Appendix A

Fullarton Dam

Hydrotechnical and Geotechnical

Review

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January 17, 2017

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Introduction

The dam controls a very small drainage area of 4 km^2 comprising mostly agricultural land. The conservation reservoir surface area is small and is impounded by a low earth-fill embankment dam located at the northern end of the reservoir. Flow releases from the dam outlet enter a narrow channel, and flow in a northeasterly direction for approximately 0.45 km before entering the main stem of the North Thames River.

The discharge facilities at the dam consist of a concrete drop inlet structure with a set of stop logs at the upstream face and an inverted V-shaped trashrack anchored to the top of the inlet. There is an emergency spillway located on the right or east bank. This is a lower section at the end of the embankment dam which is covered with cable-connected concrete blocks. The mouth of the spillway measured 9.5 m in length and appeared to be in good condition. The emergency spillway has a grassed discharge channel that runs parallel to the creek before joining it.

A review of previous investigations, mainly the 2007 Dam Safety Assessment Report for Fullarton Dam by Acres International and the 2008 Geotechnical Investigation Fullarton Dam Embankment Stability Assessment by Naylor Engineering Associates, was completed in order to summarize and highlight key information that can be used for future analysis and decision-making regarding Fullarton Dam.

Geotechnical Review

In order to assess the stability of the dam, the soil properties of the dam needed to be determined. To accomplish this, boreholes were taken. The two boreholes were taken by Acres International between November 24 to November 26, 2003, and four additional boreholes were taken by Naylor Engineering Associates on November 11, 2005. The locations of the boreholes are indicated on Figure 1.

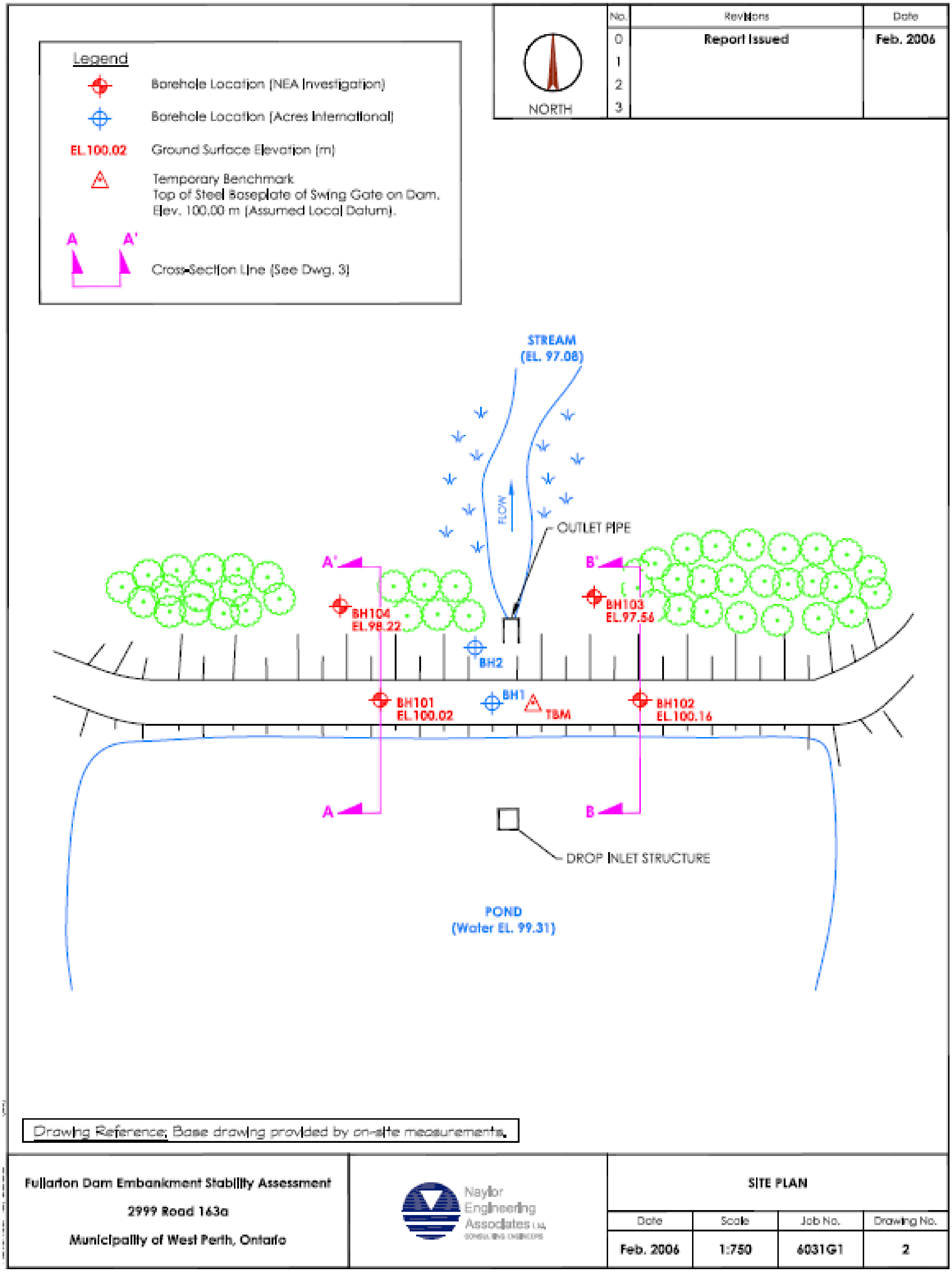

Figure 1: Location of Boreholes at Fullarton Dam

Acres International Stability Assessment

To be designated as stable, a dam must meet or exceed the requirements set by the Canadian Dam Safety Association and the Ontario Ministry of Natural Resources and Forestry. In the Dam Safety Assessment Report, the stability of the dam was calculated using the limit equilibrium method of slope analysis utilizing SLOPE/W and the Morgenstern-Price method of slices with half-sine function. Table 1 summarizes the soil properties used for the stability analysis as well as the results of the safety analysis.

Table 1: Stability Analysis of Earth Embankments by Acres International

Item	Criteria	Calculated	Comments
General			
IHP		Very Low	
Flood Conditions			
IDF		50-yr flood	
Materials			
Embankment			
- embankment fill (CL)			
cohesion (kPa)		0	
ϕ (deg)		32	
moist unit weight (kN/m^3)		17.8	
saturated unit weight (kN/m^3)		19.0	
Foundation			
- SP - SM			
cohesion (kPa)		0	
ϕ (deg)		32	
moist unit weight (kN/m^3)		18.5	
saturated unit weight (kN/m^3)		21.0	
- glacial till			
cohesion (kPa)		0	
ϕ (deg)		38	
moist unit weight (kN/m^3)		18.5	
saturated unit weight (kN/m^3)		20.3	
Loads			
Normal water level (NWL)		99.28	
IDF water level		100.05	
Seismic, horizontal (S_h) PGA (g)		0.020*	* 2/3, i.e., 0.013g, was used in pseudostatic analyses
Load Combinations			
Upstream Slope			
Normal (NWL)	1.50	1.32	Does not meet the criteria
Extreme (NWL, S_h)	1.10	1.26	
Extreme (IDF)	1.30	1.35	
Rapid Drawdown	1.20	N/A	
Downstream Slope			
Normal (NWL)	1.50	1.41	Does not meet the criteria
Extreme (NWL, S_h)	1.10	1.36	
Extreme (IDF)	1.30	1.41	
Rapid Drawdown	N/A	N/A	

As seen from Table 1, under normal water level conditions the upstream and the downstream slopes did not meet the criteria required to be classified as stable. The cross section of the dam and the areas of predicted failure from the Dam Safety Report are provided in Figure 2 and Figure 3.

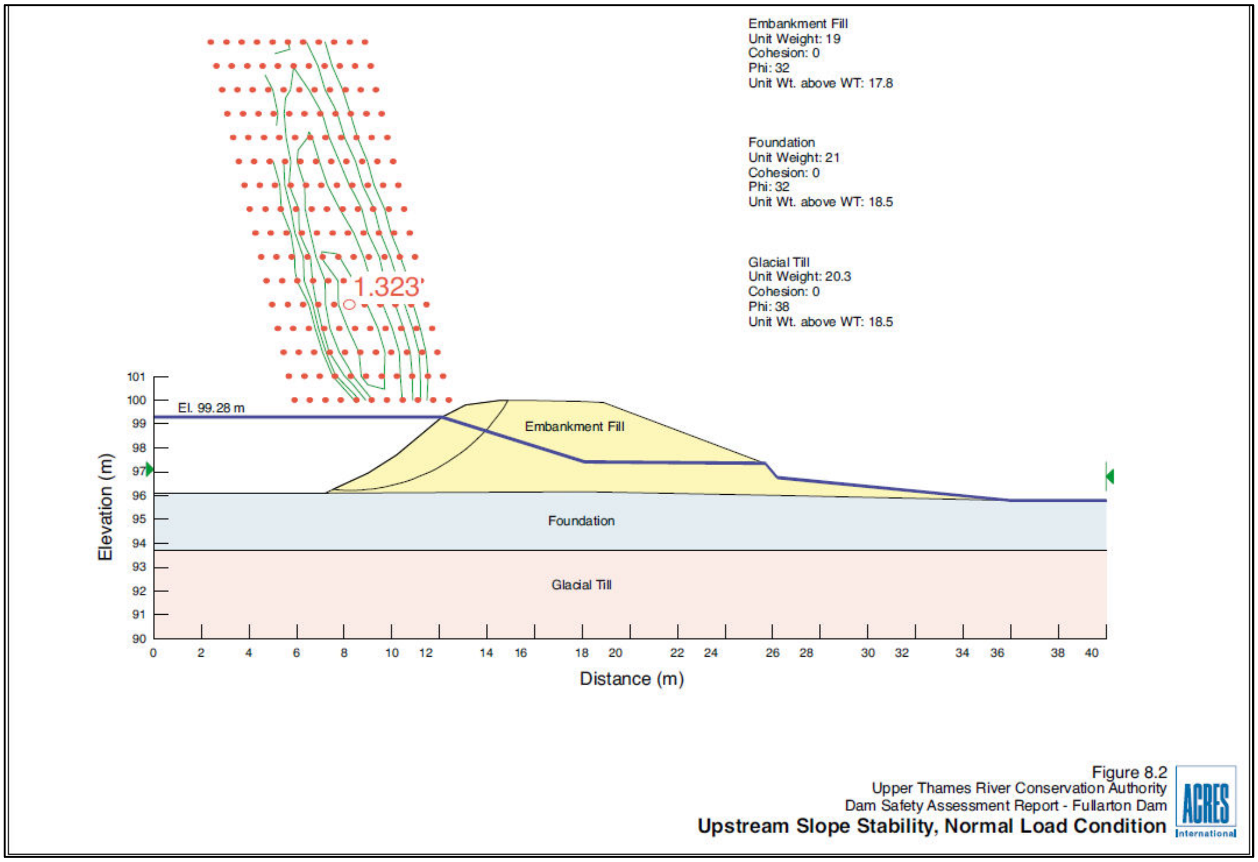

Figure 2: Upstream Slope Stability Under Normal Load Conditions

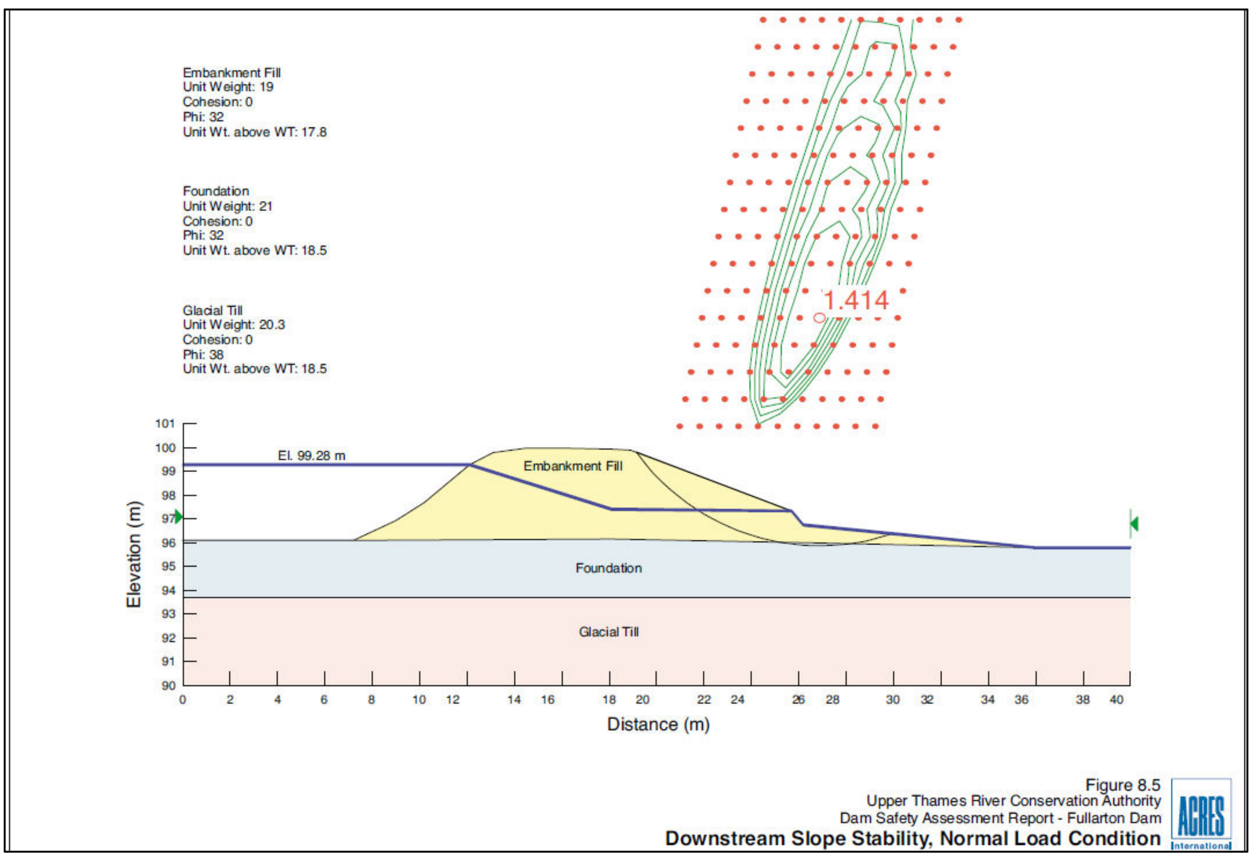

Figure 3: Downstream Slope Stability Under Normal Load Conditions

Naylor Engineering Associates Stability Assessment

As the calculations resulted in the dam not meeting the criteria by a very small amount it was recommended that the internal angle of friction assumed for the calculations be confirmed through shear strength tests.

Laboratory testing was completed on the soil samples from the four additional boreholes taken by Naylor Engineering Associates. From the samples taken from the boreholes it was determined that the internal angle of friction was 34 degrees. The calculated factors of safety from the stability analysis performed by Naylor Engineering Associates are provided in Table 2, below. These indicate that embankment maintains high stability under steady state, rapid draw down, and seismic conditions.

Table 2: Stability Analysis of Earthen Embankments by Naylor Engineering and Associates

Loading Conditions	Slope	Minimum Factor of Safety	Calculated Factor of Safety
Steady State Seepage with maximum storage pool	Downstream	1.5	2.7 to 3.2
Full or partial rapid drawdown	Upstream	1.3	1.5 to 1.7
Horizontal seismic load	Downstream and Upstream	1.3	1.3 to 2.6

Hydrotechnical Review

Hazard Potential Classification

There are no permanent dwellings or development in the immediate downstream reach of the discharge channel. Overall, no potential incremental loss of life under flood conditions is expected. Incremental economic, social and environmental losses are not expected to exceed the VERY LOW category. The dam has, therefore, been designated as a VERY LOW Incremental Hazard Potential (IHP) structure. See Table 3 below for detailed breakdown of Incremental Hazard Potential classifications from draft Ontario Dam Safety Guidelines 1999.

Table 3: Incremental Hazard Potential of Dams (MNR 1999)

Hazard Potential	Loss of Life	Economic and Social Losses	Environmental Losses
Very Low	Potential for LOL: None.	Damage to dam only. Little damage to other property. Estimated losses do not exceed $100,000.	Environmental Consequences: Short-term: Minimal Long-term: None
Low	Potential for LOL: None. The inundation area (the area that could be flooded if the dam fails) is typically undeveloped.	Minimal damage to agriculture, other dams or structures not for human habitation. No damage to residential, commercial, industrial or land to be developed within 20 years. Estimated losses do not exceed $1 million.	No significant loss or deterioration of fish and/or wildlife habitat. Loss of marginal habitat only. Feasibility and/or practicality of restoration or compensating in kind is high, and/or good capability of channel to maintain or restore itself.
Significant	Potential for LOL: None expected. Development within inundation area is predominantly rural or agricultural, or is managed so that the land usage is for transient activities such as with day-use facilities. There must be a reliable element of warning if larger development exists.	Appreciable damage to agricultural operations, other dams or residential, commercial, industrial development, or land to be developed within 20 years. Estimated losses do not exceed $10 million.	Loss or significant deterioration of important fish and/or wildlife habitat. Feasibility and/or practicality of restoration and/or compensating in kind is high, and/or good capability of channel to maintain or restore itself.
High	Potential for LOL: One or more. Development within inundation area typically includes communities, extensive commercial and industrial areas, main highways, public utilities and other infrastructure.	Extensive damage to communities, agricultural operations, other dams and infrastructure. Typically includes destruction of or extensive damage to large residential areas, concentrated commercial and industrial land uses, highways, railways, power lines, pipelines and other utilities. Estimated losses exceed $10 million.	Loss or significant deterioration of critical fish and/or wildlife habitat. Feasibility and/or practicality of restoration and/or compensating in kind is low, and/or poor capability of channel to maintain or restore itself.

* Supporting References: MNR Guidelines for Approval Under the Lakes and River Improvement Act, 1977
MNR Fisheries Section, 1999
US Army Corps of Engineers, Dam Safety Assurance Program, 1995
Dam Structure Assessment Program, Ontario Hydro, 1990

Notes:

1. Consideration should be given to the cascade effect of dam failures in situations where several dams are situated along the same watercourse. If failure of an upstream dam could contribute to failure of a downstream dam(s), the minimum hazard potential classification of the upstream dam should be the same as or greater than the highest downstream hazard potential classification of the downstream dam(s).
2. Economic losses refer to all direct and indirect losses to third parties; they do not include losses to owner, such as loss of the dam, associated facilities and appurtenances, loss of revenue, etc.
3. Estimated losses refer to incremental losses resulting from failure of the dam or misoperation of the dam and appurtenant facilities.
4. For Hazard Potential Classification and Safety Criteria for tailings dams, refer to "Guidelines for Proponents, Rehabilitation of Mines", issued by Ontario Ministry of Northern Development and Mines, 1995.

Updates to the Dam Hazard classification methodology were made after Fullarton dam was assessed using the MNR's Dam Safety Guidelines (Table 3). This updated methodology has been provided in Table 4, below.

Table 4: Incremental Hazard Classification of Dams (MNR 2011)

	Hazard Categories – Incremental Losses[1]			
Hazard Potential	**Life Safety[2]**	**Property Losses[3]**	**Environmental Losses**	**Cultural – Built Heritage Losses**
Low	No potential loss of life.	Minimal damage to property with estimated losses not to exceed $300,000.	Minimal loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a very low likelihood of negatively affecting the status of the population.	Reversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act.
Moderate	No potential loss of life.	Moderate damage with estimated losses not to exceed $3 million, to agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, other dams or structures not for human habitation, infrastructure and services including local roads and railway lines. The inundation zone is typically undeveloped or predominantly rural or agricultural, or it is managed so that the land usage is for transient activities such as with day-use facilities Minimal damage to residential, commercial, and industrial areas, or land identified as designated growth areas as shown in official plans.	Moderate loss or deterioration of fish and/or wildlife habitat with moderate capability of natural restoration resulting in a low likelihood of negatively affecting the status of the population	Irreversible damage to municipally designated cultural heritage sites under the Ontario Heritage Act. Reversible damage to provincially designated cultural heritage sites under the Ontario Heritage Act or nationally recognized heritage sites.
High	Potential loss of life of 1-10 persons	Appreciable damage with estimated losses not to exceed $30 million, to agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, other dams or residential, commercial, industrial areas, infrastructure and services, or land identified as designated growth areas as shown in official plans Infrastructure and services includes regional roads, railway lines, or municipal water and wastewater treatment facilities and publicly-owned utilities.	Appreciable loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/or wildlife habitat with reasonable likelihood of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a portion of the population of a species classified under the Ontario Endangered Species Act as Extirpated, Threatened or Endangered, or reversible damage to the habitat of that species.	Irreversible damage to provincially designated cultural heritage sites under the Ontario Heritage Act or damage to nationally recognized heritage sites.
Very High	Potential loss of life of 11 or more persons.	Extensive damage, estimated losses in excess of $30 million, to buildings, agricultural, forestry, mineral aggregate and mining, and petroleum resource operations, infrastructure and services. Typically includes destruction of, or extensive damage to, large residential, institutional, concentrated commercial and industrial areas and major infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes highways, railway lines or municipal water and wastewater treatment facilities and publicly-owned utilities.	Extensive loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/or wildlife habitat with very little or no feasibility of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a viable portion of the population of a species classified under the Ontario Endangered Species Act as Extirpated, Threatened or Endangered or irreversible damage to the habitat of that species.	

Notes
1. Incremental losses are those losses resulting from dam failure above those which would occur under the same conditions (flood, earthquake or other event) with the dam in place but without failure of the dam.
2. Life safety. Refer to Technical Guide – River and Streams Systems: Flooding Hazard Limits, Ontario Ministry of Natural Resources,

2002, for definition of 2 x 2 rule. The 2 x 2 rule defines that people would be at risk if the product of the velocity and the depth exceeded 0.37 square metres per second or if velocity exceeds 1.7 metres per second or if depth of water exceeds 0.8 metres. For dam failures under normal (sunny day) conditions the potential for loss of life is assessed based on both permanent dwellings (including habitable dwellings, trailer parks and seasonal campgrounds) and transient persons.
3. Property losses refer to all direct losses to third parties; they do not include losses to the owner, such as loss of the dam, or revenue. The dollar losses, where identified, are indexed of Statistics Canada values Year 2000.
4. An HPC must be developed under both flood and normal (sunny day) conditions.
5. Evaluation of the hazard potential is based on both present land use and on anticipated development as outlined in the pertinent official planning documents (e.g. Official Plan). In the absence of an approved Official Plan the HPC should be based on expected development within the foreseeable future. Under the Provincial Policy Statement, '*designated growth areas*' means lands within *settlement areas* designated in an official plan for growth over the long-term planning horizon (specifies normal time horizon of up to 20 years), but which have not yet been fully developed. *Designated growth areas* include lands which are *designated and available* for residential growth in accordance with the policy, as well as lands required for employment and other uses (Italicized terms as defined in the PPS, 2005).
6. Where several dams are situated along the same watercourse, consideration must be given to the cascade effect of failures when classifying the structures, such that if failure of an upstream dam could contribute of failure of a downstream dam, then the HPC of the upstream dam must be the same as or greater than that of the downstream structure.
7. The HPC is determined by the highest potential consequences, whether life safety, property losses, environmental losses, or cultural built heritage losses.

In these updates the classification methodology was updated to be more descriptive and to consider cultural and heritage losses. Fullarton Dam has not been assessed using these updated methodologies, but it is estimated that if it was assessed it would still be assigned the lowest possible hazard classification and as such would not affect the design criteria.

Dam Size Classification and Minimum Inflow Design Flood Return Period

The embankment dam is approximately 3.4 m high and impounds a total estimated storage volume of $20 \times 10^3\ m^3$. The dam has, therefore, been designated as a SMALL dam, based on the Ontario Dam Safety Guidelines. Due to the IHP classification of VERY LOW and the dam being classified as a SMALL dam, the inflow design flood is the 50 year flood. See Table 5 below for detailed breakdown of the determination of Minimum Inflow Design Flood return periods.

Table 5: Minimum Inflow Design Floods from Ontario Dam Safety Guidelines

Hazard Potential	Size of Dam and Inflow Design Floods					
	Small		Medium		Large	
	Height < 7.5 m	Storage $< 100 \times 10^3\ m^3$	Height 7.5 to 15 m	Storage 100×10^3 to $1000 \times 10^3\ m^3$	Height > 15 m	Storage $> 1000 \times 10^3\ m^3$
Very Low	25-year flood to 50-year flood		50-year flood to 100-year flood		100-year flood to RF	
Low	25-year flood to 100-year flood		100-year flood to RF		RF to PMF	
Significant	100-year flood to RF		RF to PMF		PMF Policy for existing dams is under consideration	
High	RF to PMF		PMF		PMF	
	Policy for existing dams is under consideration					

Legend: RF – regulatory flood
PMF – probable maximum flood

Notes:

1. For Minimum Inflow Design Floods for Mine Tailings dams, refer to "Guidelines for Proponents, Rehabilitation of Mines", issued by Ontario Ministry of Northern Development and Mines, 1995.
2. Existing dams refer to those structures built prior to 1978.

Deterministic Modelling

At Fullarton Dam, stream gauging and water level recording was not undertaken, rather the information presented is from past studies listed in the references section that estimated peak flows using deterministic modeling of the watershed on an event basis. The input data included:

- Physical parameters or the river basin such as, drainage area, stream course length and slope, and average slopes from topographic maps.
- Lag time was determined from the US Soil Conservation Service (SCS) method and then a conversion factor was applied based on the difference between the observed results and SCS results at the watershed used for calibration (Waubuno Creek watershed).
- The curve number of the watershed was based on land-use conditions, soil mapping units with physical soil characteristics (texture and infiltration rates).
- Precipitation data from the Stratford (Station 6148105) was used as it was determined to be the most representative of the storm events expected for the Fullarton basin.
- Intensity-duration-frequency (IDF) curves from Meteorological Service Canada/Environment Canada were used to determine the design storm(s) which would produce the maximum flow.
- Lake area and estimates of live storage.

The input data for the HEC-HMS model is summarized in the Table 6 below

Table 6: Summary of HEC-HMS Input Data for Fullarton Dam

Watershed	Local Drainage Area (km^2)	Total Drainage Area (km^2)	Pond Area (km^2)	Basin Lag (hrs)	Curve Numbers (CN)		Stream Length (km)	Average Slope (m/m)	Storm Event	Base Flow (m^3/s)	Initial Water Levels (m)
					II	III					
Neil Drain Catchment	4.0	4.0	0.016	2.6	79	91	2.8	0.0039	Spring Fall	0.12 0.01	99.40 99.34

Note: All elevations referred to a local datum of 100.00m based of a field survey of a steel marker at the dam surface.

Deterministic rainfall/runoff modeling results have established that the 50-yr, 3-day summer storm event is the governing flood for this site. During passage of the 50-yr, 3-day summer storm Inflow Design Flood event, approximately 84.2% of the discharge would be conveyed through the emergency overflow spillway with the remainder going through the drop inlet and over the embankment section. The inflow design flood for this frequency was estimated to be 17.7 m^3/s while the peak outflow was also 17.7 m^3/s due to negligible attenuation by the pond. Without considering wind and wave effects, the dam discharge facilities would be unable to pass this flood without slightly overtopping the main embankment dam by 0.05 m due to the upstream water level of 100.05 m (Acres International, 2007).

Minimum freeboard requirements were assessed in accordance with MNR guidelines and determined that under the inflow design flood conditions and the 1 in 100 year wind condition, the Wind Set-up and

Wave Run-Up would result in an additional height of 0.02 cm and 0.24 cm, respectively (Acres International, 2007).

Therefore, the dam does not have adequate spillway capacity or adequate freeboard to pass the inflow design flood.

Sedimentation

The Fullarton reservoir was surveyed on May 30, May 31, June 1, and June 2, 2016. The survey was completed using a Trimble GPS Geo7x unit with the minimum vertical accuracy set to 5 cm. Measurements were taken at the top of the sediment and below the sediment. The elevation below the sediment was determined by pushing the GPS rod through the sediment until a significant increase in resistance was felt which indicated the native reservoir bottom had been reached.

Upstream of the reservoir was surveyed on February 10, 2017, using the same techniques and equipment as described above.

The Fullarton reservoir was previously surveyed on August 22, 2006, using a slightly different methodology. In the 2006 survey a GPS unit accurate to ~ 1 m was used to determine the horizontal position in the pond and a large rod was used to manually measure the vertical depth to the top of the sediment and the vertical depth to the native bottom.

The effect of Fullarton Dam on sediment transport is most evident between Station 150 and Station 250 (See Figure 4 and Figure 5), where the depth of sediment was on average approximately 0.6 m thick. For context the water depth (i.e. water surface to top of sediment) in this reach is less than 0.3 m, in other words less than half of the depth of sediment. At Fullarton Dam, all of the water below the elevation of the drop inlet is slowed, which results in sediment that would normally be suspended in the watercourse to instead settle out. As the sediment accumulates in the reservoir, over time the open water surface area will decrease and the pond will take on wetland characteristics.

Typically the length of watercourse impacted by backwater effects of a dam can be identified by changes in substrate size. Smaller diameter substrates (silts, and fine sand) are found in lengths impacted by backwater effects and larger diameter substrates (gravels and pebbles) are visible further upstream in lengths not impacted by backwater effects. It is estimated that the extent of the backwater effect concludes at approximately Station -165, about 50 m downstream of the culvert at Road 163. There is some added uncertainty to this location due to the fact that at the date of the survey there were 3 beaver dams located further upstream between 18 Line and Road 163. Beaver dams have an impact on sediment transport that is similar to the impact from man-made dams in that water is slowed which allows sediments to settle out.

There is some uncertainty in estimating the loading rate at Fullarton Pond. Records indicate that a large quantity of silt was removed and the pond was deepened in the winter of 1966/1967 (estimated as Jan 15, 1967), it was assumed that at this date there was no sediment in the pond. From the 2016 survey it was determined that in the pond there was approximately 6015 m^3 of sediment, this equates to a sediment accumulation rate of ~ 119 m^3 of sediment/year. From the 2006 survey it was determined that in the pond there was approximately 6400 m^3 of sediment, this equates to a sediment accumulation rate of ~ 158 m^3 of sediment/year. There are a number of factors that can be used to estimate soil loss and sediment accumulation (e.g. slope, land-use, barriers), one of these factors is the size of the catchment area. From the recent Environmental Assessments completed for Harrington Dam and Embro Dam, the sediment accumulation rate was 24.3 and 23.0 m^3 of sediment/km^2 of catchment area per year, respectively. If this average sediment accumulation rate per catchment area was applied to Fullarton Dam, the expected sediment accumulation rate would be ~ 95 m^3 of sediment accumulation per year. A reasonable estimate of the sediment accumulation rate at Fullarton dam would be between 90 – 160 m^3 of sediment per year.

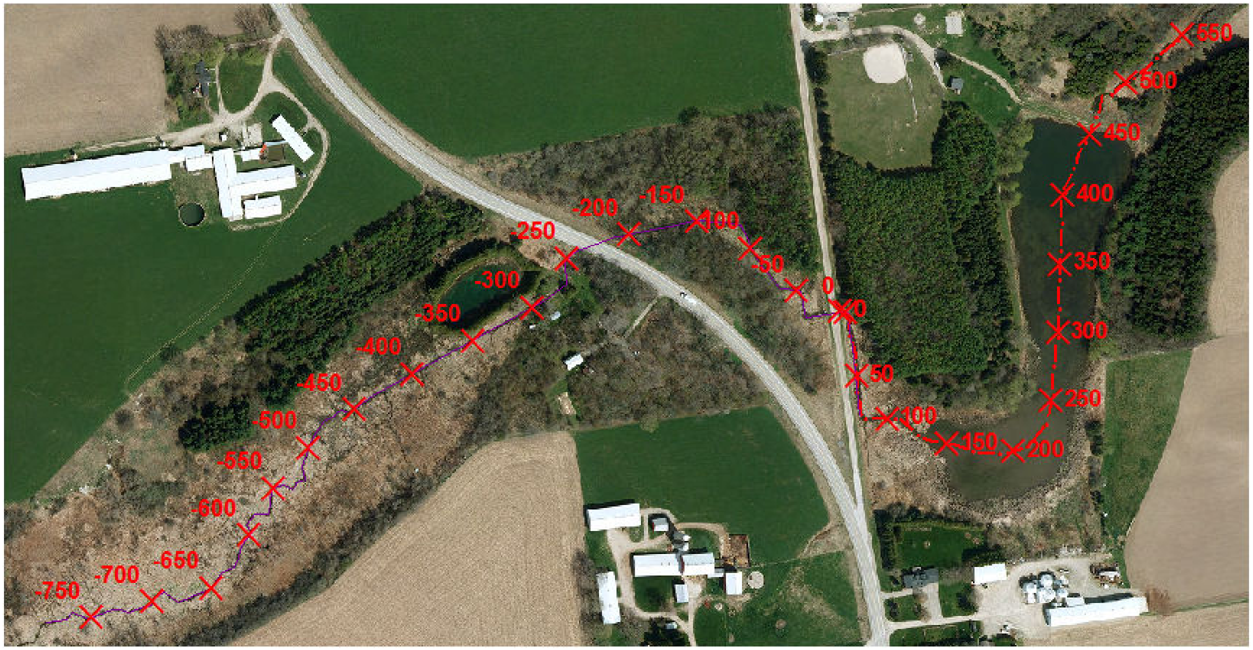

Figure 4: Stations of Surveyed Streambed

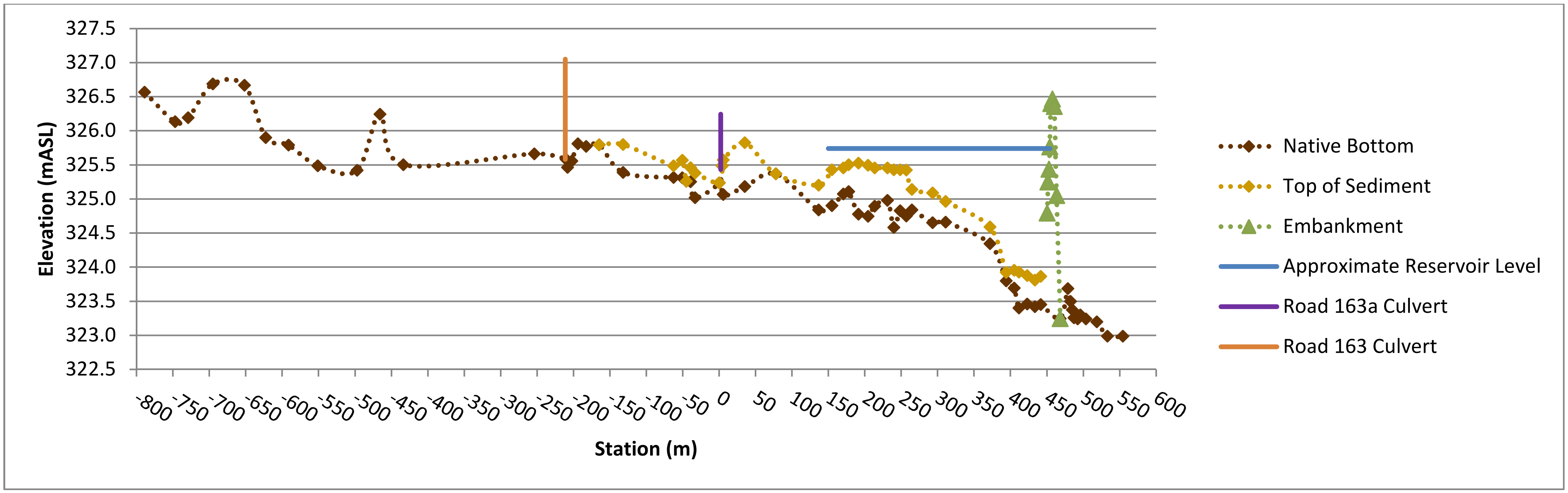

Figure 5: Profiles of Streambed and Top of Sediment

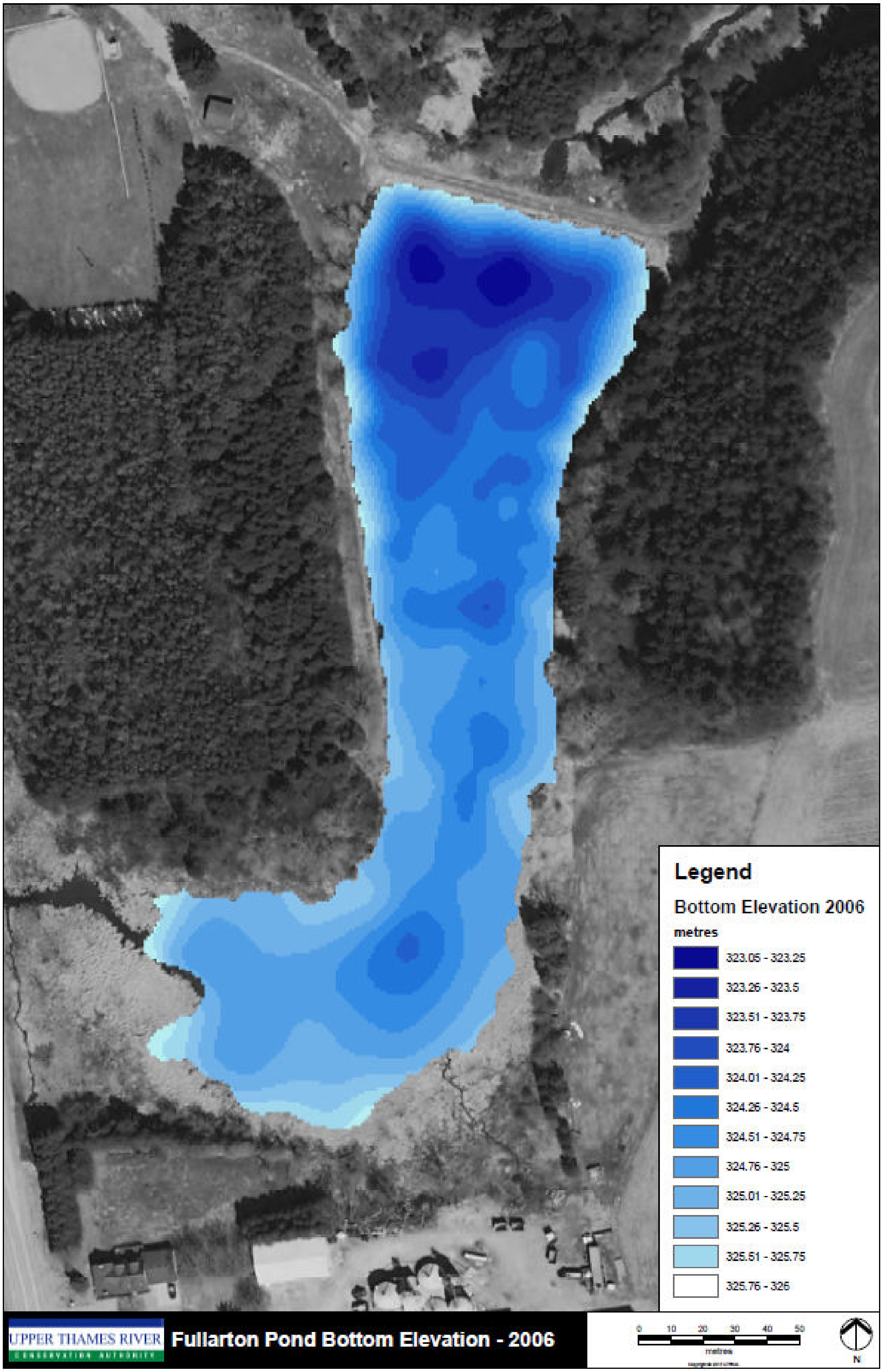

Figure 6: Fullarton Pond Bottom from 2006 Survey

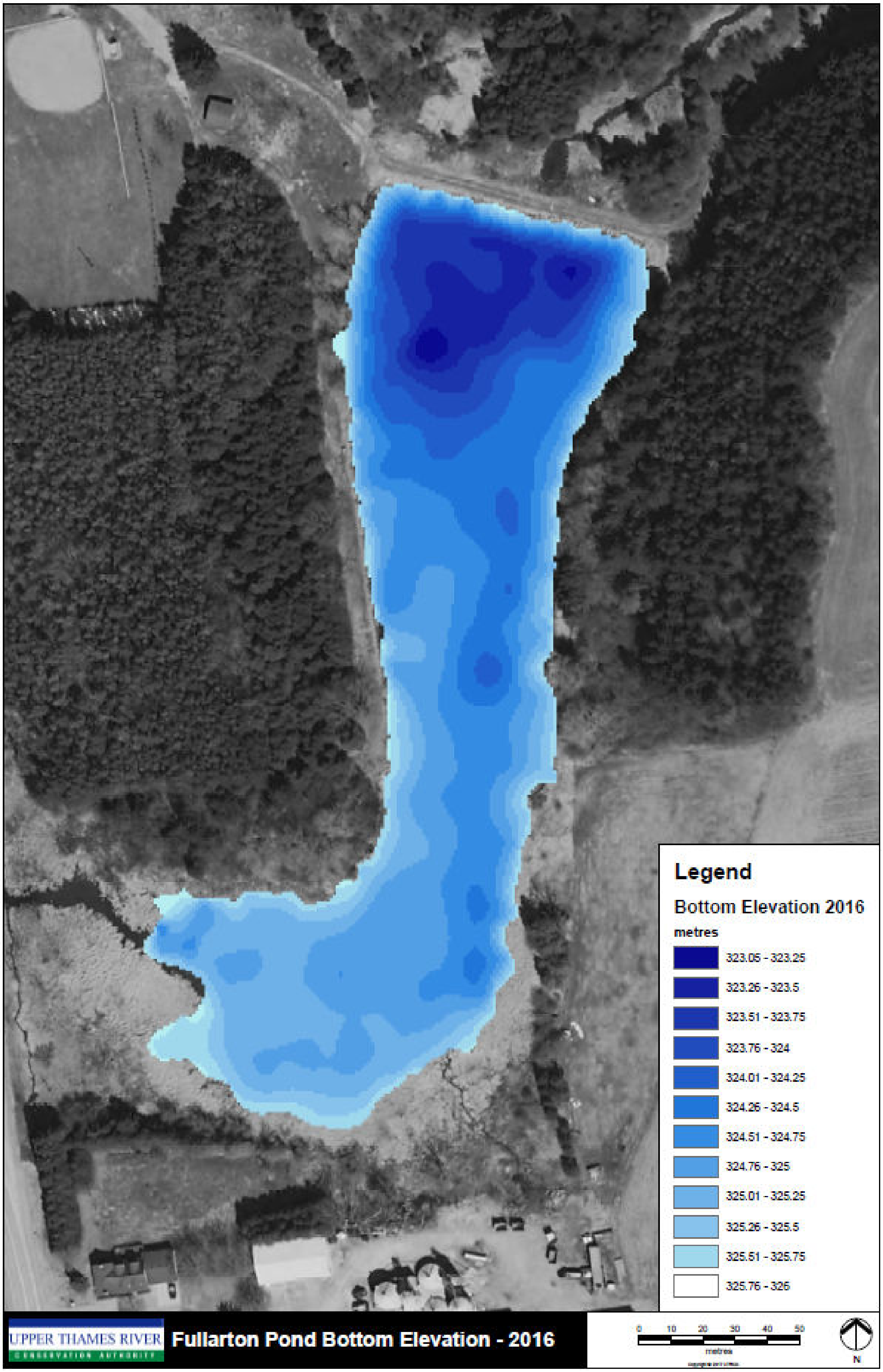

Figure 7: Fullarton Pond Bottom from 2016 Survey

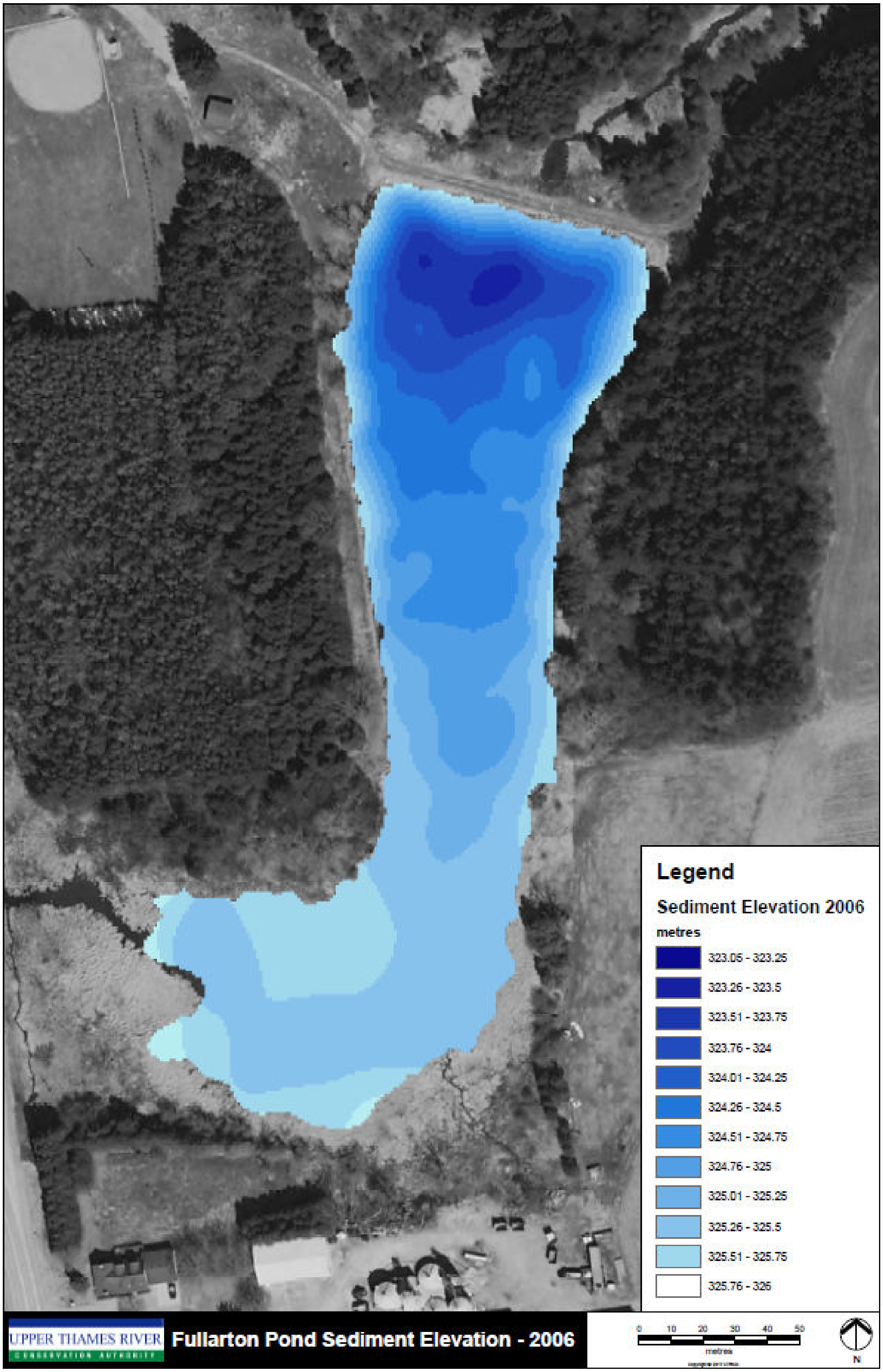

Figure 8: Fullarton Top of Sediment from 2006 Survey

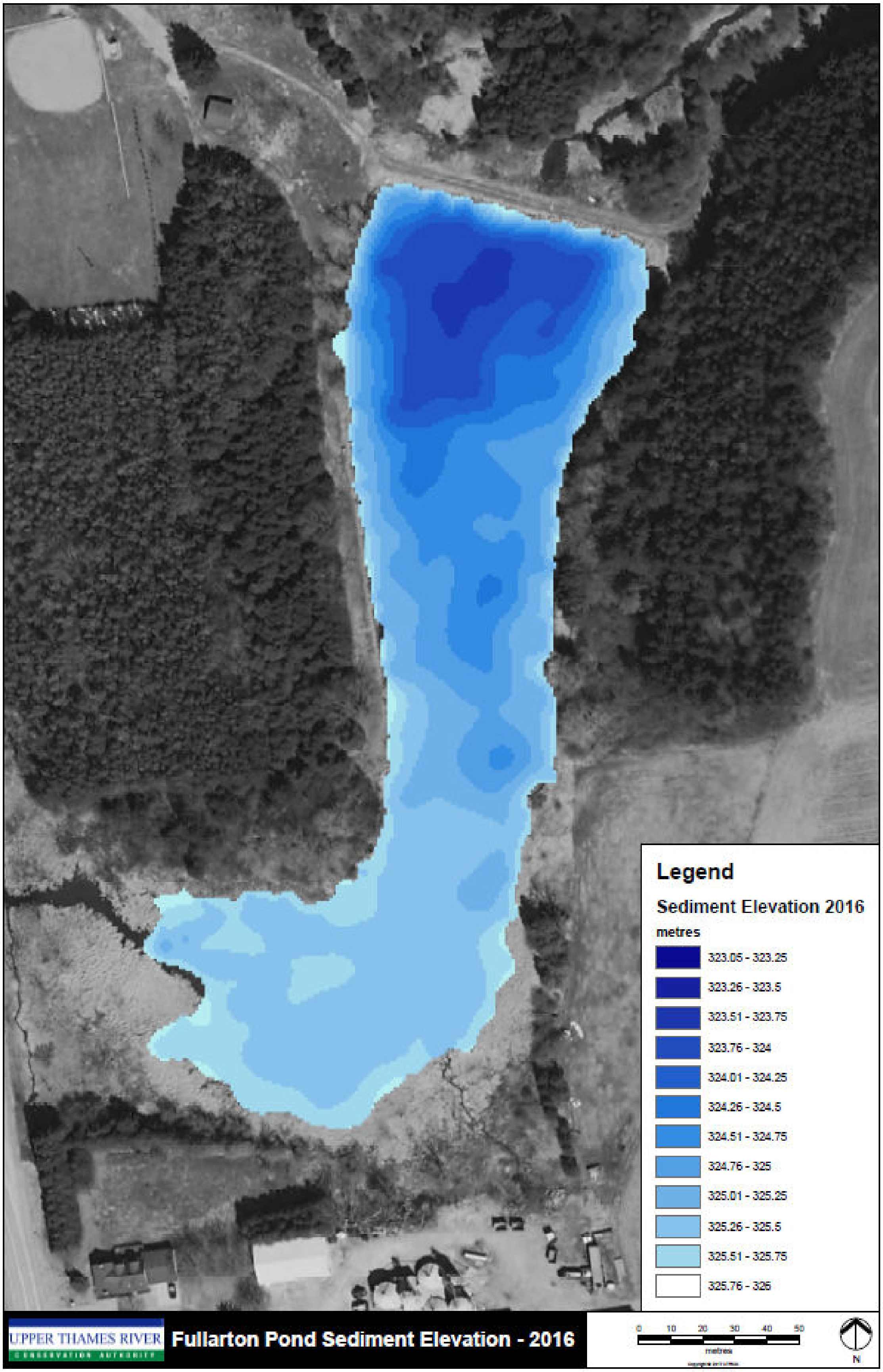

Figure 9: Fullarton Top of Sediment from 2016 Survey

Recommendations

Both the Dam Safety Assessment by Acres International and the Geotechnical Investigation by Naylor Engineering Associates produced recommendations to maintain or improve the stability of the dam. These recommendations and the cost estimates to complete them (updated to 2016 dollars) are detailed in Table 7. Estimated UTRCA costs for project management have also been included.

The total cost to complete all of the recommendations from Acres International and Naylor Engineering Associates is estimated at approximately $101,000.

It is recommended that the following work be completed in order to assist with decision making on future options regarding Fullarton Dam:

- a repeat of sediment surveys in order to allow sediment loading rates to be monitored
- investigate unit costs for sediment removal, testing, stabilization, and appropriate disposal
- investigate costs for dam removal and stream restoration

Table 7: Recommendations and Costs

Item	Contract Quantity	Unit	Unit Price ($)	Contract Total
UTRCA Project Management	1	LS	9000	9000
Design, Tender, and Admin @ 30%	1	LS	18170	18170
Contingency @ 15%	1	LS	9090	9090
Mobilization and Demobilization	1	LS	3030	3030
Bonding and Insurance	1	LS	1820	1820
Sediment Control (Silt Fencing)	1	LS	1640	1640
Clear and Grub Dam Embankments -to allow crest to be raised and to maintain the capacity of the emergency spillway	1	LS	2740	2740
Raise Crest Height -place and compact clay fill to prevent the dam crest from being overtopped during the inflow design flood	150	cu.m	110	16420
Supply and Install 100-300mm diameter Rip-Rap over filter cloth and sand and Granular "A" gravel base -required on upstream face of embankment and 10m downstream of dam outlet	380	sq.m	50	18720
Supply and Install 150 mm diameter Toe Drain with filter sand and sock that runs perpendicular to the outlet pipe 50 m on either side of the pipe -required to prevent seepage piping erosion	110	m	190	21070
Total Cost				101,700

References

Acres International Inc. (2007). *Dam Safety Assessment for Fullarton Dam.*

Naylor Engineering Associates Inc., Kelly, Dennis. (2006). *Geotechnical Investigation Fullarton Dam Embankment Stability Assessment Municipality of West Perth, Ontario for Upper Thames River Conservation Authority*

R.J. Burnside & Associates Ltd., MacIntyre, Paul. (2010). *Dam Rehabilitation* (p. 8).