01 | 0.01 | 138.76 | **1.92** | **1.43** | **1.53** | 0.17 | 0.16 | 0.10 | 0.33 | 0.23 | 0.15 | 1.28 | 0.09 | 0.07 | 0.07 | 0.28 | 0.22 | 0.15 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | **3.25** | **1.12** | **0.88** | 0.00 | | | | | | 137.45 | **3.53** | **1.40** | **1.16** | 0.01 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | 0.28 | 0.01 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | **3.31** | **1.18** | **0.94** | | | | | | | 138.46 | **4.54** | **2.41** | **2.17** | 0.04 | 0.04 | 0.04 | 0.18 | 0.10 | 0.09 | 1.23 | 0.04 | 0.04 | 0.04 | 0.18 | 0.10 | 0.09 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | **3.31** | **1.18** | **0.94** | | | | | | | 138.53 | **4.61** | **2.48** | **2.24** | 0.04 | 0.04 | 0.04 | 0.18 | 0.10 | 0.09 | 1.30 | 0.04 | 0.04 | 0.04 | 0.18 | 0.10 | 0.09 | Safe | Safe |
| 3342 | 1.19 | 10 | 21.50 | 20 | 137.30 | **3.38** | **1.25** | **1.01** | 0.01 | | | 0.03 | | | 138.58 | **4.66** | **2.53** | **2.29** | 0.04 | 0.04 | 0.04 | 0.19 | 0.10 | 0.09 | 1.28 | 0.03 | 0.04 | 0.04 | 0.15 | 0.10 | 0.09 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | **3.46** | **1.33** | **1.09** | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 138.65 | **4.73** | **2.60** | **2.36** | 0.05 | 0.04 | 0.04 | 0.24 | 0.10 | 0.09 | 1.27 | 0.04 | 0.03 | 0.03 | 0.20 | 0.09 | 0.08 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | **3.51** | **1.38** | **1.14** | 0.01 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | 138.69 | **4.77** | **2.64** | **2.40** | 0.05 | 0.04 | 0.04 | 0.24 | 0.11 | 0.10 | 1.26 | 0.04 | 0.03 | 0.03 | 0.20 | 0.09 | 0.08 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | **3.56** | **1.43** | **1.19** | 0.01 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | 138.76 | **4.84** | **2.71** | **2.47** | 0.05 | 0.04 | 0.04 | 0.24 | 0.11 | 0.10 | 1.28 | 0.04 | 0.03 | 0.03 | 0.21 | 0.09 | 0.09 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.59 | 0.57 | 0.54 | 0.00 | | | | | | 137.45 | **0.87** | **0.85** | **0.82** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.28 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.65 | 0.63 | 0.60 | | | | | | | 138.46 | **1.88** | **1.86** | **1.83** | 0.04 | 0.03 | 0.04 | 0.08 | 0.06 | 0.07 | 1.23 | 0.04 | 0.03 | 0.04 | 0.08 | 0.06 | 0.07 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.65 | 0.63 | 0.60 | | | 0.01 | | | 0.01 | 138.53 | **1.95** | **1.93** | **1.90** | 0.04 | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 1.30 | 0.04 | 0.04 | 0.03 | 0.08 | 0.08 | 0.07 | Safe | Safe |
| 3206 | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.72 | 0.70 | 0.67 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.58 | **2.00** | **1.98** | **1.95** | 0.04 | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 1.28 | 0.03 | 0.03 | 0.03 | 0.07 | 0.07 | 0.07 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.80 | 0.78 | 0.75 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.65 | **2.07** | **2.05** | **2.02** | 0.04 | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 1.27 | 0.03 | 0.03 | 0.03 | 0.07 | 0.07 | 0.07 | Safe | Safe |

**Whitney Dam HEC-RAS Model Results**
**Steady Flow Scenarios**

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Depth (m) | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | | |
| | | | | | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.85 | 0.83 | 0.80 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.69 | 2.11 | 2.09 | 2.06 | 0.04 | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 1.26 | 0.03 | 0.03 | 0.03 | 0.08 | 0.08 | 0.07 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.90 | 0.88 | 0.85 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.76 | 2.18 | 2.16 | 2.13 | 0.04 | 0.04 | 0.04 | 0.09 | 0.09 | 0.09 | 1.28 | 0.03 | 0.03 | 0.03 | 0.08 | 0.08 | 0.08 | Safe | Safe |
| 3085 | 0.22 | Sunny | 2.4 | 2 | 137.17 | 1.51 | 0.89 | 0.65 | 0.01 | | | 0.02 | | | 137.45 | 1.79 | 1.17 | 0.93 | 0.04 | 0.02 | 0.02 | 0.07 | 0.02 | 0.02 | 0.28 | 0.03 | 0.02 | 0.02 | 0.06 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 1.57 | 0.95 | 0.71 | 0.01 | | 0.01 | 0.02 | | 0.01 | 138.46 | 2.80 | 2.18 | 1.94 | 0.10 | 0.07 | 0.07 | 0.28 | 0.15 | 0.14 | 1.23 | 0.09 | 0.07 | 0.06 | 0.26 | 0.15 | 0.13 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 1.57 | 0.95 | 0.71 | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 138.53 | 2.87 | 2.25 | 2.01 | 0.10 | 0.07 | 0.08 | 0.29 | 0.16 | 0.16 | 1.30 | 0.08 | 0.06 | 0.07 | 0.26 | 0.15 | 0.15 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.30 | 1.64 | 1.02 | 0.78 | 0.03 | 0.01 | 0.01 | 0.05 | 0.01 | 0.01 | 138.58 | 2.92 | 2.30 | 2.06 | 0.10 | 0.07 | 0.08 | 0.29 | 0.16 | 0.16 | 1.28 | 0.07 | 0.06 | 0.07 | 0.24 | 0.15 | 0.16 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 1.72 | 1.10 | 0.86 | 0.04 | 0.02 | 0.02 | 0.07 | 0.02 | 0.02 | 138.65 | 2.99 | 2.37 | 2.13 | 0.10 | 0.07 | 0.08 | 0.30 | 0.17 | 0.17 | 1.27 | 0.06 | 0.05 | 0.06 | 0.23 | 0.14 | 0.15 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 1.77 | 1.15 | 0.91 | 0.04 | 0.02 | 0.02 | 0.07 | 0.02 | 0.02 | 138.69 | 3.03 | 2.41 | 2.17 | 0.10 | 0.07 | 0.08 | 0.30 | 0.17 | 0.17 | 1.26 | 0.06 | 0.05 | 0.06 | 0.23 | 0.15 | 0.16 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 1.82 | 1.20 | 0.96 | 0.05 | 0.02 | 0.03 | 0.09 | 0.02 | 0.03 | 138.76 | 3.10 | 2.48 | 2.24 | 0.11 | 0.08 | 0.08 | 0.34 | 0.20 | 0.18 | 1.28 | 0.06 | 0.06 | 0.05 | 0.25 | 0.17 | 0.15 | Safe | Safe |
| 2912 | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.40 | 0.38 | 0.38 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.44 | 0.67 | 0.65 | 0.65 | 0.04 | 0.03 | 0.04 | 0.03 | 0.02 | 0.03 | 0.27 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.46 | 0.44 | 0.44 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.46 | 1.69 | 1.67 | 1.67 | 0.10 | 0.09 | 0.09 | 0.17 | 0.15 | 0.15 | 1.23 | 0.09 | 0.08 | 0.08 | 0.16 | 0.15 | 0.15 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.46 | 0.44 | 0.44 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.52 | 1.75 | 1.73 | 1.73 | 0.10 | 0.09 | 0.09 | 0.18 | 0.16 | 0.16 | 1.29 | 0.08 | 0.07 | 0.07 | 0.17 | 0.15 | 0.15 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.53 | 0.51 | 0.51 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.57 | 1.80 | 1.78 | 1.78 | 0.10 | 0.09 | 0.09 | 0.18 | 0.16 | 0.16 | 1.27 | 0.07 | 0.07 | 0.07 | 0.16 | 0.15 | 0.15 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.61 | 0.59 | 0.59 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 138.65 | 1.88 | 1.86 | 1.86 | 0.11 | 0.10 | 0.09 | 0.21 | 0.19 | 0.17 | 1.27 | 0.08 | 0.07 | 0.06 | 0.19 | 0.17 | 0.15 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.66 | 0.64 | 0.64 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 138.69 | 1.92 | 1.90 | 1.90 | 0.11 | 0.10 | 0.09 | 0.21 | 0.19 | 0.17 | 1.26 | 0.07 | 0.07 | 0.06 | 0.18 | 0.17 | 0.15 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.71 | 0.69 | 0.69 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 138.75 | 1.98 | 1.96 | 1.96 | 0.11 | 0.10 | 0.10 | 0.22 | 0.20 | 0.20 | 1.27 | 0.07 | 0.06 | 0.06 | 0.19 | 0.17 | 0.17 | Safe | Safe |
| 2806 | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.46 | 0.44 | 0.34 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.44 | 0.73 | 0.71 | 0.61 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.27 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.52 | 0.50 | 0.40 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 138.45 | 1.74 | 1.72 | 1.62 | 0.14 | 0.12 | 0.14 | 0.24 | 0.21 | 0.23 | 1.22 | 0.12 | 0.11 | 0.13 | 0.23 | 0.20 | 0.22 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.52 | 0.50 | 0.40 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.52 | 1.81 | 1.79 | 1.69 | 0.15 | 0.13 | 0.14 | 0.27 | 0.23 | 0.24 | 1.29 | 0.12 | 0.11 | 0.12 | 0.26 | 0.22 | 0.23 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.59 | 0.57 | 0.47 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 138.57 | 1.86 | 1.84 | 1.74 | 0.15 | 0.13 | 0.14 | 0.28 | 0.24 | 0.24 | 1.27 | 0.11 | 0.10 | 0.11 | 0.26 | 0.22 | 0.23 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.67 | 0.65 | 0.55 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 138.64 | 1.93 | 1.91 | 1.81 | 0.15 | 0.13 | 0.15 | 0.29 | 0.25 | 0.27 | 1.26 | 0.11 | 0.09 | 0.11 | 0.26 | 0.22 | 0.25 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.72 | 0.70 | 0.60 | 0.05 | 0.04 | 0.05 | 0.04 | 0.03 | 0.03 | 138.68 | 1.97 | 1.95 | 1.85 | 0.16 | 0.13 | 0.15 | 0.32 | 0.25 | 0.28 | 1.25 | 0.11 | 0.09 | 0.10 | 0.28 | 0.23 | 0.25 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.77 | 0.75 | 0.65 | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 138.75 | 2.04 | 2.02 | 1.92 | 0.16 | 0.14 | 0.15 | 0.33 | 0.28 | 0.29 | 1.27 | 0.10 | 0.09 | 0.10 | 0.28 | 0.25 | 0.26 | Safe | Safe |
| 2755 | 0.22 | Sunny | 2.4 | 2 | 137.17 | 0.37 | 0.28 | 0.34 | 0.01 | | | 0.00 | | | 137.44 | 0.64 | 0.55 | 0.61 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.27 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.23 | 0.43 | 0.34 | 0.40 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.45 | 1.65 | 1.56 | 1.62 | 0.13 | 0.09 | 0.08 | 0.21 | 0.14 | 0.13 | 1.22 | 0.12 | 0.08 | 0.07 | 0.21 | 0.14 | 0.13 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.23 | 0.43 | 0.34 | 0.40 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 138.52 | 1.72 | 1.63 | 1.69 | 0.13 | 0.09 | 0.09 | 0.22 | 0.15 | 0.15 | 1.29 | 0.11 | 0.08 | 0.07 | 0.22 | 0.14 | 0.14 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.30 | 0.50 | 0.41 | 0.47 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 138.57 | 1.77 | 1.68 | 1.74 | 0.13 | 0.09 | 0.09 | 0.23 | 0.15 | 0.16 | 1.27 | 0.10 | 0.07 | 0.07 | 0.22 | 0.14 | 0.15 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.38 | 0.58 | 0.49 | 0.55 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 138.64 | 1.84 | 1.75 | 1.81 | 0.14 | 0.09 | 0.09 | 0.26 | 0.16 | 0.16 | 1.26 | 0.11 | 0.06 | 0.07 | 0.24 | 0.14 | 0.15 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.43 | 0.63 | 0.54 | 0.60 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 138.68 | 1.88 | 1.79 | 1.85 | 0.14 | 0.09 | 0.09 | 0.26 | 0.16 | 0.17 | 1.25 | 0.10 | 0.06 | 0.06 | 0.24 | 0.14 | 0.15 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.48 | 0.68 | 0.59 | 0.65 | 0.05 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 138.75 | 1.95 | 1.86 | 1.92 | 0.14 | 0.10 | 0.09 | 0.27 | 0.19 | 0.17 | 1.27 | 0.09 | 0.07 | 0.06 | 0.24 | 0.17 | 0.15 | Safe | Safe |
| 2723 | 0.22 | Sunny | 2.4 | 2 | 137.14 | 0.12 | | 0.05 | 0.81 | | 0.46 | 0.10 | | 0.02 | 137.32 | 0.30 | | 0.23 | 1.28 | 0.00 | 0.62 | 0.38 | | 0.14 | 0.18 | 0.47 | 0.00 | 0.16 | 0.29 | 0.00 | 0.12 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 137.18 | 0.16 | | 0.09 | 0.85 | | 0.55 | 0.14 | | 0.05 | 138.44 | 1.42 | 1.11 | 1.35 | 0.58 | 0.26 | 0.29 | 0.82 | 0.29 | 0.39 | 1.26 | -0.27 | 0.26 | -0.26 | 0.69 | 0.29 | 0.34 | Safe | Safe to Not Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.22 | 0.20 | | 0.13 | 0.98 | | 0.61 | 0.20 | | 0.08 | 138.51 | 1.49 | 1.18 | 1.42 | 0.58 | 0.27 | 0.29 | 0.86 | 0.32 | 0.41 | 1.29 | -0.40 | 0.27 | -0.32 | 0.67 | 0.32 | 0.33 | Safe | Safe to Not Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.26 | 0.24 | | 0.17 | 0.97 | | 0.53 | 0.23 | | 0.09 | 138.56 | 1.54 | 1.23 | 1.47 | 0.58 | 0.27 | 0.29 | 0.89 | 0.33 | 0.43 | 1.30 | -0.39 | 0.27 | -0.24 | 0.66 | 0.33 | 0.34 | Safe | Safe to Not Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.30 | 0.28 | | 0.21 | 1.06 | | 0.57 | 0.30 | | 0.12 | 138.63 | 1.61 | 1.30 | 1.54 | 0.57 | 0.27 | 0.29 | 0.92 | 0.35 | 0.45 | 1.33 | -0.49 | 0.27 | -0.28 | 0.62 | 0.35 | 0.33 | Safe | Safe to Not Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.31 | 0.29 | | 0.22 | 1.28 | | 0.68 | 0.37 | | 0.15 | 138.67 | 1.65 | 1.34 | 1.58 | 0.57 | 0.27 | 0.29 | 0.94 | 0.36 | 0.46 | 1.36 | -0.71 | 0.27 | -0.39 | 0.57 | 0.36 | 0.31 | Safe | Safe to Not Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.36 | 0.34 | 0.03 | 0.27 | 1.15 | 0.15 | 0.52 | 0.39 | 0.00 | 0.14 | 138.74 | 1.72 | 1.41 | 1.65 | 0.57 | 0.27 | 0.29 | 0.98 | 0.38 | 0.48 | 1.38 | -0.58 | 0.12 | -0.23 | 0.59 | 0.38 | 0.34 | Safe to Not Safe | Safe to Not Safe |
| 2648 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.21 | | | 0.10 | 0.06 | | 0.02 | | | 137.32 | 0.70 | 0.47 | 0.48 | 0.14 | 0.11 | 0.07 | 0.10 | 0.05 | 0.03 | 0.49 | 0.04 | 0.05 | 0.07 | 0.08 | 0.05 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.93 | 0.31 | 0.08 | 0.09 | 0.09 | 0.07 | 0.03 | 0.03 | 0.01 | 0.00 | 138.44 | 1.82 | 1.59 | 1.60 | 0.26 | 0.21 | 0.10 | 0.47 | 0.33 | 0.16 | 1.51 | 0.17 | 0.14 | 0.07 | 0.45 | 0.33 | 0.16 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.41 | 0.18 | 0.19 | 0.10 | 0.08 | 0.04 | 0.04 | 0.01 | 0.01 | 138.50 | 1.88 | 1.65 | 1.66 | 0.26 | 0.21 | 0.10 | 0.49 | 0.35 | 0.17 | 1.47 | 0.16 | 0.13 | 0.06 | 0.45 | 0.33 | 0.16 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.50 | 0.27 | 0.28 | 0.11 | 0.09 | 0.05 | 0.06 | 0.02 | 0.01 | 138.55 | 1.93 | 1.70 | 1.71 | 0.26 | 0.21 | 0.10 | 0.50 | 0.36 | 0.17 | 1.43 | 0.15 | 0.12 | 0.05 | 0.45 | 0.33 | 0.16 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.61 | 0.38 | 0.39 | 0.12 | 0.10 | 0.07 | 0.07 | 0.04 | 0.03 | 138.62 | 2.00 | 1.77 | 1.78 | 0.27 | 0.22 | 0.10 | 0.54 | 0.39 | 0.18 | 1.39 | 0.15 | 0.12 | 0.03 | 0.47 | 0.35 | 0.15 | Safe to Not Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.67 | 0.44 | 0.45 | 0.13 | 0.10 | 0.07 | 0.09 | 0.04 | 0.03 | 138.67 | 2.05 | 1.82 | 1.83 | 0.27 | 0.22 | 0.10 | 0.55 | 0.40 | 0.18 | 1.38 | 0.14 | 0.12 | 0.03 | 0.47 | 0.36 | 0.15 | Safe to Not Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 0.75 | 0.52 | 0.53 | 0.14 | 0.11 | 0.08 | 0.11 | 0.06 | 0.04 | 138.73 | 2.11 | 1.88 | 1.89 | 0.27 | 0.22 | 0.11 | 0.57 | 0.41 | 0.21 | 1.36 | 0.13 | 0.11 | 0.03 | 0.46 | 0.36 | 0.17 | Safe to Not Safe | Safe |
| 2483 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.31 | 0.12 | 0.29 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.31 | 0.79 | 0.60 | 0.77 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.48 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.40 | 0.21 | 0.38 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.43 | 1.91 | 1.72 | 1.89 | 0.06 | 0.06 | 0.06 | 0.11 | 0.10 | 0.11 | 1.51 | 0.05 | 0.05 | 0.05 | 0.11 | 0.10 | 0.11 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.51 | 0.32 | 0.49 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 138.50 | 1.98 | 1.79 | 1.96 | 0.07 | 0.06 | 0.06 | 0.14 | 0.11 | 0.12 | 1.47 | 0.05 | 0.05 | 0.05 | 0.13 | 0.10 | 0.11 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.60 | 0.41 | 0.58 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 138.55 | 2.03 | 1.84 | 2.01 | 0.07 | 0.06 | 0.06 | 0.14 | 0.11 | 0.12 | 1.43 | 0.05 | 0.05 | 0.04 | 0.13 | 0.11 | 0.11 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.71 | 0.52 | 0.69 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.62 | 2.10 | 1.91 | 2.08 | 0.07 | 0.07 | 0.07 | 0.15 | 0.13 | 0.15 | 1.39 | 0.05 | 0.05 | 0.05 | 0.13 | 0.12 | 0.13 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.77 | 0.58 | 0.75 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 138.67 | 2.15 | 1.96 | 2.13 | 0.07 | 0.07 | 0.07 | 0.15 | 0.14 | 0.15 | 1.38 | 0.05 | 0.05 | 0.05 | 0.14 | 0.13 | 0.13 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 0.85 | 0.66 | 0.83 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.02 | 138.73 | 2.21 | 2.02 | 2.19 | 0.07 | 0.07 | 0.07 | 0.15 | 0.14 | 0.15 | 1.36 | 0.04 | 0.05 | 0.05 | 0.13 | 0.13 | 0.14 | Safe | Safe |
| 2196 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 1.28 | 0.92 | 1.02 | 0.00 | | | | | | 137.31 | 1.76 | 1.40 | 1.50 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.48 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 1.37 | 1.01 | 1.11 | | | | | | | 138.43 | 2.88 | 2.52 | 2.62 | 0.04 | 0.03 | 0.03 | 0.12 | 0.08 | 0.08 | 1.51 | 0.04 | 0.03 | 0.03 | 0.12 | 0.08 | 0.08 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.48 | 1.12 | 1.22 | 0.01 | | | 0.01 | | | 138.50 | 2.95 | 2.59 | 2.69 | 0.04 | 0.03 | 0.04 | 0.12 | 0.08 | 0.11 | 1.47 | 0.03 | 0.03 | 0.04 | 0.10 | 0.08 | 0.11 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.57 | 1.21 | 1.31 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.55 | 3.00 | 2.64 | 2.74 | 0.04 | 0.04 | 0.04 | 0.12 | 0.11 | 0.11 | 1.43 | 0.03 | 0.03 | 0.03 | 0.10 | 0.09 | 0.10 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.68 | 1.32 | 1.42 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.62 | 3.07 | 2.71 | 2.81 | 0.04 | 0.04 | 0.04 | 0.12 | 0.11 | 0.11 | 1.39 | 0.03 | 0.03 | 0.03 | 0.11 | 0.10 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.74 | 1.38 | 1.48 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.67 | 3.12 | 2.76 | 2.86 | 0.05 | 0.04 | 0.04 | 0.16 | 0.11 | 0.11 | 1.38 | 0.04 | 0.03 | 0.03 | 0.14 | 0.10 | 0.10 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.82 | 1.46 | 1.56 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 138.73 | 3.18 | 2.82 | 2.92 | 0.05 | 0.04 | 0.04 | 0.16 | 0.11 | 0.12 | 1.36 | 0.04 | 0.03 | 0.03 | 0.14 | 0.10 | 0.10 | Safe | Safe |
| | 0.22 | Sunny | 2.4 | 2 | 136.83 | 1.36 | 1.20 | 1.23 | 0.00 | | | | | | 137.31 | 1.84 | 1.68 | 1.71 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.48 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | Safe | Safe |

**Whitney Dam HEC-RAS Model Results**
**Steady Flow Scenarios**

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Depth (m) | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | | |
| | | | | | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | |
| 2082 | 0.44 | 2 | 19.00 | 19 | 136.92 | 1.45 | 1.29 | 1.32 | | | | | | | 138.43 | 2.96 | 2.80 | 2.83 | 0.04 | 0.03 | 0.04 | 0.12 | 0.08 | 0.11 | 1.51 | 0.04 | 0.03 | 0.04 | 0.12 | 0.08 | 0.11 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.56 | 1.40 | 1.43 | 0.01 | | | 0.02 | | | 138.50 | 3.03 | 2.87 | 2.90 | 0.04 | 0.03 | 0.04 | 0.12 | 0.09 | 0.12 | 1.47 | 0.03 | 0.03 | 0.04 | 0.11 | 0.09 | 0.12 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.65 | 1.49 | 1.52 | 0.01 | | 0.01 | 0.02 | | 0.02 | 138.55 | 3.08 | 2.92 | 2.95 | 0.05 | 0.03 | 0.04 | 0.15 | 0.09 | 0.12 | 1.43 | 0.04 | 0.03 | 0.03 | 0.14 | 0.09 | 0.10 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.76 | 1.60 | 1.63 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.62 | 3.15 | 2.99 | 3.02 | 0.05 | 0.04 | 0.04 | 0.16 | 0.12 | 0.12 | 1.39 | 0.04 | 0.03 | 0.03 | 0.14 | 0.10 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.82 | 1.66 | 1.69 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.67 | 3.20 | 3.04 | 3.07 | 0.05 | 0.04 | 0.04 | 0.16 | 0.12 | 0.12 | 1.38 | 0.04 | 0.03 | 0.03 | 0.14 | 0.11 | 0.11 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.90 | 1.74 | 1.77 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.73 | 3.26 | 3.10 | 3.13 | 0.05 | 0.04 | 0.04 | 0.16 | 0.12 | 0.13 | 1.36 | 0.04 | 0.03 | 0.03 | 0.14 | 0.11 | 0.11 | Safe | Safe |
| 1956 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 1.34 | 1.18 | 1.18 | 0.00 | | | | | | 137.31 | 1.82 | 1.66 | 1.66 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.48 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 1.43 | 1.27 | 1.27 | | | | | | | 138.43 | 2.94 | 2.78 | 2.78 | 0.06 | 0.05 | 0.05 | 0.18 | 0.14 | 0.14 | 1.51 | 0.06 | 0.05 | 0.05 | 0.18 | 0.14 | 0.14 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.54 | 1.38 | 1.38 | 0.01 | | 0.01 | 0.02 | | 0.01 | 138.50 | 3.01 | 2.85 | 2.85 | 0.06 | 0.05 | 0.05 | 0.18 | 0.14 | 0.14 | 1.47 | 0.05 | 0.05 | 0.04 | 0.17 | 0.14 | 0.13 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.63 | 1.47 | 1.47 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.55 | 3.06 | 2.90 | 2.90 | 0.06 | 0.05 | 0.05 | 0.18 | 0.15 | 0.15 | 1.43 | 0.05 | 0.04 | 0.04 | 0.17 | 0.13 | 0.13 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.74 | 1.58 | 1.58 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.62 | 3.13 | 2.97 | 2.97 | 0.06 | 0.05 | 0.06 | 0.19 | 0.15 | 0.18 | 1.39 | 0.05 | 0.04 | 0.05 | 0.17 | 0.13 | 0.16 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.80 | 1.64 | 1.64 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 138.67 | 3.18 | 3.02 | 3.02 | 0.07 | 0.06 | 0.06 | 0.22 | 0.18 | 0.18 | 1.38 | 0.06 | 0.05 | 0.05 | 0.20 | 0.16 | 0.16 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.88 | 1.72 | 1.72 | 0.02 | 0.01 | 0.01 | 0.04 | 0.02 | 0.02 | 138.73 | 3.24 | 3.08 | 3.08 | 0.07 | 0.06 | 0.06 | 0.23 | 0.18 | 0.18 | 1.36 | 0.05 | 0.05 | 0.05 | 0.19 | 0.17 | 0.17 | Safe | Safe |
| 1856 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 1.18 | 1.07 | 1.16 | 0.00 | | | | | | 137.31 | 1.66 | 1.55 | 1.64 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.48 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 1.27 | 1.16 | 1.25 | | | | | | | 138.43 | 2.78 | 2.67 | 2.76 | 0.06 | 0.05 | 0.05 | 0.17 | 0.13 | 0.14 | 1.51 | 0.06 | 0.05 | 0.05 | 0.17 | 0.13 | 0.14 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.38 | 1.27 | 1.36 | 0.01 | 0.01 | | 0.01 | 0.01 | | 138.50 | 2.85 | 2.74 | 2.83 | 0.06 | 0.05 | 0.05 | 0.17 | 0.14 | 0.14 | 1.47 | 0.05 | 0.04 | 0.05 | 0.16 | 0.12 | 0.14 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.47 | 1.36 | 1.45 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.55 | 2.90 | 2.79 | 2.88 | 0.06 | 0.05 | 0.05 | 0.17 | 0.14 | 0.14 | 1.43 | 0.05 | 0.04 | 0.04 | 0.16 | 0.13 | 0.13 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.58 | 1.47 | 1.56 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 138.62 | 2.97 | 2.86 | 2.95 | 0.06 | 0.06 | 0.05 | 0.18 | 0.17 | 0.15 | 1.39 | 0.05 | 0.05 | 0.04 | 0.16 | 0.16 | 0.13 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.64 | 1.53 | 1.62 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 138.67 | 3.02 | 2.91 | 3.00 | 0.07 | 0.06 | 0.06 | 0.21 | 0.17 | 0.18 | 1.38 | 0.05 | 0.05 | 0.05 | 0.18 | 0.16 | 0.16 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.72 | 1.61 | 1.70 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 138.73 | 3.08 | 2.97 | 3.06 | 0.07 | 0.06 | 0.06 | 0.22 | 0.18 | 0.18 | 1.36 | 0.05 | 0.05 | 0.05 | 0.18 | 0.16 | 0.17 | Safe | Safe |
| 1762 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.87 | 0.71 | 0.81 | 0.01 | | | 0.01 | | | 137.31 | 1.35 | 1.19 | 1.29 | 0.03 | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 | 0.48 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.96 | 0.80 | 0.90 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.43 | 2.47 | 2.31 | 2.41 | 0.07 | 0.05 | 0.06 | 0.17 | 0.12 | 0.14 | 1.51 | 0.06 | 0.04 | 0.05 | 0.16 | 0.11 | 0.14 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.07 | 0.91 | 1.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.50 | 2.54 | 2.38 | 2.48 | 0.07 | 0.06 | 0.06 | 0.18 | 0.14 | 0.15 | 1.47 | 0.05 | 0.05 | 0.05 | 0.16 | 0.13 | 0.14 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.16 | 1.00 | 1.10 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.55 | 2.59 | 2.43 | 2.53 | 0.07 | 0.06 | 0.06 | 0.18 | 0.15 | 0.15 | 1.43 | 0.05 | 0.05 | 0.05 | 0.16 | 0.14 | 0.14 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.27 | 1.11 | 1.21 | 0.02 | 0.01 | 0.02 | 0.03 | 0.01 | 0.02 | 138.62 | 2.66 | 2.50 | 2.60 | 0.08 | 0.06 | 0.07 | 0.21 | 0.15 | 0.18 | 1.39 | 0.06 | 0.05 | 0.05 | 0.19 | 0.14 | 0.16 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.33 | 1.17 | 1.27 | 0.03 | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 | 138.66 | 2.70 | 2.54 | 2.64 | 0.08 | 0.06 | 0.07 | 0.22 | 0.15 | 0.18 | 1.37 | 0.05 | 0.04 | 0.05 | 0.18 | 0.13 | 0.16 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.41 | 1.25 | 1.35 | 0.03 | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 | 138.73 | 2.77 | 2.61 | 2.71 | 0.08 | 0.06 | 0.07 | 0.22 | 0.16 | 0.19 | 1.36 | 0.05 | 0.04 | 0.05 | 0.18 | 0.13 | 0.16 | Safe | Safe |
| 1550 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 1.10 | 0.21 | 0.05 | 0.01 | | | 0.01 | | | 137.31 | 1.58 | 0.69 | 0.53 | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.48 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 1.19 | 0.30 | 0.14 | 0.01 | | | 0.01 | | | 138.43 | 2.70 | 1.81 | 1.65 | 0.04 | 0.03 | 0.03 | 0.11 | 0.05 | 0.05 | 1.51 | 0.03 | 0.03 | 0.03 | 0.10 | 0.05 | 0.05 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 1.30 | 0.41 | 0.25 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 138.50 | 2.77 | 1.88 | 1.72 | 0.04 | 0.03 | 0.04 | 0.11 | 0.06 | 0.07 | 1.47 | 0.03 | 0.02 | 0.03 | 0.10 | 0.05 | 0.07 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 1.39 | 0.50 | 0.34 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 138.55 | 2.82 | 1.93 | 1.77 | 0.04 | 0.03 | 0.04 | 0.11 | 0.06 | 0.07 | 1.43 | 0.03 | 0.02 | 0.03 | 0.10 | 0.05 | 0.07 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 1.50 | 0.61 | 0.45 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 138.62 | 2.89 | 2.00 | 1.84 | 0.04 | 0.04 | 0.04 | 0.12 | 0.08 | 0.07 | 1.39 | 0.03 | 0.03 | 0.03 | 0.10 | 0.07 | 0.07 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 1.56 | 0.67 | 0.51 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 138.66 | 2.93 | 2.04 | 1.88 | 0.04 | 0.04 | 0.04 | 0.12 | 0.08 | 0.08 | 1.37 | 0.03 | 0.03 | 0.03 | 0.10 | 0.07 | 0.07 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 1.64 | 0.75 | 0.59 | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 138.73 | 3.00 | 2.11 | 1.95 | 0.04 | 0.04 | 0.04 | 0.12 | 0.08 | 0.08 | 1.36 | 0.02 | 0.03 | 0.03 | 0.09 | 0.08 | 0.07 | Safe | Safe |
| 1396 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.34 | 0.30 | 0.33 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.31 | 0.82 | 0.78 | 0.81 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.48 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.43 | 0.39 | 0.42 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.43 | 1.94 | 1.90 | 1.93 | 0.05 | 0.04 | 0.04 | 0.10 | 0.08 | 0.08 | 1.51 | 0.04 | 0.03 | 0.03 | 0.09 | 0.07 | 0.07 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.54 | 0.50 | 0.53 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.50 | 2.01 | 1.97 | 2.00 | 0.05 | 0.04 | 0.04 | 0.10 | 0.08 | 0.08 | 1.47 | 0.04 | 0.03 | 0.03 | 0.10 | 0.07 | 0.07 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.63 | 0.59 | 0.62 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.55 | 2.06 | 2.02 | 2.05 | 0.05 | 0.04 | 0.05 | 0.10 | 0.08 | 0.10 | 1.43 | 0.04 | 0.03 | 0.04 | 0.10 | 0.07 | 0.10 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.74 | 0.70 | 0.73 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.62 | 2.13 | 2.09 | 2.12 | 0.05 | 0.04 | 0.05 | 0.11 | 0.08 | 0.11 | 1.39 | 0.03 | 0.03 | 0.04 | 0.09 | 0.08 | 0.10 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.80 | 0.76 | 0.79 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 138.66 | 2.17 | 2.13 | 2.16 | 0.05 | 0.04 | 0.05 | 0.11 | 0.09 | 0.11 | 1.37 | 0.03 | 0.02 | 0.03 | 0.09 | 0.07 | 0.09 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 0.88 | 0.84 | 0.87 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 138.73 | 2.24 | 2.20 | 2.23 | 0.05 | 0.05 | 0.05 | 0.11 | 0.11 | 0.11 | 1.36 | 0.03 | 0.03 | 0.03 | 0.09 | 0.09 | 0.09 | Safe | Safe |
| 1316 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.39 | 0.20 | 0.33 | 0.01 | | 0.01 | 0.00 | | 0.00 | 137.31 | 0.87 | 0.68 | 0.81 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.48 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.48 | 0.29 | 0.42 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.43 | 1.99 | 1.80 | 1.93 | 0.05 | 0.04 | 0.05 | 0.10 | 0.07 | 0.10 | 1.51 | 0.04 | 0.03 | 0.04 | 0.09 | 0.07 | 0.09 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.59 | 0.40 | 0.53 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.50 | 2.06 | 1.87 | 2.00 | 0.06 | 0.04 | 0.05 | 0.12 | 0.07 | 0.10 | 1.47 | 0.05 | 0.03 | 0.04 | 0.12 | 0.07 | 0.09 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.68 | 0.49 | 0.62 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 138.55 | 2.11 | 1.92 | 2.05 | 0.06 | 0.04 | 0.05 | 0.13 | 0.08 | 0.10 | 1.43 | 0.05 | 0.03 | 0.04 | 0.12 | 0.07 | 0.10 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.79 | 0.60 | 0.73 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 138.62 | 2.18 | 1.99 | 2.12 | 0.06 | 0.05 | 0.06 | 0.13 | 0.10 | 0.13 | 1.39 | 0.04 | 0.04 | 0.04 | 0.12 | 0.09 | 0.11 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.85 | 0.66 | 0.79 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 138.66 | 2.22 | 2.03 | 2.16 | 0.06 | 0.05 | 0.06 | 0.13 | 0.10 | 0.13 | 1.37 | 0.04 | 0.03 | 0.04 | 0.12 | 0.09 | 0.11 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 0.93 | 0.74 | 0.87 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 138.73 | 2.29 | 2.10 | 2.23 | 0.06 | 0.05 | 0.06 | 0.14 | 0.11 | 0.13 | 1.36 | 0.04 | 0.03 | 0.04 | 0.12 | 0.09 | 0.12 | Safe | Safe |
| 1258 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.28 | 0.21 | 0.24 | 0.01 | | 0.01 | 0.00 | | 0.00 | 137.31 | 0.76 | 0.69 | 0.72 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.48 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.37 | 0.30 | 0.33 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.43 | 1.88 | 1.81 | 1.84 | 0.05 | 0.04 | 0.04 | 0.09 | 0.07 | 0.07 | 1.51 | 0.04 | 0.03 | 0.03 | 0.09 | 0.07 | 0.07 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.48 | 0.41 | 0.44 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.50 | 1.95 | 1.88 | 1.91 | 0.05 | 0.05 | 0.04 | 0.10 | 0.09 | 0.08 | 1.47 | 0.04 | 0.04 | 0.03 | 0.09 | 0.09 | 0.07 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.57 | 0.50 | 0.53 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 138.55 | 2.00 | 1.93 | 1.96 | 0.05 | 0.05 | 0.04 | 0.10 | 0.10 | 0.08 | 1.43 | 0.04 | 0.04 | 0.03 | 0.09 | 0.09 | 0.07 | Safe | Safe |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.68 | 0.61 | 0.64 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 138.62 | 2.07 | 2.00 | 2.03 | 0.05 | 0.05 | 0.04 | 0.10 | 0.10 | 0.08 | 1.39 | 0.03 | 0.04 | 0.02 | 0.09 | 0.09 | 0.07 | Safe | Safe |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.74 | 0.67 | 0.70 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 138.66 | 2.11 | 2.04 | 2.07 | 0.05 | 0.05 | 0.05 | 0.11 | 0.10 | 0.10 | 1.37 | 0.03 | 0.04 | 0.03 | 0.09 | 0.10 | 0.09 | Safe | Safe |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | 0.82 | 0.75 | 0.78 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 138.73 | 2.18 | 2.11 | 2.14 | 0.06 | 0.05 | 0.05 | 0.13 | 0.11 | 0.11 | 1.36 | 0.04 | 0.03 | 0.03 | 0.11 | 0.09 | 0.09 | Safe | Safe |
| 1233 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.38 | 0.37 | 0.29 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 137.31 | 0.86 | 0.85 | 0.77 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.48 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | Safe | Safe |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.47 | 0.46 | 0.38 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 138.43 | 1.98 | 1.97 | 1.89 | 0.07 | 0.06 | 0.06 | 0.14 | 0.12 | 0.11 | 1.51 | 0.06 | 0.05 | 0.05 | 0.13 | 0.11 | 0.11 | Safe | Safe |
| | 0.79 | 5 | 20.40 | 20 | 137.03 | 0.58 | 0.57 | 0.49 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 138.50 | 2.05 | 2.04 | 1.96 | 0.08 | 0.06 | 0.06 | 0.16 | 0.12 | 0.12 | 1.47 | 0.07 | 0.05 | 0.05 | 0.16 | 0.12 | 0.11 | Safe | Safe |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.67 | 0.66 | 0.58 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.55 | 2.10 | 2.09 | 2.01 | 0.08 | 0.07 | 0.06 | 0.17 | 0.15 | 0.12 | 1.43 | 0.06 | 0.05 | 0.04 | 0.15 | 0.13 | 0.11 | Safe | Safe |

**Whitney Dam HEC-RAS Model Results**
**Steady Flow Scenarios**

| River Station | Base Flow Rate ($m^3/s$) | Design Storm | Peak Unsteady Flow Rate ($m^3/s$) | Flow Rate Increase ($m^3/s$) | No Dam Breach | | | | | | | | | | Dam Breach | | | | | | | | | | Change No Dam Breach to Dam Breach | | | | | | | Life Safety Assessment (2x2 Rule) Left Overbank | Life Safety Assessment (2x2 Rule) Right Overbank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Level (m) | Water Depth (m) | | | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | Water Depth (m) | Velocity (m/s) | | | Hazard Rating (2x2 Rule) | | | | |
| | | | | | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | Channel | L. Overbank | R. Overbank | Channel | L. Overbank | R. Overbank | | |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.78 | 0.77 | 0.69 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 138.62 | **2.17** | **2.16** | **2.08** | 0.08 | 0.07 | 0.06 | 0.17 | 0.15 | 0.12 | 1.39 | 0.06 | 0.05 | 0.04 | 0.16 | 0.14 | 0.11 | **Safe** | **Safe** |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | **0.84** | **0.83** | 0.75 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 138.66 | **2.21** | **2.20** | **2.12** | 0.08 | 0.07 | 0.06 | 0.18 | 0.15 | 0.13 | 1.37 | 0.05 | 0.05 | 0.04 | 0.15 | 0.14 | 0.11 | **Safe** | **Safe** |
| | 2.83 | 100 | 25.60 | 23 | 137.37 | **0.92** | **0.91** | **0.83** | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 138.73 | **2.28** | **2.27** | **2.19** | 0.08 | 0.07 | 0.07 | 0.18 | 0.16 | 0.15 | 1.36 | 0.05 | 0.04 | 0.05 | 0.15 | 0.13 | 0.14 | **Safe** | **Safe** |
| 1130 | 0.22 | Sunny | 2.4 | 2 | 136.83 | 0.40 | 0.05 | 0.18 | 0.05 | 0.03 | 0.03 | 0.02 | 0.00 | 0.01 | 137.31 | **0.88** | 0.53 | 0.66 | 0.05 | 0.04 | 0.06 | 0.04 | 0.02 | 0.04 | 0.48 | 0.00 | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | **Safe** | **Safe** |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.49 | 0.14 | 0.27 | 0.05 | 0.03 | 0.04 | 0.02 | 0.00 | 0.01 | 138.43 | **2.00** | **1.65** | **1.78** | 0.08 | 0.07 | 0.12 | 0.16 | 0.12 | 0.21 | 1.51 | 0.03 | 0.04 | 0.08 | 0.14 | 0.11 | 0.20 | **Safe** | **Safe** |
| | 0.79 | 5 | 20.40 | 20 | 137.02 | 0.59 | 0.24 | 0.37 | 0.05 | 0.04 | 0.04 | 0.03 | 0.01 | 0.01 | 138.50 | **2.07** | **1.72** | **1.85** | 0.09 | 0.08 | 0.13 | 0.19 | 0.14 | 0.24 | 1.48 | 0.04 | 0.04 | 0.09 | 0.16 | 0.13 | 0.23 | **Safe** | **Safe** |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.69 | 0.34 | 0.47 | 0.05 | 0.04 | 0.05 | 0.03 | 0.01 | 0.02 | 138.55 | **2.12** | **1.77** | **1.90** | 0.09 | 0.08 | 0.13 | 0.19 | 0.14 | 0.25 | 1.43 | 0.04 | 0.04 | 0.08 | 0.16 | 0.13 | 0.22 | **Safe** | **Safe** |
| | 1.8 | 25 | 23.10 | 21 | 137.23 | 0.80 | 0.45 | 0.58 | 0.05 | 0.04 | 0.05 | 0.04 | 0.02 | 0.03 | 138.62 | **2.19** | **1.84** | **1.97** | 0.09 | 0.08 | 0.13 | 0.20 | 0.15 | 0.26 | 1.39 | 0.04 | 0.04 | 0.08 | 0.16 | 0.13 | 0.23 | **Safe** | **Safe** |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | **0.86** | 0.51 | 0.64 | 0.05 | 0.04 | 0.06 | 0.04 | 0.02 | 0.04 | 138.66 | **2.23** | **1.88** | **2.01** | 0.09 | 0.08 | 0.13 | 0.20 | 0.15 | 0.26 | 1.37 | 0.04 | 0.04 | 0.07 | 0.16 | 0.13 | 0.22 | **Safe** | **Safe** |
| | 2.83 | 100 | 25.60 | 23 | 137.36 | **0.93** | 0.58 | 0.71 | 0.05 | 0.04 | 0.06 | 0.05 | 0.02 | 0.04 | 138.72 | **2.29** | **1.94** | **2.07** | 0.09 | 0.08 | 0.13 | 0.21 | 0.16 | 0.27 | 1.36 | 0.04 | 0.04 | 0.07 | 0.16 | 0.13 | 0.23 | **Safe** | **Safe** |
| 1000 | 0.22 | Sunny | 2.4 | 2 | 136.82 | 0.20 | 0.15 | 0.18 | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 137.31 | 0.69 | 0.64 | 0.67 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.49 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | **Safe** | **Safe** |
| | 0.44 | 2 | 19.00 | 19 | 136.92 | 0.30 | 0.25 | 0.28 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 138.43 | **1.81** | **1.76** | **1.79** | 0.08 | 0.07 | 0.06 | 0.14 | 0.12 | 0.11 | 1.51 | 0.06 | 0.05 | 0.04 | 0.14 | 0.12 | 0.10 | **Safe** | **Safe** |
| | 0.79 | 5 | 20.40 | 20 | 137.02 | 0.40 | 0.35 | 0.38 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 138.49 | **1.87** | **1.82** | **1.85** | 0.08 | 0.07 | 0.06 | 0.15 | 0.13 | 0.11 | 1.47 | 0.05 | 0.04 | 0.04 | 0.14 | 0.12 | 0.10 | **Safe** | **Safe** |
| | 1.19 | 10 | 21.50 | 20 | 137.12 | 0.50 | 0.45 | 0.48 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 138.54 | **1.92** | **1.87** | **1.90** | 0.08 | 0.07 | 0.07 | 0.15 | 0.13 | 0.13 | 1.42 | 0.05 | 0.04 | 0.05 | 0.14 | 0.12 | 0.12 | **Safe** | **Safe** |
| | 1.8 | 25 | 23.10 | 21 | 137.22 | 0.60 | 0.55 | 0.58 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 138.61 | **1.99** | **1.94** | **1.97** | 0.08 | 0.08 | 0.07 | 0.16 | 0.16 | 0.14 | 1.39 | 0.04 | 0.05 | 0.05 | 0.14 | 0.14 | 0.13 | **Safe** | **Safe** |
| | 2.25 | 50 | 24.10 | 22 | 137.29 | 0.67 | 0.62 | 0.65 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 138.66 | **2.04** | **1.99** | **2.02** | 0.08 | 0.08 | 0.07 | 0.16 | 0.16 | 0.14 | 1.37 | 0.04 | 0.04 | 0.04 | 0.14 | 0.13 | 0.12 | **Safe** | **Safe** |
| | 2.83 | 100 | 25.60 | 23 | 137.36 | 0.74 | 0.69 | 0.72 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 138.72 | **2.10** | **2.05** | **2.08** | 0.09 | 0.08 | 0.07 | 0.19 | 0.16 | 0.15 | 1.36 | 0.05 | 0.04 | 0.04 | 0.16 | 0.14 | 0.12 | **Safe** | **Safe** |

## Incremental Property Damages for Sunny Event



**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.25 | $ 791 | $ 51,415 | $ 51,415 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.00 | $ - | $ - | 0.15 | $ 791 | $ 47,460 | $ 47,460 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ -** | | | **$ 98,875.00** | **$ 98,875.00** |

| Incremental Property Damages for 2 Event | Sheet 2 of 7 |
|---|---|

**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.03 | $ 621 | $ 40,365 | 1.27 | $ 1,072 | $ 69,680 | $ 29,315 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.00 | $ - | $ - | 1.16 | $ 1,072 | $ 64,320 | $ 64,320 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 40,365.00** | | | **$ 134,000.00** | **$ 93,635.00** |

## Incremental Property Damages for 5 Event



**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.03 | $ 621 | $ 40,365 | 1.33 | $ 1,072 | $ 69,680 | $ 29,315 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.00 | $ - | $ - | 1.23 | $ 1,072 | $ 64,320 | $ 64,320 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 40,365.00** | | | **$ 134,000.00** | **$ 93,635.00** |

## Incremental Property Damages for 10 Event



**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.10 | $ 621 | $ 40,365 | 1.38 | $ 1,072 | $ 69,680 | $ 29,315 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.00 | $ - | $ - | 1.28 | $ 1,072 | $ 64,320 | $ 64,320 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 40,365.00** | | | **$ 134,000.00** | **$ 93,635.00** |

| Incremental Property Damages for 25 Event | Sheet 5 of 7 |
|---|---|

**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.18 | $ 791 | $ 51,415 | 1.45 | $ 1,072 | $ 69,680 | $ 18,265 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.08 | $ 621 | $ 37,260 | 1.35 | $ 1,072 | $ 64,320 | $ 27,060 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 88,675.00** | | | **$ 134,000.00** | **$ 45,325.00** |

| Incremental Property Damages for 50 Event | Sheet 6 of 7 |
|---|---|

**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.23 | $ 791 | $ 51,415 | 1.49 | $ 1,072 | $ 69,680 | $ 18,265 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.13 | $ 791 | $ 47,460 | 1.39 | $ 1,072 | $ 64,320 | $ 16,860 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 98,875.00** | | | **$ 134,000.00** | **$ 35,125.00** |

| Incremental Property Damages for 100 Event | Sheet 7 of 7 |
| --- | --- |

**Project No:** 5394
**Project Name:** 14 Island Lake Dam
**Date:** 9/23/22

| Address | Structure | Area ($m^2$) | No Dam Breach | | | Dam Breach | | | Incremental Damages ($) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | Depth (m) | Estimated Damages ($/$m^2$) | Estimated Damages ($) | |
| 9 Sunflower Lane | Class B - Residential One Storey | 115 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 11 Sunflower Lane | Class B - Residential One Storey | 65 | 0.28 | $ 791 | $ 51,415 | 1.56 | $ 1,073 | $ 69,745 | $ 18,330 |
| 1012 Cousins Lane | Class B - Residential One Storey | 110 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1010 Pete's Lane | Class B - Residential One Storey | 65 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 1003 Gramps Lane | Class B - Residential One Storey | 60 | 0.18 | $ 791 | $ 47,460 | 1.46 | $ 1,072 | $ 64,320 | $ 16,860 |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| 0 | 0 | 0 | 0.00 | $ - | $ - | 0.00 | $ - | $ - | $ - |
| **Totals** | | | | | **$ 98,875.00** | | | **$ 134,065.00** | **$ 35,190.00** |

# Appendix D

## Structural Stability Assessment

# 2015 National Building Code Seismic Hazard Calculation

**INFORMATION:** Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

**Site:** 44.489N 76.645W **User File Reference:** 14 Island Lake Dam 2022-10-17 15:48 UT

**Requested by:** D.M. Wills Associates Limited

| Probability of exceedance per annum | 0.000404 | 0.001 | 0.0021 | 0.01 |
|---|---|---|---|---|
| Probability of exceedance in 50 years | 2 % | 5 % | 10 % | 40 % |
| Sa (0.05) | 0.131 | 0.082 | 0.054 | 0.020 |
| Sa (0.1) | 0.175 | 0.113 | 0.077 | 0.030 |
| Sa (0.2) | 0.166 | 0.110 | 0.077 | 0.031 |
| Sa (0.3) | 0.140 | 0.094 | 0.066 | 0.027 |
| Sa (0.5) | 0.113 | 0.076 | 0.053 | 0.021 |
| Sa (1.0) | 0.067 | 0.045 | 0.031 | 0.011 |
| Sa (2.0) | 0.035 | 0.023 | 0.015 | 0.005 |
| Sa (5.0) | 0.009 | 0.006 | 0.004 | 0.001 |
| Sa (10.0) | 0.004 | 0.002 | 0.002 | 0.001 |
| PGA (g) | 0.101 | 0.065 | 0.044 | 0.017 |
| PGV (m/s) | 0.096 | 0.061 | 0.040 | 0.014 |

**Notes:** Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 $m/s^2$). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

---

## References


**National Building Code of Canada 2015 NRCC no. 56190;** Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

**Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)**
**Commentary J**: Design for Seismic Effects

**Geological Survey of Canada Open File 7893** Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada


See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

Natural Resources Canada Ressources naturelles Canada

Canada

# Overflow Weir Inputs

| | |
|---|---|
| **Project No:** | 21-5465 |
| **Project Name:** | Willoughby Stone Cutter's Dam |
| **Designed/Checked By:** | DG |
| **Date:** | 10/21/22 |

**Material Properties**

| | | |
|---|---|---|
| 9.81 | $m/s^2$ | Gravitational Acceleration, g |
| 1000 | $kg/m^3$ | Density of Water, $\rho_{water}$ |
| 9810 | $N/m^3$ | Specific Weight of Water, $\gamma_{water}$ |
| 2200 | $kg/m^3$ | Density of Concrete, $\rho_{concrete}$ |
| 30 | degrees | Angle of Friction (Concrete/Foundation), $Ø_{cf}$ |
| 9700 | $N/m^3$ | Specific Weight of Silt (Sediment), $\gamma_{silt}$ |
| 32 | degrees | Angle of Internal Friction Silt (Sediment), $Ø'_{silt}$ |
| 7700 | $N/m^3$ | Specific Weight of Backfill, $\gamma_{fill}$ |
| 30 | degrees | Angle of Internal Friction Backfill, $Ø'_{fill}$ |

| | | |
|---|---|---|
| 500 | $kN/m^2$ | Allowable Foundation Bearing Pressure |
| 3000 | $kN/m^2$ | Allowable Compressive Stress in Concrete |
| 420 | $kN/m^2$ | Allowable Tensile Stress in Concrete |
| 250 | $kN/m^2$ | Allowable Shear Stress |

**Water Levels**

**Usual Summer Operating Levels**

| | | |
|---|---|---|
| 142.27 | m | Headwater |
| 140.86 | m | Tailwater |

**Usual Winter Operating Levels**

| | | |
|---|---|---|
| 142.27 | m | Headwater |
| 140.86 | m | Tailwater |

**Usual Flood Discharge Levels**

| | | |
|---|---|---|
| 142.87 | m | Headwater |
| 140.86 | m | Tailwater |

**Ice Loading**

| | | |
|---|---|---|
| 75 | kN/m | Usual Ice Load |
| 95 | kN/m | Unusual Ice Load |

**Seismic Acceleration**

| | | |
|---|---|---|
| 0.040 | g | Horizonal, $S_H$ |
| 0.027 | g | Vertical, $S_V$ (2/3 $S_H$) |

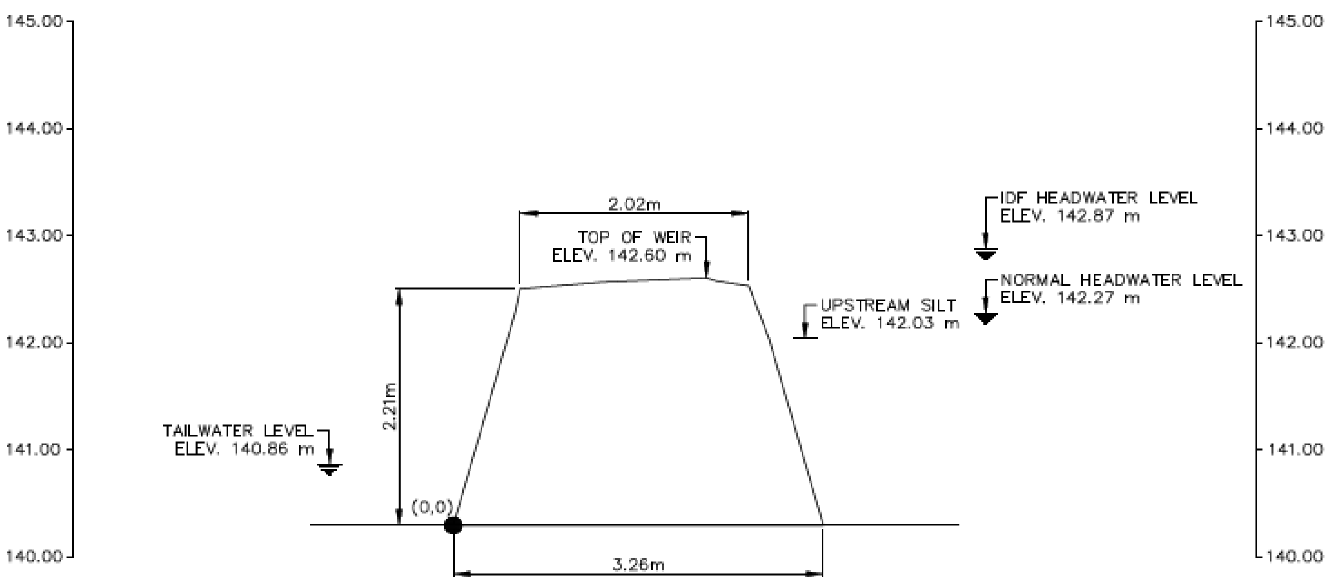
**Structure Geometry**

| | | |
|---|---|---|
| 142.60 | m | Top of Dam Elevation |
| 140.29 | m | Upstream Base Elevation |
| 140.29 | m | Downstream Base Elevation |
| 3.26 | m | Width of Dam, T |
| 1.00 | m | Sectional Length of Dam, t |
| 5.98 | $m^2$ | Area of Dam Section |
| 0 | degrees | Angle with toe vertical face (α) |
| 0 | degrees | Angle with heel vertical face (φ) |
| No | | Rock/Soil Anchors Present? |

**Additional Geometrical Definitions**

| | | |
|---|---|---|
| 142.03 | m | Upstream Silt Elevation |
| 0.00 | $m^2$ | Upstream Area of Silt on Dam |

**Dimensioned Sketch of Dam Section**



WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

## Material Properties

| | | | | | |
|---|---|---|---|---|---|
| 9.81 | $m/s^2$ | Gravitational Acceleration, g | 500 | $kN/m^2$ | Allowable Foundation Bearing Pressure |
| 1000 | $kg/m^3$ | Density of Water, $\rho_{water}$ | 3000 | $kN/m^2$ | Allowable Compressive Stress in Concrete |
| 9810 | $N/m^3$ | Specific Weight of Water, $\gamma_{water}$ | 420 | $kN/m^2$ | Allowable Tensile Stress in Concrete |
| 2200 | $kg/m^3$ | Density of Concrete, $\rho_{concrete}$ | 250 | $kN/m^2$ | Allowable Shear Stress |
| 30 | degrees | Angle of Friction (Concrete/Foundation), $Ø_{cf}$ | | | |
| 9700 | $N/m^3$ | Specific Weight of Silt (Sediment), $\gamma_{silt}$ | | | |
| 32 | degrees | Angle of Internal Friction Silt (Sediment), $Ø'_{silt}$ | | | |
| 7700 | $N/m^3$ | Specific Weight of Backfill, $\gamma_{fill}$ | | | |
| 30 | degrees | Angle of Internal Friction Backfill, $Ø'_{fill}$ | | | |

## Structure Geometry

| | | |
|---|---|---|
| 142.60 | m | Top of Dam Elevation |
| 140.29 | m | Upstream Base Elevation |
| 140.29 | m | Downstream Base Elevation |
| 3.26 | m | Width of Dam, T |
| 1.00 | m | Sectional Length of Dam, t |
| 5.98 | $m^2$ | Area of Dam Section |
| 0 | degrees | Angle with toe vertical face (α) |
| 0 | degrees | Angle with heel vertical face (φ) |
| No | | Rock/Soil Anchors Present? |

## Additional Geometrical Definitions

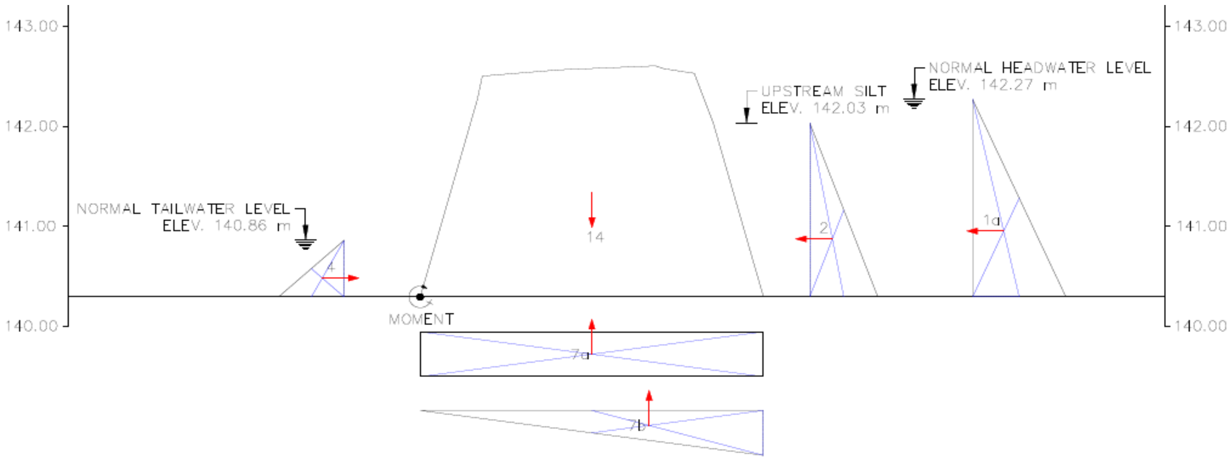
| | | |
|---|---|---|
| 142.03 | m | Upstream Silt Elevation |

## Loading Combination

1. Usual Load (Summer) — Includes the following loads in combination: Dead Loads; Hydrostatic Load (maximum normal operating level); Soil Load; Uplift

1. Headwater Horizontal Hydrostatic Force
2. Upstream Horizontal Silt Force
4. Tailwater Horizontal Hydrostatic Force
7. Uplift Force
14. Dead Weight of Dam

## Loading Combination Sketch

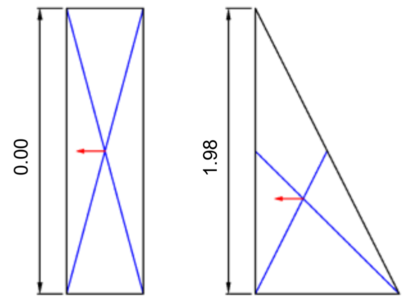


**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

## 1. Headwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

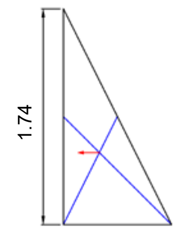
| | | |
|---|---|---|
| Headwater Elevation | 142.27 | m |
| Total Height of Water , h | 1.98 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 1.98 | m |
| **Hydrostatic Force (Triangular; 1a)** | **19230** | **N** |
| Moment Arm Length | 0.66 | m |
| **Hydrostatic Force (Rectangular; 1b)** | **0** | **N** |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **19230** | **N** |




## 2. Upstream Horizontal Silt Force

Upstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 1.74 | m |
| **Upstream Horizontal Silt Force** | **4512** | **N** |
| Moment Arm Length | 0.58 | m |

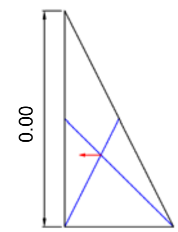



## 3. Upstream Horizontal Backfill Force

N/A

Upstream Horizontal Backfill Force = $(\gamma_{Fill} h^2 t/2) * (1-\sin Ø'_{Fill}/1+\sin Ø'_{Fill})$

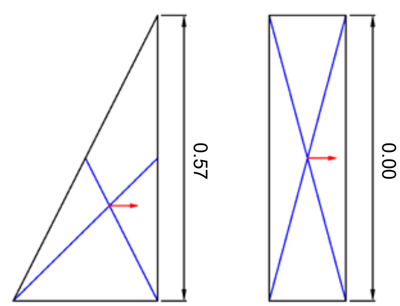
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Upstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




## 4. Tailwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

| | | |
|---|---|---|
| Tailwater Elevation | 140.86 | m |
| Total Height of Water , h | 0.57 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 0.57 | m |
| **Hydrostatic Force (Triangular; 4a)** | **1594** | **N** |
| Moment Arm Length | 0.19 | m |
| **Hydrostatic Force (Rectangular; 4b)** | **0** | N |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **1594** | **N** |

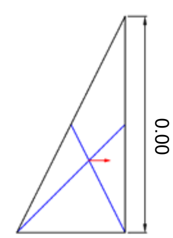



## 5. Downstream Horizontal Silt Force

N/A

Downstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 0.00 | m |
| **Downstream Horizontal Silt Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |



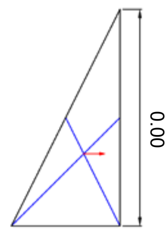
**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**6. Downstream Horizontal Backfill Force**

N/A

Downstream Horizontal Backfill Force = $(\gamma_{Fill}h^2t/2) * (1\text{-}\sin\varnothing'_{Fill}/1+\sin\varnothing'_{Fill})$

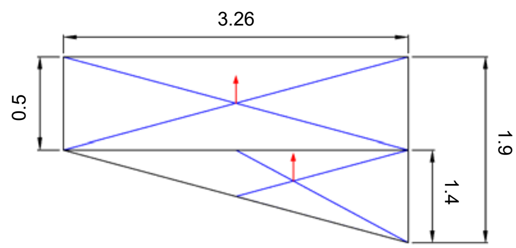
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Downstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**7. Uplift Force**

Uplfit Force = $T((\gamma_{water}h+\gamma_{water}h')/2)t$

| | | |
|---|---|---|
| Width of Dam, T | 3.26 | m |
| Headwater Height, h | 1.98 | m |
| Tailwater Height, h' | 0.57 | m |
| **Uplift Force (Rectangular Component; 7a)** | **18229** | **N** |
| Moment Arm Length | 1.63 | m |
| **Uplift Force (Triangular Component; 7b)** | **22546** | **N** |
| Moment Arm Length | 2.17 | m |
| **Total Uplift Force** | **40775** | **N** |

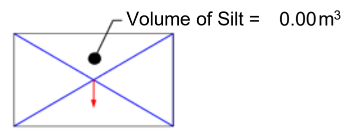



**8. Upstream Weight of Silt**

N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Upstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

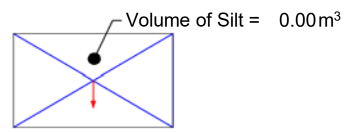



**9. Downstream Weight of Silt**

N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Downstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

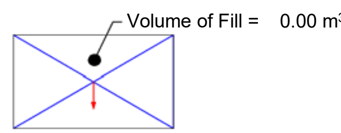



**10. Upstream Weight of Backfill**

N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Upstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

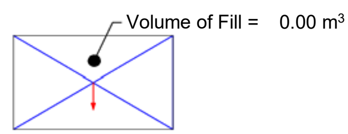



**11. Downstream Weight of Backfill**

N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Downstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

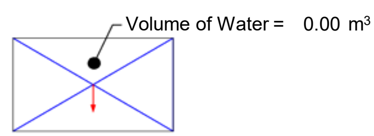



**12. Upstream Weight of Water**

N/A

Weight of Water = $V_{water} * \rho_{water} * g$

| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Upstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |



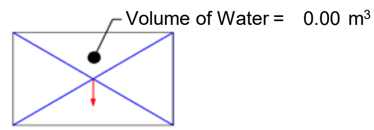
**Overflow Weir - Loading Condition: 1. Usual Load (Summer)**

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**13. Downstream Weight of Water**

N/A

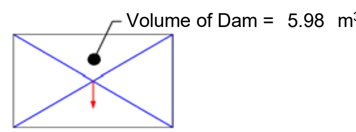
Weight of Water = $V_{water} * \rho_{water} * g$




| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Downstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

**14. Dead Weight of Dam**

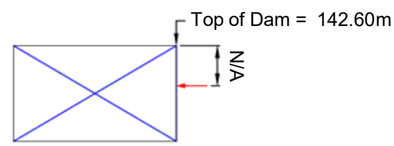
Dead Weight of Dam = $V_{dam} * \rho_{dam} * g$




| | | |
|---|---|---|
| Volume of Dam, $V_{dam}$ | 5.98 | $m^3$ |
| **Dead Weight of Dam** | **129060** | **N** |
| Moment Arm Length | 1.63 | m |

**15. Ice Loading**

N/A

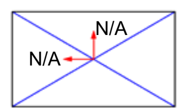



| | | |
|---|---|---|
| **Ice Load** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

**16. Seismic Loading**

N/A

Horizontal Earhtquake Force = $V_{dam} * \rho_{dam} * S_H * g$




| | | |
|---|---|---|
| **Horizontal Earthquake Force; 16a** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

Vertical Earthquake Force = $V_{dam} * \rho_{dam} * S_v * g$

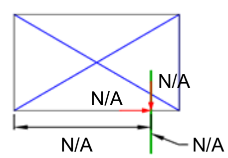
| | | |
|---|---|---|
| **Vertical Earthquake Force: 16b** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

**17. Rock/Soil Anchors**

N/A

| | | | | | |
|---|---|---|---|---|---|
| **Anchor 1 Tension; 17a** | **0** | **N** | **Anchor 1 Shear; 17e** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 2 Tension; 17b** | **0** | **N** | **Anchor 2 Shear; 17f** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 3 Tension; 17c** | **0** | **N** | **Anchor 3 Shear; 17g** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 4 Tension; 17d** | **0** | **N** | **Anchor 4 Shear; 17h** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |

Example Shown for Anchor 1



## Overflow Weir - Loading Condition: 1. Usual Load (Summer)

WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**Summary of Forces and Moments**

| Name of Force | Magnitude of Forces (N) | | | | Moment Arm Length (m) | Moments About the Toe (N-m) | |
|---|---|---|---|---|---|---|---|
| | Vertical Forces | | Horizontal Forces | | | Clockwise (+) | Counter Clockwise (-) |
| | Down (+) | Up (-) | To U/S (+) | To D/S (-) | | | |
| Headwater Horizontal Hydrostatic Force, 1a | | | | 19230 | 0.66 | | 12692 |
| Headwater Horizontal Hydrostatic Force, 1b | | | | | | | |
| Upstream Horizontal Silt Force, 2 | | | | 4512 | 0.58 | | 2617 |
| Upstream Horizontal Backfill Force, 3 | | | | | | | |
| Tailwater Horizontal Hydrostatic Force, 4a | | | 1594 | | 0.19 | 303 | |
| Tailwater Horizontal Hydrostatic Force, 4b | | | | | | | |
| Downstream Horizontal Silt Force, 5 | | | | | | | |
| Downstream Horizontal Backfill Force, 6 | | | | | | | |
| Uplift Force, 7a | | 18229 | | | 1.63 | | 29713 |
| Uplift Force, 7b | | 22546 | | | 2.17 | | 49001 |
| Upstream Weight of Silt, 8 | | | | | | | |
| Downstream Weight of Silt, 9 | | | | | | | |
| Upstream Weight of Backfill, 10 | | | | | | | |
| Downstream Weight of Backfill, 11 | | | | | | | |
| Upstream Weight of Water, 12 | | | | | | | |
| Downstream Weight of Water, 13 | | | | | | | |
| Dead Weight of Dam, 14 | 129060 | | | | 1.63 | 210368 | |
| Ice Loading, 15 | | | | | | | |
| Seismic Loading, 16a | | | | | | | |
| Seismic Loading, 16b | | | | | | | |
| Rock/Soil Anchors, 17a | | | | | | | |
| Rock/Soil Anchors, 17b | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17e | | | | | | | |
| Rock/Soil Anchors, 17f | | | | | | | |
| Rock/Soil Anchors, 17g | | | | | | | |
| Rock/Soil Anchors, 17h | | | | | | | |
| **Sum** | **129060** | **40775** | **1594** | **23741** | **- -** | **210671** | **94022** |

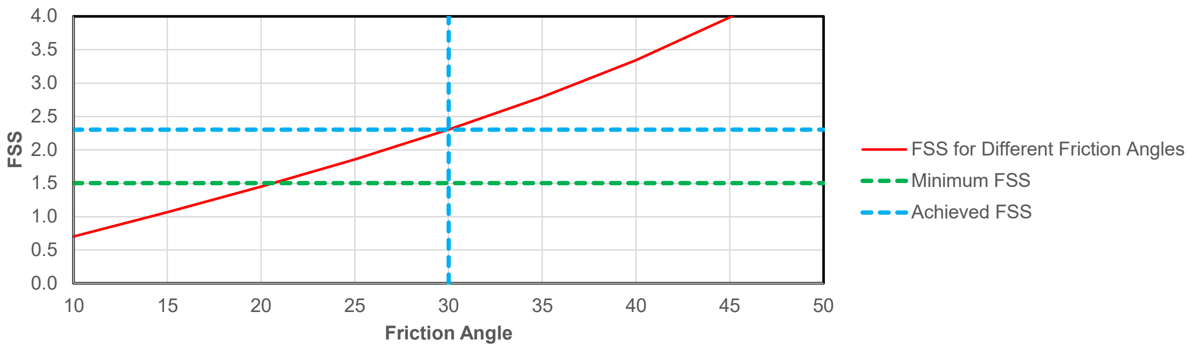
| | | |
|---|---|---|
| **∑Horizontal Forces =** | **-22148** | **N** |
| **∑Vertical Forces =** | **88285** | **N** |
| **∑Clockwise Moment =** | **210671** | **N-m** |
| **∑Counterclockwise Moment =** | **-94022** | **N-m** |
| **∑ Moment =** | **116649** | **N-m** |

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

## Factor of Safety of Sliding

Factor of Safety Against Sliding = (Sliding Coefficient, μ) x (∑Vertical Forces / ∑Horizontal Forces)

Sliding Coefficient, μ = 0.58
**Factor of Safety Against Sliding = 2.30** Acceptable




## Factor of Safety of Overturning, Location of the Resultant and Bearing Stresses

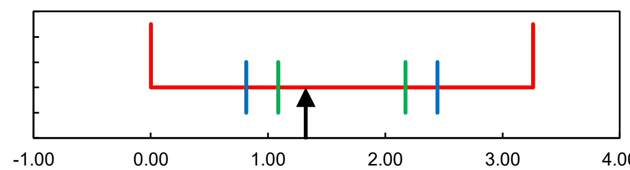
Factor of Safety Against Overturning = ∑Counterclockwise Moments / ∑Clockwise Moments)

**Factor of Safety Against Overturning = 2.24** Acceptable

Position of Resultant from Toe = ∑Moments / ∑Vertical Forces)

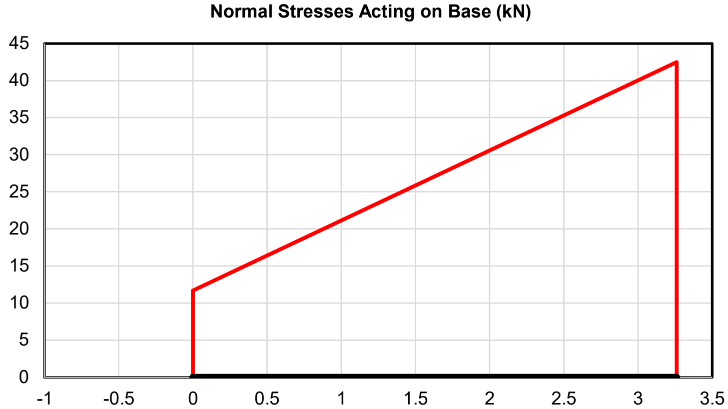
**Position of Resultant from Toe = 1.32** m
**Eccentricity (e) = 0.31** m

**Location of Resultant =** Inside Middle Third




| | | | Concrete | Foundation |
|---|---|---|---|---|
| **Average Vertical Stress =** | 27081 | $N/m^2$ | | |
| **Normal Compressive Stress at Toe =** | 11694 | $N/m^2$ | Acceptable | Acceptable |
| **Normal Compressive Stress at Heel =** | 42469 | $N/m^2$ | Acceptable | Acceptable |
| **Maximum Normal Compressive Stess =** | 42469 | $N/m^2$ | | |

**Normal Stresses Acting on Base (kN)**




| | | | |
|---|---|---|---|
| **Principle Stress at Toe =** | 11694 | $N/m^2$ | Acceptable |
| **Principle Stress at Heel =** | 42469 | $N/m^2$ | Acceptable |
| **Shear Stress at Toe =** | 0 | $N/m^2$ | Acceptable |
| **Shear Stress at Heel =** | 0 | $N/m^2$ | Acceptable |

## Overflow Weir - Loading Condition: 2. Usual Load (Winter)

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

### Material Properties

| | | | | | |
|---|---|---|---|---|---|
| 9.81 | $m/s^2$ | Gravitational Acceleration, g | 500 | $kN/m^2$ | Allowable Foundation Bearing Pressure |
| 1000 | $kg/m^3$ | Density of Water, $\rho_{water}$ | 3000 | $kN/m^2$ | Allowable Compressive Stress in Concrete |
| 9810 | $N/m^3$ | Specific Weight of Water, $\gamma_{water}$ | 420 | $kN/m^2$ | Allowable Tensile Stress in Concrete |
| 2200 | $kg/m^3$ | Density of Concrete, $\rho_{concrete}$ | 250 | $kN/m^2$ | Allowable Shear Stress |
| 30 | degrees | Angle of Friction (Concrete/Foundation), $Ø_{cf}$ | | | |
| 9700 | $N/m^3$ | Specific Weight of Silt (Sediment), $\gamma_{silt}$ | | | |
| 32 | degrees | Angle of Internal Friction Silt (Sediment), $Ø'_{silt}$ | | | |
| 7700 | $N/m^3$ | Specific Weight of Backfill, $\gamma_{fill}$ | | | |
| 30 | degrees | Angle of Internal Friction Backfill, $Ø'_{fill}$ | | | |

### Structure Geometry

| | | |
|---|---|---|
| 142.60 | m | Top of Dam Elevation |
| 140.29 | m | Upstream Base Elevation |
| 140.29 | m | Downstream Base Elevation |
| 3.26 | m | Width of Dam, T |
| 1.00 | m | Sectional Length of Dam, t |
| 5.98 | $m^2$ | Area of Dam Section |
| 0 | degrees | Angle with toe vertical face (α) |
| 0 | degrees | Angle with heel vertical face (φ) |
| No | | Rock/Soil Anchors Present? |

### Additional Geometrical Definitions

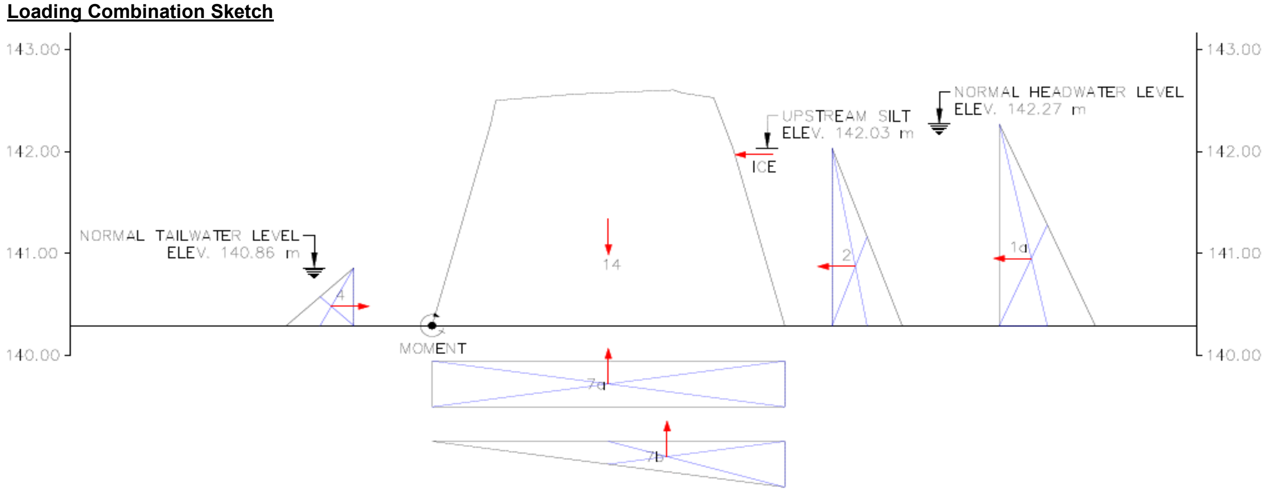
| | | |
|---|---|---|
| 142.03 | m | Upstream Silt Elevation |

### Loading Combination

2. Usual Load (Winter) — Includes the following loads in combination: Dead Loads; Hydrostatic Load (maximum normal operating level); Ice Load (usual); Soil Load; Uplift

1. Headwater Horizontal Hydrostatic Force
2. Upstream Horizontal Silt Force
4. Tailwater Horizontal Hydrostatic Force
7. Uplift Force
14. Dead Weight of Dam
15. Ice Loading

### Loading Combination Sketch



**Overflow Weir - Loading Condition: 2. Usual Load (Winter)**

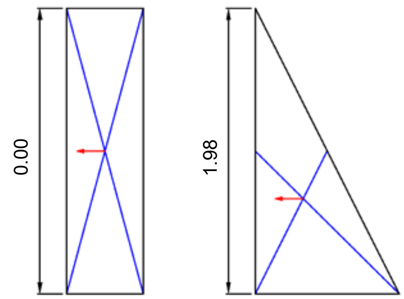
WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

### 1. Headwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

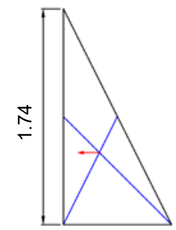
| | | |
|---|---|---|
| Headwater Elevation | 142.27 | m |
| Total Height of Water , h | 1.98 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 1.98 | m |
| **Hydrostatic Force (Triangular; 1a)** | **19230** | **N** |
| Moment Arm Length | 0.66 | m |
| **Hydrostatic Force (Rectangular; 1b)** | **0** | **N** |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **19230** | **N** |




### 2. Upstream Horizontal Silt Force

Upstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 1.74 | m |
| **Upstream Horizontal Silt Force** | **4512** | **N** |
| Moment Arm Length | 0.58 | m |

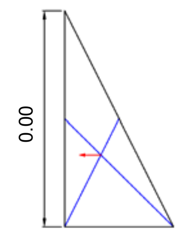



### 3. Upstream Horizontal Backfill Force

**N/A**

Upstream Horizontal Backfill Force = $(\gamma_{Fill} h^2 t/2) * (1-\sin Ø'_{Fill}/1+\sin Ø'_{Fill})$

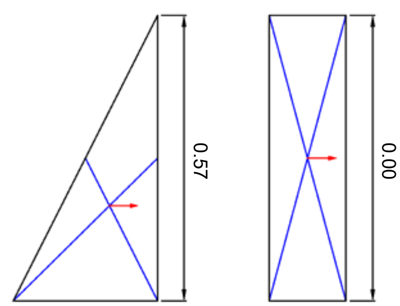
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Upstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




### 4. Tailwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

| | | |
|---|---|---|
| Tailwater Elevation | 140.86 | m |
| Total Height of Water , h | 0.57 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 0.57 | m |
| **Hydrostatic Force (Triangular; 4a)** | **1594** | **N** |
| Moment Arm Length | 0.19 | m |
| **Hydrostatic Force (Rectangular; 4b)** | **0** | N |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **1594** | **N** |

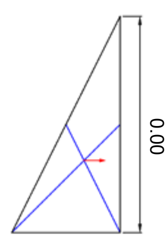



### 5. Downstream Horizontal Silt Force

**N/A**

Downstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 0.00 | m |
| **Downstream Horizontal Silt Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

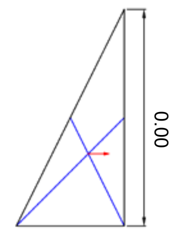


**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**6. Downstream Horizontal Backfill Force**
N/A

Downstream Horizontal Backfill Force = $(\gamma_{Fill}h^2t/2) * (1-\sin Ø'_{Fill}/1+\sin Ø'_{Fill})$

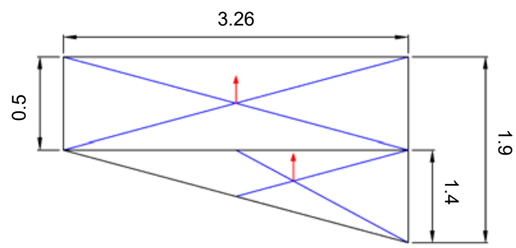
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Downstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**7. Uplift Force**

Uplfit Force = $T((\gamma_{water}h+\gamma_{water}h')/2)t$

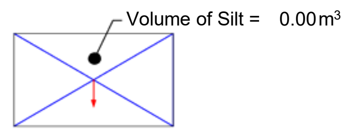
| | | |
|---|---|---|
| Width of Dam, T | 3.26 | m |
| Headwater Height, h | 1.98 | m |
| Tailwater Height, h' | 0.57 | m |
| **Uplift Force (Rectangular Component; 7a)** | **18229** | **N** |
| Moment Arm Length | 1.63 | m |
| **Uplift Force (Triangular Component; 7b)** | **22546** | **N** |
| Moment Arm Length | 2.17 | m |
| **Total Uplift Force** | **40775** | **N** |




**8. Upstream Weight of Silt**
N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

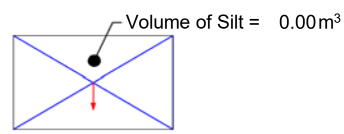
| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Upstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**9. Downstream Weight of Silt**
N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

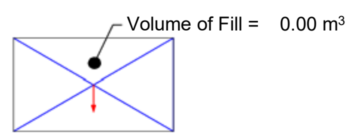
| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Downstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**10. Upstream Weight of Backfill**
N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

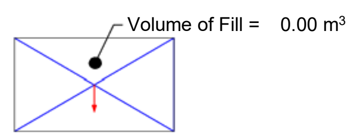
| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Upstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**11. Downstream Weight of Backfill**
N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

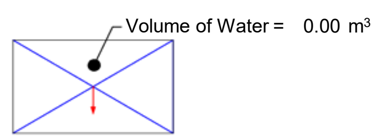
| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Downstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**12. Upstream Weight of Water**
N/A

Weight of Water = $V_{water} * \rho_{water} * g$

| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Upstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |



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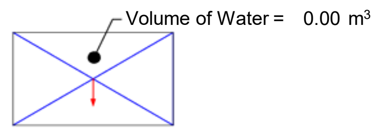
## 13. Downstream Weight of Water

N/A

Weight of Water = $V_{water} * \rho_{water} * g$

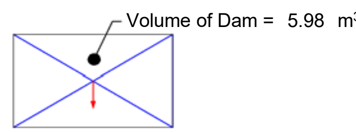
| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Downstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




## 14. Dead Weight of Dam

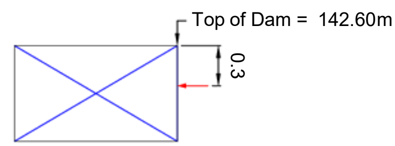
Dead Weight of Dam = $V_{dam} * \rho_{dam} * g$

| | | |
|---|---|---|
| Volume of Dam, $V_{dam}$ | 5.98 | $m^3$ |
| **Dead Weight of Dam** | **129060** | **N** |
| Moment Arm Length | 1.63 | m |




## 15. Ice Loading

| | | |
|---|---|---|
| **Ice Load** | **75000** | **N** |
| Moment Arm Length | 1.68 | m |




## 16. Seismic Loading

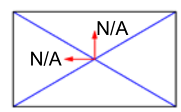
N/A

Horizontal Earhtquake Force = $V_{dam} * \rho_{dam} * S_H * g$

| | | |
|---|---|---|
| **Horizontal Earthquake Force; 16a** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

Vertical Earthquake Force = $V_{dam} * \rho_{dam} * S_v * g$

| | | |
|---|---|---|
| **Vertical Earthquake Force: 16b** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

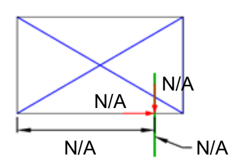



## 17. Rock/Soil Anchors

N/A

| | | | | | |
|---|---|---|---|---|---|
| **Anchor 1 Tension; 17a** | **0** | **N** | **Anchor 1 Shear; 17e** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 2 Tension; 17b** | **0** | **N** | **Anchor 2 Shear; 17f** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 3 Tension; 17c** | **0** | **N** | **Anchor 3 Shear; 17g** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 4 Tension; 17d** | **0** | **N** | **Anchor 4 Shear; 17h** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |

Example Shown for Anchor 1



## Overflow Weir - Loading Condition: 2. Usual Load (Winter)

WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**Summary of Forces and Moments**

| Name of Force | Magnitude of Forces (N) | | | | Moment Arm Length (m) | Moments About the Toe (N-m) | |
|---|---|---|---|---|---|---|---|
| | Vertical Forces | | Horizontal Forces | | | | |
| | Down (+) | Up (-) | To U/S (+) | To D/S (-) | | Clockwise (+) | Counter Clockwise (-) |
| Headwater Horizontal Hydrostatic Force, 1a | | | | 19230 | 0.66 | | 12692 |
| Headwater Horizontal Hydrostatic Force, 1b | | | | | | | |
| Upstream Horizontal Silt Force, 2 | | | | 4512 | 0.58 | | 2617 |
| Upstream Horizontal Backfill Force, 3 | | | | | | | |
| Tailwater Horizontal Hydrostatic Force, 4a | | | 1594 | | 0.19 | 303 | |
| Tailwater Horizontal Hydrostatic Force, 4b | | | | | | | |
| Downstream Horizontal Silt Force, 5 | | | | | | | |
| Downstream Horizontal Backfill Force, 6 | | | | | | | |
| Uplift Force, 7a | | 18229 | | | 1.63 | | 29713 |
| Uplift Force, 7b | | 22546 | | | 2.17 | | 49001 |
| Upstream Weight of Silt, 8 | | | | | | | |
| Downstream Weight of Silt, 9 | | | | | | | |
| Upstream Weight of Backfill, 10 | | | | | | | |
| Downstream Weight of Backfill, 11 | | | | | | | |
| Upstream Weight of Water, 12 | | | | | | | |
| Downstream Weight of Water, 13 | | | | | | | |
| Dead Weight of Dam, 14 | 129060 | | | | 1.63 | 210368 | |
| Ice Loading, 15 | | | | 75000 | 1.68 | | 126000 |
| Seismic Loading, 16a | | | | | | | |
| Seismic Loading, 16b | | | | | | | |
| Rock/Soil Anchors, 17a | | | | | | | |
| Rock/Soil Anchors, 17b | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17e | | | | | | | |
| Rock/Soil Anchors, 17f | | | | | | | |
| Rock/Soil Anchors, 17g | | | | | | | |
| Rock/Soil Anchors, 17h | | | | | | | |
| **Sum** | **129060** | **40775** | **1594** | **98741** | **- -** | **210671** | **220022** |

| | | |
|---|---|---|
| **∑Horizontal Forces =** | **-97148** | **N** |
| **∑Vertical Forces =** | **88285** | **N** |
| **∑Clockwise Moment =** | **210671** | **N-m** |
| **∑Counterclockwise Moment =** | **-220022** | **N-m** |
| **∑ Moment =** | **-9351** | **N-m** |

**Project No:** 21-5465
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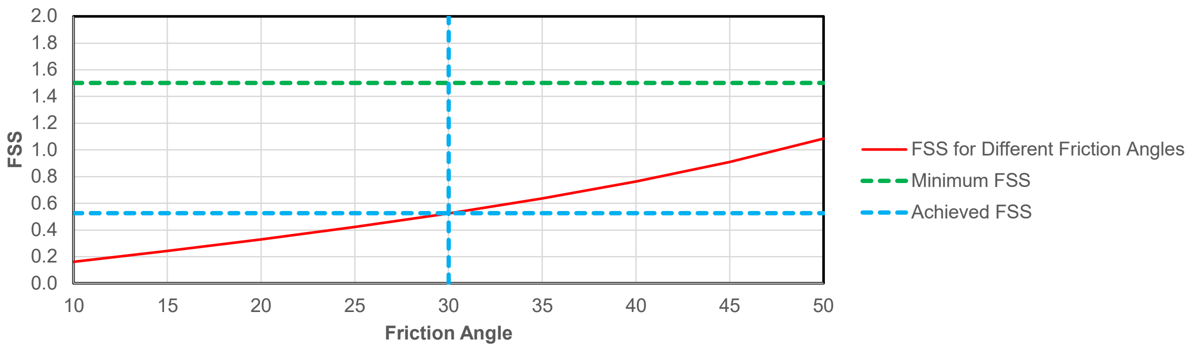
**Factor of Safety of Sliding**

Factor of Safety Against Sliding = (Sliding Coefficient, μ) x (∑Vertical Forces / ∑Horizontal Forces)

Sliding Coefficient, μ = 0.58
**Factor of Safety Against Sliding = 0.52** **Not Acceptable**




**Factor of Safety of Overturning, Location of the Resultant and Bearing Stresses**

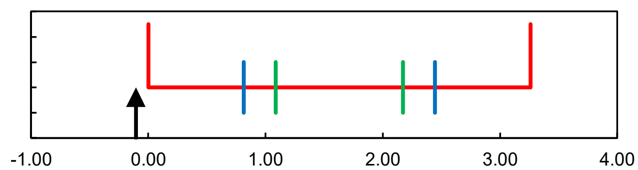
Factor of Safety Against Overturning = ∑Counterclockwise Moments / ∑Clockwise Moments)

**Factor of Safety Against Overturning = 0.96** **Not Acceptable**

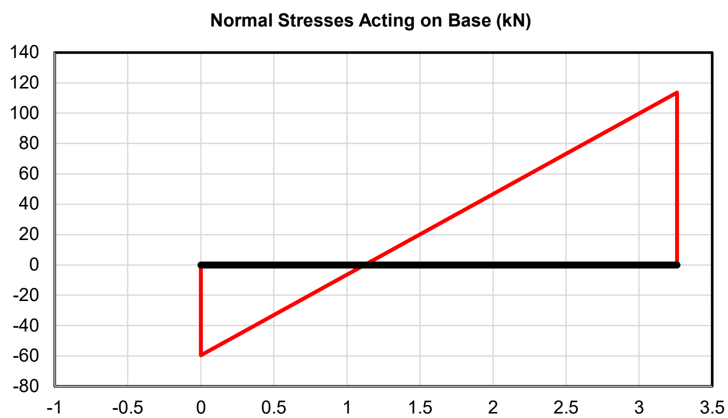
Position of Resultant from Toe = ∑Moments / ∑Vertical Forces)

**Position of Resultant from Toe = -0.11** **m**
**Eccentricity (e) = 1.74** **m**

**Location of Resultant = Outside Middle Third**




| | | | Concrete | Foundation |
|---|---|---|---|---|
| **Average Vertical Stress =** | **27081** | **N/m²** | | |
| **Normal Compressive Stress at Toe =** | **-59442** | **N/m²** | Acceptable | Acceptable |
| **Normal Compressive Stress at Heel =** | **113605** | **N/m²** | Acceptable | Acceptable |
| **Maximum Normal Compressive Stess =** | **113605** | **N/m²** | | |




| | | | |
|---|---|---|---|
| **Principle Stress at Toe =** | **-59442** | **N/m²** | Acceptable |
| **Principle Stress at Heel =** | **113605** | **N/m²** | Acceptable |
| **Shear Stress at Toe =** | **0** | **N/m²** | Acceptable |
| **Shear Stress at Heel =** | **0** | **N/m²** | Acceptable |

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**Material Properties**

| | | | | | |
|---|---|---|---|---|---|
| 9.81 | $m/s^2$ | Gravitational Acceleration, g | 500 | $kN/m^2$ | Allowable Foundation Bearing Pressure |
| 1000 | $kg/m^3$ | Density of Water, $\rho_{water}$ | 3000 | $kN/m^2$ | Allowable Compressive Stress in Concrete |
| 9810 | $N/m^3$ | Specific Weight of Water, $\gamma_{water}$ | 420 | $kN/m^2$ | Allowable Tensile Stress in Concrete |
| 2200 | $kg/m^3$ | Density of Concrete, $\rho_{concrete}$ | 250 | $kN/m^2$ | Allowable Shear Stress |
| 30 | degrees | Angle of Friction (Concrete/Foundation), $Ø_{cf}$ | | | |
| 9700 | $N/m^3$ | Specific Weight of Silt (Sediment), $\gamma_{silt}$ | | | |
| 32 | degrees | Angle of Internal Friction Silt (Sediment), $Ø'_{silt}$ | | | |
| 7700 | $N/m^3$ | Specific Weight of Backfill, $\gamma_{fill}$ | | | |
| 30 | degrees | Angle of Internal Friction Backfill, $Ø'_{fill}$ | | | |

**Structure Geometry**

| | | |
|---|---|---|
| 142.60 | m | Top of Dam Elevation |
| 140.29 | m | Upstream Base Elevation |
| 140.29 | m | Downstream Base Elevation |
| 3.26 | m | Width of Dam, T |
| 1.00 | m | Sectional Length of Dam, t |
| 5.98 | $m^2$ | Area of Dam Section |
| 0 | degrees | Angle with toe vertical face (α) |
| 0 | degrees | Angle with heel vertical face (φ) |
| No | | Rock/Soil Anchors Present? |

**Additional Geometrical Definitions**

| | | |
|---|---|---|
| 142.03 | m | Upstream Silt Elevation |

**Loading Combination**

3. Unusual Load (Flood) — Includes the following loads in combination: Dead Loads; Hydrostatic Load (IDF level); Soil Load; Uplift

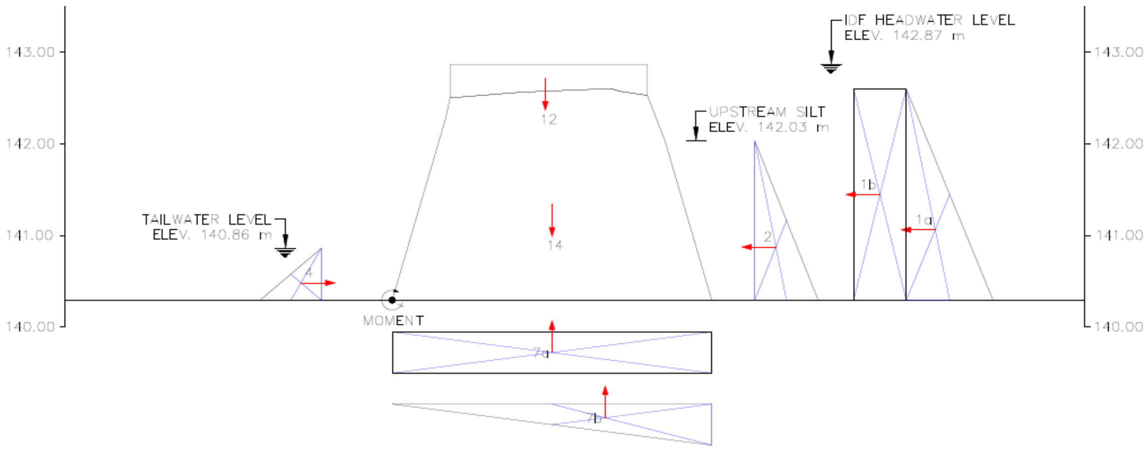
1. Headwater Horizontal Hydrostatic Force
2. Upstream Horizontal Silt Force

4. Tailwater Horizontal Hydrostatic Force

7. Uplift Force

14. Dead Weight of Dam

**Loading Combination Sketch**



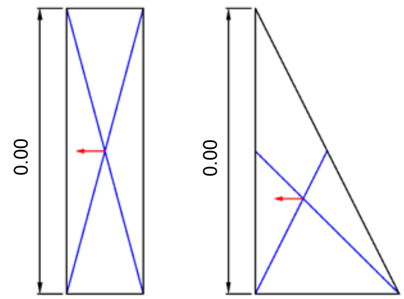
WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

## 1. Headwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

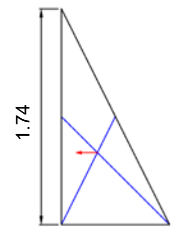
| | | |
|---|---|---|
| Headwater Elevation | 142.87 | m |
| Total Height of Water , h | 2.58 | m |
| Height of Water (Above Dam Crest), h' | 0.27 | m |
| Height of Water (Below Dam Crest), h" | 0.00 | m |
| **Hydrostatic Force (Triangular; 1a)** | **32650** | **N** |
| Moment Arm Length | 0.00 | m |
| **Hydrostatic Force (Rectangular; 1b)** | **0** | **N** |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **32650** | **N** |




## 2. Upstream Horizontal Silt Force

Upstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1\text{-}\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 1.74 | m |
| **Upstream Horizontal Silt Force** | **4512** | **N** |
| Moment Arm Length | 0.58 | m |

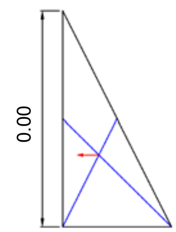



## 3. Upstream Horizontal Backfill Force

**N/A**

Upstream Horizontal Backfill Force = $(\gamma_{Fill} h^2 t/2) * (1\text{-}\sin Ø'_{Fill}/1+\sin Ø'_{Fill})$

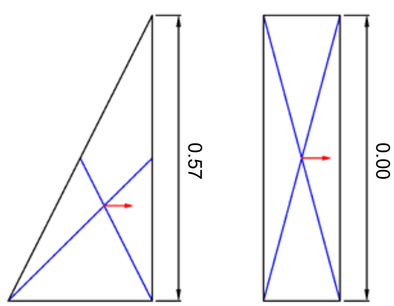
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Upstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




## 4. Tailwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

| | | |
|---|---|---|
| Tailwater Elevation | 140.86 | m |
| Total Height of Water , h | 0.57 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 0.57 | m |
| **Hydrostatic Force (Triangular; 4a)** | **1594** | **N** |
| Moment Arm Length | 0.19 | m |
| **Hydrostatic Force (Rectangular; 4b)** | **0** | N |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **1594** | **N** |

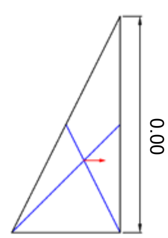



## 5. Downstream Horizontal Silt Force

**N/A**

Downstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1\text{-}\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 0.00 | m |
| **Downstream Horizontal Silt Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

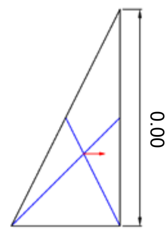


**6. Downstream Horizontal Backfill Force**

N/A

Downstream Horizontal Backfill Force = $(\gamma_{Fill}h^2t/2) * (1\text{-sin}Ø'_{Fill}/1\text{+sin}Ø'_{Fill})$

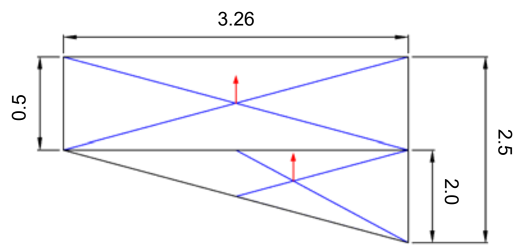
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Downstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




**7. Uplift Force**

Uplfit Force = $T((\gamma_{water}h+\gamma_{water}h')/2)t$

| | | |
|---|---|---|
| Width of Dam, T | 3.26 | m |
| Headwater Height, h | 2.58 | m |
| Tailwater Height, h' | 0.57 | m |
| **Uplift Force (Rectangular Component; 7a)** | **18229** | **N** |
| Moment Arm Length | 1.63 | m |
| **Uplift Force (Triangular Component; 7b)** | **32141** | **N** |
| Moment Arm Length | 2.17 | m |
| **Total Uplift Force** | **50369** | **N** |

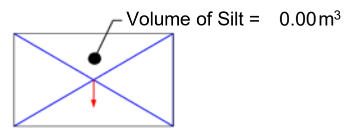



**8. Upstream Weight of Silt**

N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Upstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

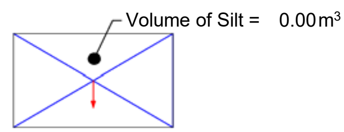



**9. Downstream Weight of Silt**

N/A

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Downstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

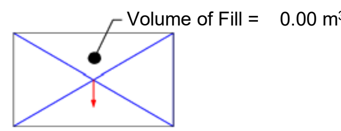



**10. Upstream Weight of Backfill**

N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Upstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

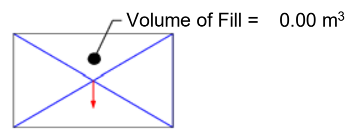



**11. Downstream Weight of Backfill**

N/A

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Downstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

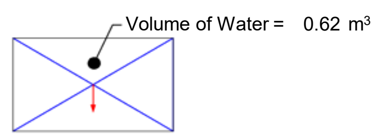



**12. Upstream Weight of Water**

N/A

Weight of Water = $V_{water} * \rho_{water} * g$

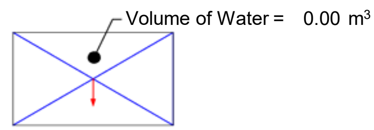
| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.62 | $m^3$ |
| **Upstream Weight of Water** | **6082** | **N** |
| Moment Arm Length | 1.56 | m |



## 13. Downstream Weight of Water

N/A

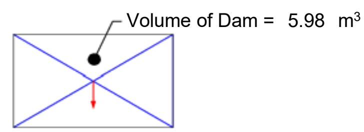
Weight of Water = $V_{water} * \rho_{water} * g$




| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Downstream Weight of Water** | 0 | **N** |
| Moment Arm Length | 0.00 | m |

## 14. Dead Weight of Dam

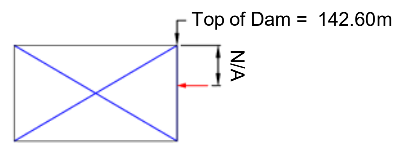
Dead Weight of Dam = $V_{dam} * \rho_{dam} * g$




| | | |
|---|---|---|
| Volume of Dam, $V_{dam}$ | 5.98 | $m^3$ |
| **Dead Weight of Dam** | 129060 | **N** |
| Moment Arm Length | 1.63 | m |

## 15. Ice Loading

N/A



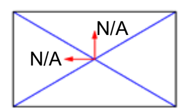

| | | |
|---|---|---|
| **Ice Load** | 0 | **N** |
| Moment Arm Length | 0.00 | m |

## 16. Seismic Loading

N/A

Horizontal Earhtquake Force = $V_{dam} * \rho_{dam} * S_H * g$

| | | |
|---|---|---|
| **Horizontal Earthquake Force; 16a** | 0 | **N** |
| Moment Arm Length | 0.00 | m |




Vertical Earthquake Force = $V_{dam} * \rho_{dam} * S_v * g$

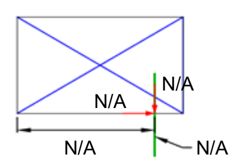
| | | |
|---|---|---|
| **Vertical Earthquake Force: 16b** | 0 | **N** |
| Moment Arm Length | 0.00 | m |

## 17. Rock/Soil Anchors

N/A

| | | | | | |
|---|---|---|---|---|---|
| **Anchor 1 Tension; 17a** | 0 | **N** | **Anchor 1 Shear; 17e** | 0 | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 2 Tension; 17b** | 0 | **N** | **Anchor 2 Shear; 17f** | 0 | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 3 Tension; 17c** | 0 | **N** | **Anchor 3 Shear; 17g** | 0 | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 4 Tension; 17d** | 0 | **N** | **Anchor 4 Shear; 17h** | 0 | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |

Example Shown for Anchor 1



**Overflow Weir - Loading Condition: 3. Unusual Load (Flood)**

WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**Summary of Forces and Moments**

| Name of Force | Magnitude of Forces (N) | | | | Moment Arm Length (m) | Moments About the Toe (N-m) | |
|---|---|---|---|---|---|---|---|
| | Vertical Forces | | Horizontal Forces | | | | |
| | Down (+) | Up (-) | To U/S (+) | To D/S (-) | | Clockwise (+) | Counter Clockwise (-) |
| Headwater Horizontal Hydrostatic Force, 1a | | | | 32650 | | | |
| Headwater Horizontal Hydrostatic Force, 1b | | | | | | | |
| Upstream Horizontal Silt Force, 2 | | | | 4512 | 0.58 | | 2617 |
| Upstream Horizontal Backfill Force, 3 | | | | | | | |
| Tailwater Horizontal Hydrostatic Force, 4a | | | 1594 | | 0.19 | 303 | |
| Tailwater Horizontal Hydrostatic Force, 4b | | | | | | | |
| Downstream Horizontal Silt Force, 5 | | | | | | | |
| Downstream Horizontal Backfill Force, 6 | | | | | | | |
| Uplift Force, 7a | | 18229 | | | 1.63 | | 29713 |
| Uplift Force, 7b | | 32141 | | | 2.17 | | 69852 |
| Upstream Weight of Silt, 8 | | | | | | | |
| Downstream Weight of Silt, 9 | | | | | | | |
| Upstream Weight of Backfill, 10 | | | | | | | |
| Downstream Weight of Backfill, 11 | | | | | | | |
| Upstream Weight of Water, 12 | 6082 | | | | 1.56 | 9488 | |
| Downstream Weight of Water, 13 | | | | | | | |
| Dead Weight of Dam, 14 | 129060 | | | | 1.63 | 210368 | |
| Ice Loading, 15 | | | | | | | |
| Seismic Loading, 16a | | | | | | | |
| Seismic Loading, 16b | | | | | | | |
| Rock/Soil Anchors, 17a | | | | | | | |
| Rock/Soil Anchors, 17b | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17e | | | | | | | |
| Rock/Soil Anchors, 17f | | | | | | | |
| Rock/Soil Anchors, 17g | | | | | | | |
| Rock/Soil Anchors, 17h | | | | | | | |
| **Sum** | **135143** | **50369** | **1594** | **37161** | **- -** | **220159** | **102182** |

| | | |
|---|---|---|
| **∑Horizontal Forces =** | **-35568** | **N** |
| **∑Vertical Forces =** | **84773** | **N** |
| **∑Clockwise Moment =** | **220159** | **N-m** |
| **∑Counterclockwise Moment =** | **-102182** | **N-m** |
| **∑ Moment =** | **117977** | **N-m** |

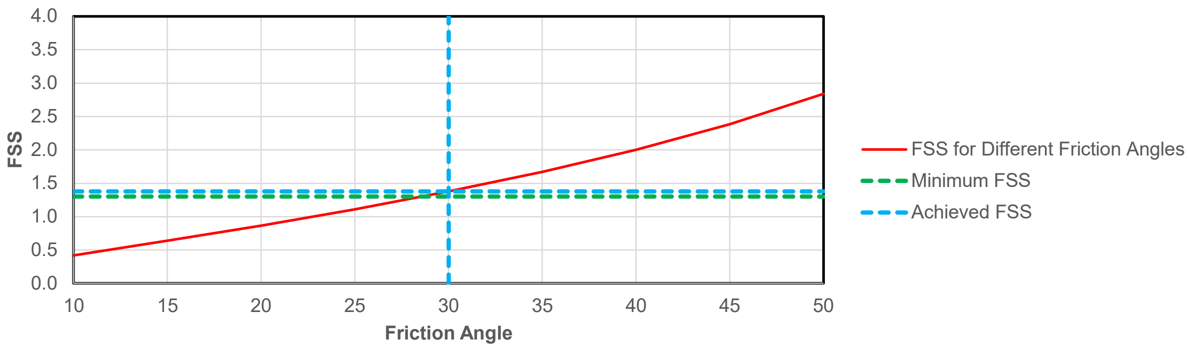
WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**Factor of Safety of Sliding**

Factor of Safety Against Sliding = (Sliding Coefficient, μ) x (∑Vertical Forces / ∑Horizontal Forces)

Sliding Coefficient, μ = 0.58
**Factor of Safety Against Sliding = 1.38** Acceptable




**Factor of Safety of Overturning, Location of the Resultant and Bearing Stresses**

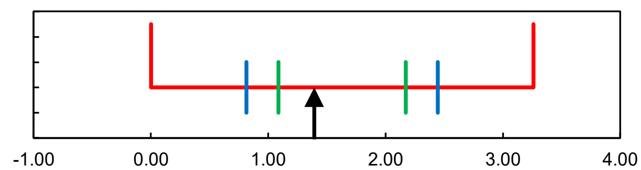
Factor of Safety Against Overturning = ∑Counterclockwise Moments / ∑Clockwise Moments)

**Factor of Safety Against Overturning = 2.15** Acceptable

Position of Resultant from Toe = ∑Moments / ∑Vertical Forces)

**Position of Resultant from Toe = 1.39** m
**Eccentricity (e) = 0.24** m

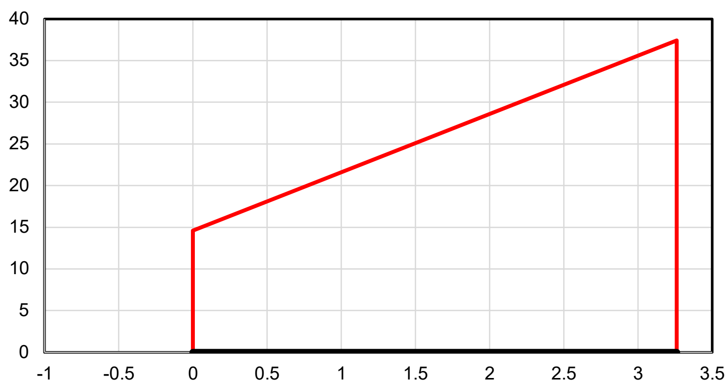
**Location of Resultant =** Inside Middle Third




**Average Vertical Stress = 26004** N/m$^2$

| | | | Concrete | Foundation |
|---|---|---|---|---|
| **Normal Compressive Stress at Toe =** | 14598 | N/m$^2$ | Acceptable | Acceptable |
| **Normal Compressive Stress at Heel =** | 37410 | N/m$^2$ | Acceptable | Acceptable |
| **Maximum Normal Compressive Stess =** | 37410 | N/m$^2$ | | |

**Normal Stresses Acting on Base (kN)**




| | | | |
|---|---|---|---|
| **Principle Stress at Toe =** | 14598 | N/m$^2$ | Acceptable |
| **Principle Stress at Heel =** | 37410 | N/m$^2$ | Acceptable |
| **Shear Stress at Toe =** | 0 | N/m$^2$ | Acceptable |
| **Shear Stress at Heel =** | 0 | N/m$^2$ | Acceptable |

## Overflow Weir - Loading Condition: 5. Extreme Load (Earthquake)

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

### Material Properties

| | | | | | |
|---|---|---|---|---|---|
| 9.81 | $m/s^2$ | Gravitational Acceleration, g | 500 | $kN/m^2$ | Allowable Foundation Bearing Pressure |
| 1000 | $kg/m^3$ | Density of Water, $\rho_{water}$ | 3000 | $kN/m^2$ | Allowable Compressive Stress in Concrete |
| 9810 | $N/m^3$ | Specific Weight of Water, $\gamma_{water}$ | 420 | $kN/m^2$ | Allowable Tensile Stress in Concrete |
| 2200 | $kg/m^3$ | Density of Concrete, $\rho_{concrete}$ | 250 | $kN/m^2$ | Allowable Shear Stress |
| 30 | degrees | Angle of Friction (Concrete/Foundation), $Ø_{cf}$ | | | |
| 9700 | $N/m^3$ | Specific Weight of Silt (Sediment), $\gamma_{silt}$ | | | |
| 32 | degrees | Angle of Internal Friction Silt (Sediment), $Ø'_{silt}$ | | | |
| 7700 | $N/m^3$ | Specific Weight of Backfill, $\gamma_{fill}$ | | | |
| 30 | degrees | Angle of Internal Friction Backfill, $Ø'_{fill}$ | | | |

### Structure Geometry

| | | |
|---|---|---|
| 142.60 | m | Top of Dam Elevation |
| 140.29 | m | Upstream Base Elevation |
| 140.29 | m | Downstream Base Elevation |
| 3.26 | m | Width of Dam, T |
| 1.00 | m | Sectional Length of Dam, t |
| 5.98 | $m^2$ | Area of Dam Section |
| 0 | degrees | Angle with toe vertical face (α) |
| 0 | degrees | Angle with heel vertical face (φ) |
| No | | Rock/Soil Anchors Present? |

### Additional Geometrical Definitions

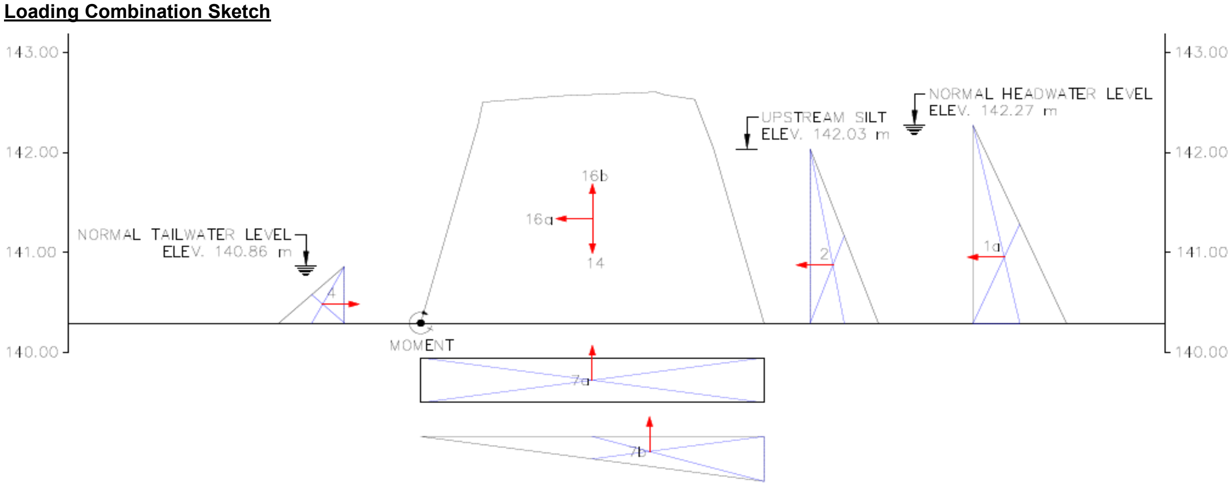
| | | |
|---|---|---|
| 142.03 | m | Upstream Silt Elevation |

### Loading Combination

5. Extreme Load (Earthquake) — Includes the following loads in combination: Dead Loads; Maximum Design Earthquake; Hydrostatic Load (maximum normal operating level); Soil Load; Uplift

1. Headwater Horizontal Hydrostatic Force
2. Upstream Horizontal Silt Force
4. Tailwater Horizontal Hydrostatic Force
7. Uplift Force
14. Dead Weight of Dam
16. Seismic Loading

### Loading Combination Sketch



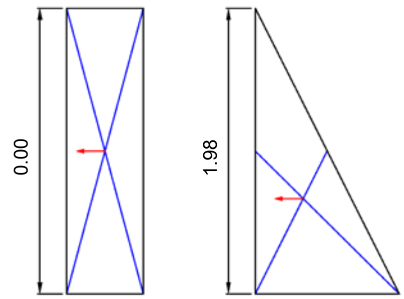
**Overflow Weir - Loading Condition: 5. Extreme Load (Earthquake)**

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

## 1. Headwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

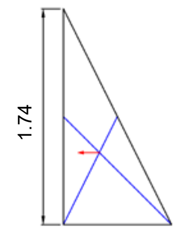
| | | |
|---|---|---|
| Headwater Elevation | 142.27 | m |
| Total Height of Water , h | 1.98 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 1.98 | m |
| **Hydrostatic Force (Triangular; 1a)** | **19230** | **N** |
| Moment Arm Length | 0.66 | m |
| **Hydrostatic Force (Rectangular; 1b)** | **0** | **N** |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **19230** | **N** |




## 2. Upstream Horizontal Silt Force

Upstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 1.74 | m |
| **Upstream Horizontal Silt Force** | **4512** | **N** |
| Moment Arm Length | 0.58 | m |

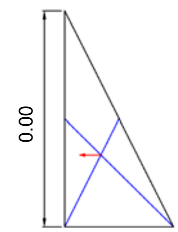



## 3. Upstream Horizontal Backfill Force

N/A

Upstream Horizontal Backfill Force = $(\gamma_{Fill} h^2 t/2) * (1-\sin Ø'_{Fill}/1+\sin Ø'_{Fill})$

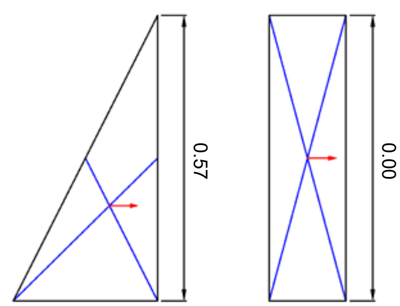
| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Upstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




## 4. Tailwater Horizontal Hydrostatic Force

Headwater Horizontal Hydrostatic Force = $0.5 * \gamma_{water} * h^2 * t$

| | | |
|---|---|---|
| Tailwater Elevation | 140.86 | m |
| Total Height of Water , h | 0.57 | m |
| Height of Water (Above Dam Crest), h' | 0.00 | m |
| Height of Water (Below Dam Crest), h" | 0.57 | m |
| **Hydrostatic Force (Triangular; 4a)** | **1594** | **N** |
| Moment Arm Length | 0.19 | m |
| **Hydrostatic Force (Rectangular; 4b)** | **0** | N |
| Moment Arm Length | 0.00 | m |
| **Total Headwater Hydrostatic Force** | **1594** | **N** |

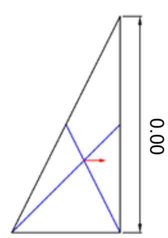



## 5. Downstream Horizontal Silt Force

N/A

Downstream Horizontal Silt Force = $(\gamma_{Silt} h^2 t/2) * (1-\sin Ø'_{Silt}/1+\sin Ø'_{Silt})$

| | | |
|---|---|---|
| Height of Silt, h | 0.00 | m |
| **Downstream Horizontal Silt Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |



WILLS

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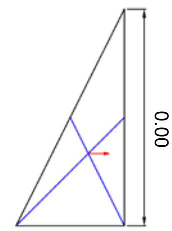
## 6. Downstream Horizontal Backfill Force

**N/A**

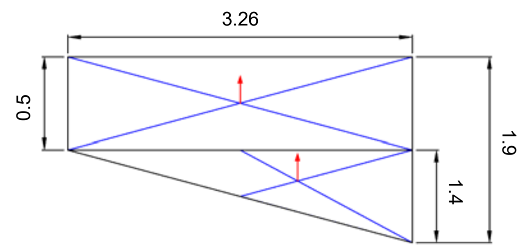
Downstream Horizontal Backfill Force = $(\gamma_{Fill} h^2 t/2) * (1\text{-}\sin\text{Ø}'_{Fill}/1+\sin\text{Ø}'_{Fill})$




| | | |
|---|---|---|
| Height of Backfill, h | 0.00 | m |
| **Downstream Horizontal Backfill Force** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

## 7. Uplift Force

Uplfit Force = $T((\gamma_{water}h+\gamma_{water}h')/2)t$

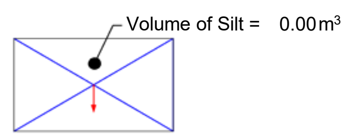



| | | |
|---|---|---|
| Width of Dam, T | 3.26 | m |
| Headwater Height, h | 1.98 | m |
| Tailwater Height, h' | 0.57 | m |
| **Uplift Force (Rectangular Component; 7a)** | **18229** | **N** |
| Moment Arm Length | 1.63 | m |
| **Uplift Force (Triangular Component; 7b)** | **22546** | **N** |
| Moment Arm Length | 2.17 | m |
| **Total Uplift Force** | **40775** | **N** |

## 8. Upstream Weight of Silt

**N/A**

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

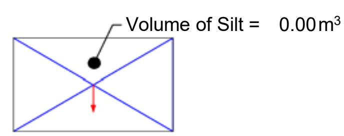



| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Upstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

## 9. Downstream Weight of Silt

**N/A**

Weight of Silt = $V_{Silt} * \gamma_{Silt}$

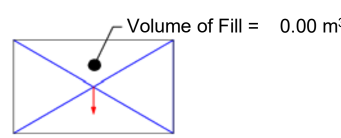



| | | |
|---|---|---|
| Volume of Silt, $V_{Silt}$ | 0.00 | $m^3$ |
| **Downstream Weight of Silt** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

## 10. Upstream Weight of Backfill

**N/A**

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

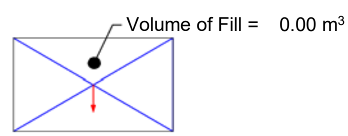



| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Upstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

## 11. Downstream Weight of Backfill

**N/A**

Weight of Fill = $V_{Fill} * \gamma_{Fill}$

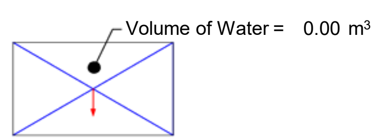



| | | |
|---|---|---|
| Volume of Fill, $V_{Fill}$ | 0.00 | $m^3$ |
| **Downstream Weight of Fill** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

## 12. Upstream Weight of Water

**N/A**

Weight of Water = $V_{water} * \rho_{water} * g$




| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Upstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |

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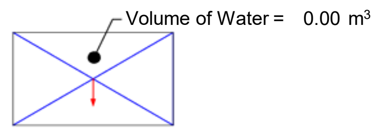
**Date:** 10/21/22

## 13. Downstream Weight of Water

N/A

Weight of Water = $V_{water} * \rho_{water} * g$

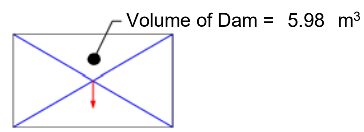
| | | |
|---|---|---|
| Volume of Water, $V_{water}$ | 0.00 | $m^3$ |
| **Downstream Weight of Water** | **0** | **N** |
| Moment Arm Length | 0.00 | m |




## 14. Dead Weight of Dam

Dead Weight of Dam = $V_{dam} * \rho_{dam} * g$

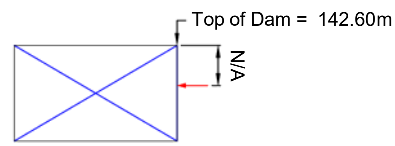
| | | |
|---|---|---|
| Volume of Dam, $V_{dam}$ | 5.98 | $m^3$ |
| **Dead Weight of Dam** | **129060** | **N** |
| Moment Arm Length | 1.63 | m |




## 15. Ice Loading

N/A

| | | |
|---|---|---|
| **Ice Load** | **0** | **N** |
| Moment Arm Length | 0.00 | m |



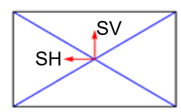

## 16. Seismic Loading

Horizontal Earhtquake Force = $V_{dam} * \rho_{dam} * S_H * g$

| | | |
|---|---|---|
| **Horizontal Earthquake Force; 16a** | **5162** | **N** |
| Moment Arm Length | 1.04 | m |

Vertical Earthquake Force = $V_{dam} * \rho_{dam} * S_v * g$

| | | |
|---|---|---|
| **Vertical Earthquake Force: 16b** | **3442** | **N** |
| Moment Arm Length | 1.63 | m |

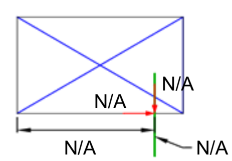



## 17. Rock/Soil Anchors

N/A

| | | | | | |
|---|---|---|---|---|---|
| **Anchor 1 Tension; 17a** | **0** | **N** | **Anchor 1 Shear; 17e** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 2 Tension; 17b** | **0** | **N** | **Anchor 2 Shear; 17f** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 3 Tension; 17c** | **0** | **N** | **Anchor 3 Shear; 17g** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |
| **Anchor 4  Tension; 17d** | **0** | **N** | **Anchor 4 Shear; 17h** | **0** | **N** |
| Moment Arm Length | 0.00 | m | Moment Arm Length | 0.00 | m |

Example Shown for Anchor 1



## Overflow Weir - Loading Condition: 5. Extreme Load (Earthquake)

WILLS

**Project No:** 21-5465
**Project Name:** Willoughby Stone Cutter's Dam
**Designed/Checked By:** DG
**Date:** 10/21/22

**Summary of Forces and Moments**

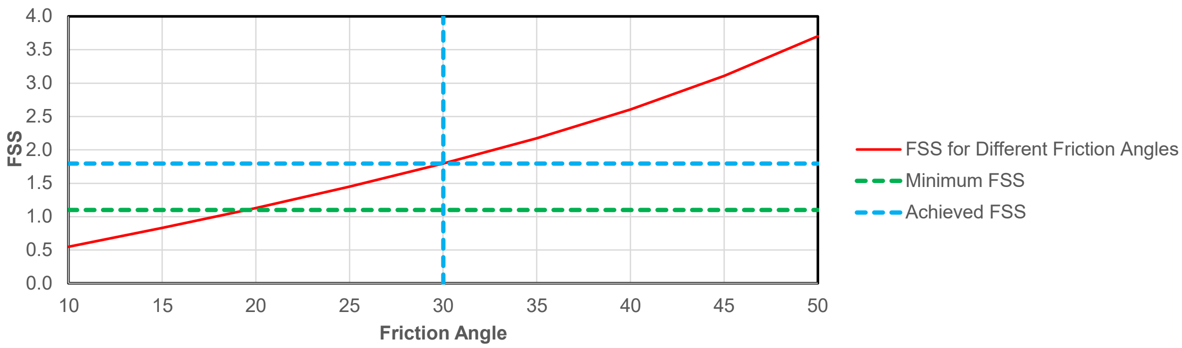
| Name of Force | Magnitude of Forces (N) | | | | Moment Arm Length (m) | Moments About the Toe (N-m) | |
|---|---|---|---|---|---|---|---|
| | Vertical Forces | | Horizontal Forces | | | | |
| | Down (+) | Up (-) | To U/S (+) | To D/S (-) | | Clockwise (+) | Counter Clockwise (-) |
| Headwater Horizontal Hydrostatic Force, 1a | | | | 19230 | 0.66 | | 12692 |
| Headwater Horizontal Hydrostatic Force, 1b | | | | | | | |
| Upstream Horizontal Silt Force, 2 | | | | 4512 | 0.58 | | 2617 |
| Upstream Horizontal Backfill Force, 3 | | | | | | | |
| Tailwater Horizontal Hydrostatic Force, 4a | | | 1594 | | 0.19 | 303 | |
| Tailwater Horizontal Hydrostatic Force, 4b | | | | | | | |
| Downstream Horizontal Silt Force, 5 | | | | | | | |
| Downstream Horizontal Backfill Force, 6 | | | | | | | |
| Uplift Force, 7a | | 18229 | | | 1.63 | | 29713 |
| Uplift Force, 7b | | 22546 | | | 2.17 | | 49001 |
| Upstream Weight of Silt, 8 | | | | | | | |
| Downstream Weight of Silt, 9 | | | | | | | |
| Upstream Weight of Backfill, 10 | | | | | | | |
| Downstream Weight of Backfill, 11 | | | | | | | |
| Upstream Weight of Water, 12 | | | | | | | |
| Downstream Weight of Water, 13 | | | | | | | |
| Dead Weight of Dam, 14 | 129060 | | | | 1.63 | 210368 | |
| Ice Loading, 15 | | | | | | | |
| Seismic Loading, 16a | | | | 5162 | 1.04 | | 5369 |
| Seismic Loading, 16b | | 3442 | | | 1.63 | | 5610 |
| Rock/Soil Anchors, 17a | | | | | | | |
| Rock/Soil Anchors, 17b | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17c | | | | | | | |
| Rock/Soil Anchors, 17e | | | | | | | |
| Rock/Soil Anchors, 17f | | | | | | | |
| Rock/Soil Anchors, 17g | | | | | | | |
| Rock/Soil Anchors, 17h | | | | | | | |
| **Sum** | **129060** | **44217** | **1594** | **28904** | **- -** | **210671** | **105001** |

| | | |
|---|---|---|
| **∑Horizontal Forces =** | **-27310** | **N** |
| **∑Vertical Forces =** | **84843** | **N** |
| **∑Clockwise Moment =** | **210671** | **N-m** |
| **∑Counterclockwise Moment =** | **-105001** | **N-m** |
| **∑ Moment =** | **105670** | **N-m** |

## Factor of Safety of Sliding

Factor of Safety Against Sliding = (Sliding Coefficient, μ) x (∑Vertical Forces / ∑Horizontal Forces)

Sliding Coefficient, μ = 0.58
**Factor of Safety Against Sliding = 1.79** Acceptable




## Factor of Safety of Overturning, Location of the Resultant and Bearing Stresses

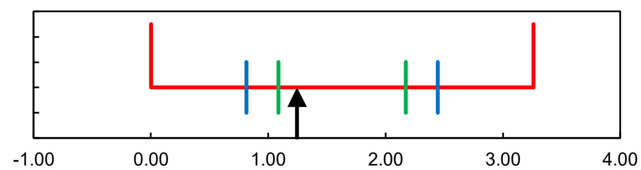
Factor of Safety Against Overturning = ∑Counterclockwise Moments / ∑Clockwise Moments)

**Factor of Safety Against Overturning = 2.01** Acceptable

Position of Resultant from Toe = ∑Moments / ∑Vertical Forces)

**Position of Resultant from Toe = 1.25 m**
**Eccentricity (e) = 0.38 m**

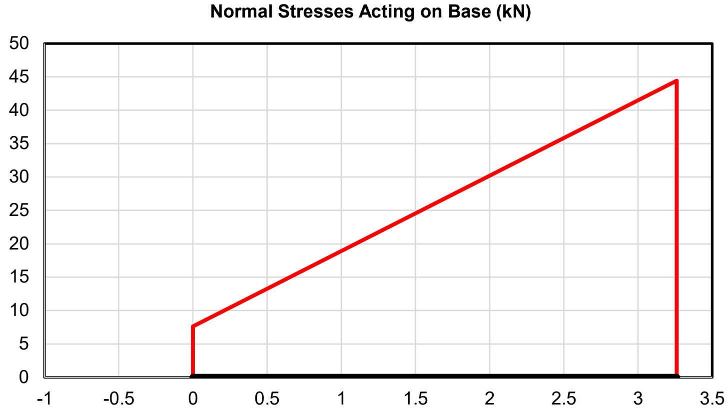
**Location of Resultant =** Inside Middle Third




**Average Vertical Stress = 26026 N/m$^2$**

| | | | Concrete | Foundation |
|---|---|---|---|---|
| **Normal Compressive Stress at Toe =** | **7607** | **N/m$^2$** | Acceptable | Acceptable |
| **Normal Compressive Stress at Heel =** | **44444** | **N/m$^2$** | Acceptable | Acceptable |
| **Maximum Normal Compressive Stess =** | **44444** | **N/m$^2$** | | |

**Normal Stresses Acting on Base (kN)**




**Principle Stress at Toe = 7607 N/m$^2$** Acceptable
**Principle Stress at Heel = 44444 N/m$^2$** Acceptable

**Shear Stress at Toe = 0 N/m$^2$** Acceptable
**Shear Stress at Heel = 0 N/m$^2$** Acceptable