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northwest hydraulic consultants ltd

NHC Ref. No.1004400

3 June 2020

Dub Architects Ltd.
#901, 10345 107 Street NW
Edmonton, AB
T5J 1K3

Attention: **Michael Dub**
Principal

Copy to:

Via email: mdub@dubarchitects.ca

Re: **Touch the Water Promenade and North Shore Promenade – Final Report Hydrotechnical Assessment**

1 INTRODUCTION

1.1 Project Overview

The City of Edmonton is proposing to build two waterfront public spaces: the Touch the Water Promenade and the North Shore Promenade. Both spaces are located on the north side (left bank) of the North Saskatchewan River in the core of Edmonton. The Touch the Water Promenade starts at the Walterdale Bridge and extends downstream to 94 Avenue. The objective of the Touch the Water Promenade is to connect the existing river valley trail, Rossdale Generating Station and pump houses, and the new Walterdale Bridge for public gathering and individual enjoyment of the River Valley. The North Shore promenade starts at Government House Park and extends downstream to the Walterdale Bridge.

1.2 Scope of Work

Northwest Hydraulic Consultants Ltd. (NHC) were retained by Dub Architects Ltd. (Dub) to provide a hydrotechnical assessment for the proposed Touch the Water Promenade and North Shore Promenade. The scope of work includes:

1) Assessment of lateral stability of the left bank including air photo analysis and assessment of field observations.

2) Development of one-dimensional hydraulic model to determine river levels under open water and ice cover conditions.
3) Development of two-dimensional hydraulic model to estimate local flow velocities along the bank. Flow velocities can be used to assess risk of bank erosion, deposition and ice forces and risk to users of the promenade.

This report describes the analysis and results of our assessment. It is expected that further analysis will be done in future phases of the project as design details arise.

2 BACKGROUND

2.1 Reach Description

Figure 2-1 shows the locations of the North Shore Promenade and Touch the Water Promenade, which is south of downtown Edmonton. The North Saskatchewan River generally flows east in the vicinity of the project.

The North Saskatchewan River at the study site is set within a winding, trench like valley of postglacial origin (Kellerhals et al., 1972). There are four fragmentary terraces that have been identified in the area, with the lowest terrace corresponding to the adjacent floodplain. The project area is located primarily on the lowest terrace. The overall channel pattern consists of irregular, entrenched meanders with frequent point and side bars. The banks consist of silt, sand and minor amounts of gravel and are relatively easily erodible. In locations where the channel flows against the valley, slow toe erosion can lead to periodic slumps. The bed consists primarily of gravel with a measured median diameter (D_{50}) equal to 31 mm. Below the riverbed, shallow bedrock is present (Edmonton Formation) consisting of poorly consolidated shales and sandstones.

2.2 Site Description

A site visit and survey were carried out by NHC personnel on 14 and 15 August 2019. During the site visit, observations of the left bank of the North Saskatchewan River were made. There are occasional locations where the is bank protected in the form of sparsely placed concrete or rock riprap. Specifically, there are concrete blocks on the bank at Government House Park and there is Class 2 Riprap with bioengineered planter boxes embedded around the abutments of the Walterdale Bridge. The bank is vegetated with trees, brush and grasses along most of the reach. There were several outfalls along the reach, which are assumed to discharge primarily stormwater into the river. The reach encompasses four bridges including: Groat Road Bridge, Menzies Bridge (LRT), High Level Bridge and Walterdale Bridge. There is a small island located adjacent to the left bank (the downstream end of island is 325 m upstream of the Menzies Bridge). The island is approximately 225 m long by about 15 m wide. There is a small subchannel (10 m wide) that runs between the island and the left bank. There are two concrete water intake structures located in the middle of the channel near the upstream end of the island. There is also a concrete water intake structure on the left bank approximately 70 m downstream of the Walterdale Bridge. There is a boat launch located on the left bank approximately 700 m downstream of the Walterdale Bridge. Selected site photos are shown in **Figure 2-2** and **Figure 2-3** with corresponding photo locations shown in **Figure 2-4**.

3 HYDROLOGY

3.1 General Hydrologic Setting

The North Saskatchewan River originates in the Rocky Mountains to the west of Edmonton. The upstream drainage area of the North Saskatchewan River in Edmonton is 28, 000 km^2. The land use upstream consists of mountainous terrain and forested foothills in the upper reaches and agricultural land in the lower reaches.

There are two hydropower dams present upstream of Edmonton: the Brazeau Dam and the Bighorn Dam. The Brazeau Dam was completed in 1963 and regulates the flow of the Brazeau River (a major tributary of the North Saskatchewan River). The Bighorn Dam was completed in 1973 and regulates the flow of the North Saskatchewan River near the headwaters. These dams tend to reduce the magnitude of the median sized summer flood events, but tend not to have a large effect on more extreme events. The dams also affect the winter ice regime due to the higher winter flows associated with hydropower generation. The operation of these dams tends to exacerbate the freeze-up severity along the river at Edmonton and upstream, but seems to have little effect on the breakup processes.

There is a Water Survey of Canada (WSC) gauge located just downstream of the proposed promenades at the Low Level Bridge. This gauge (#05DF001) has monitored water levels and discharges since 1911.

3.2 Open Water Flood Frequency Analysis

Open water hydrology on the North Saskatchewan River has been well studied by Alberta Environment and Parks (AEP). A 1990 study of a Flood Frequency Analysis North Saskatchewan River at Edmonton was conducted to determine flood peaks at Edmonton. The study naturalized flood peaks by including storage effects of the upstream reservoirs and routing the flows from the upper part of the basin to Edmonton. This flood frequency analysis was utilized for subsequent floodplain studies for the Lower Reach (Phillips Planning and Engineering, 1994) and Upper Reach (IDG, 1995) of the North Saskatchewan River at Edmonton.

A further floodplain study was completed in 2006 on the North Saskatchewan River, that included areas upstream of Edmonton (near Devon) and downstream of Edmonton (near Fort Saskatchewan). This study correlated the naturalized flood peaks with the post regulation flood peaks and applied the relationship to the post-1992 flood peaks. This study extended the period of record to 2006. The same approach is utilized in the current study to extend the period of record to 2015. **Table 3-1** shows a comparison between this analysis completed in current study and the 1990 study. The results produced are very similar, so the slightly more conservative results from the 1990 AEP flood frequency analysis will be used for the assessment herein.

It is important to note that an AEP floodplain study of the North Saskatchewan River at Edmonton is currently underway. It is recommended that future phases of the Touch the Water Promenade and the North Shore Promenade adopt the updated floodplain study flood peak results when available (anticipated in 2020).

Table 3-1 Summary of open water flood discharges, 1899-2015

Return Period (years)	Estimated Instantaneous Peak Discharge (m^3/s)		
	1990 Study	Current Study	Adopted Discharge
2	1270	1270	1270
5	2230	2170	2230
10	2940	2850	2940
25	3870	3750	3870
50	4570	4440	4570
100	5270	5140	5270

3.3 Freeze-up Flood Frequency Analysis

An ice cover typically forms during November on the North Saskatchewan River in Edmonton. The process for ice formation begins with the production of frazil ice particles, which eventually consolidate into larger ice floes (frazil pans). Once a certain density of the ice floes is present, the floes will consolidate into a solid ice cover, which corresponds to rise in water level. The WSC data is denoted with a symbol "B" when the water levels are "ice affected". This provides an indication when ice is beginning to form, but not necessarily when a full ice cover forms. For this analysis, the discharge for the first day denoted with the symbol will be representative of the discharge at freeze-up. A flood frequency analysis was performed on the freeze-up discharges using the post-1972 record. A Log-Pearson Type III distribution was utilized as it was observed to best fit the data set. The results are presented in **Table 3-2.**

Table 3-2 Summary of freeze-up peak discharges, 1972-2015

Return Period (years)	Freeze-up Peak Discharge (m^3/s)
2	126
5	159
10	180
25	204
50	221
100	238

4 HYDROTECHNICAL INVESTIGATION AND ANALYSIS

4.1 One-Dimensional Hydraulic Model

A one-dimensional model (HEC-RAS) was developed using NHC's survey data, lidar (provided by Dub) and bridge data obtained from Alberta Transportation. **Figure 4-1** shows the locations of the cross sections used in the hydraulic model. HEC-RAS is a one-dimensional hydraulic model that is the industry standard for hydraulic analysis. Data from previous floodplain studies were utilized to incorporate the bridge features into the hydraulic models. The local downstream channel gradient was based on local survey data, Alberta Transportation bridge files and data from Kellerhals et al. (1972). Manning's 'n' roughness values of 0.031 and 0.06 were selected for the river bed and bank, respectively. The Manning's "n" roughness and downstream boundary conditions were calibrated for this reach based on high water marks from the 1986 and 1982 floods. The roughness selected is consistent with site observations, air photos, satellite images and recommended values listed in Chow (1959).

4.2 Freeze-up Water Level Modeling

Freeze-up ice levels were modeled in the HEC-RAS model to provide top of ice levels for various return periods. The WSC gauge provides water level and discharge records from between 1999 and 2015. The relationship between freeze-up water discharge and water level are illustrated in **Figure 4-2**. This relationship between discharge and water level depend on various parameters including discharge, ice thickness, and ice roughness so the data plotted in **Figure 4-2** is quite variable.

The HEC-RAS model was extended downstream of the WSC gauge using geometry data from the previous floodplain study. The freeze-up water level from the WSC gauge was used to calibrate the ice jam parameters in the HEC-RAS model. The downstream end of the ice jam was established near the end of the model domain and ice jam profiles were calculated throughout the reach. A range of discharges were modeled so an ice jam rating curve could be developed. This rating curve was compared to observed data at the WSC gauge. The analysis assumed a typical freeze-up ice thickness of 0.6 m.

Two typical early winter under ice roughness' (n = 0.03 and n = 0.05) were modeled and compared to the measurements at the WSC gauge. It was found that a roughness of 0.03 did not adequately envelope the WSC data, however the roughness of 0.05 enveloped most of the data points. HEC-RAS is unable to simulate ice cover consolidation, so a freeboard of 0.5 m was added to the ice levels to account for this. Once calibrated, the ice jam model was run for the freeze-up discharges to determine the top of ice throughout the model domain.

4.3 Two-Dimensional Hydraulic Model

A two-dimensional hydraulic model (TELEMAC-2D) was developed using NHC's survey data, lidar (from Dub) and bridge data obtained from Alberta Transportation. TELEMAC-2D is widely used to simulate free-surface flows in two dimensions and was developed by the Laboratoire National d'Hydraulique et Environment. The model was utilized to predict the local water velocities during flood peak events. The model encompasses the project area, which extends from the Government House Park at the upstream end to 94 Avenue at the downstream end. Three densities were used for the North Saskatchewan River in the model: (1) 2 m around the bridge piers and left bank island (2) 10 m for the channel and banks and (3) 20 m for the overbanks. The downstream boundary condition in the two-dimensional model was considered to be the water elevation modelled in the HEC-RAS model, which was calibrated to the peak flood events in 1986 and 1982 with recorded high water marks. The two-dimensional hydraulic model was similarly calibrated to the 1986 and 1982 observations by varying the Manning's "n" roughness.

Figure 4-3 to **Figure 4-8** show the velocity distributions and extents of inundation in the North Saskatchewan River during a 2-, 5-, 10-, 25-, 50-, and 100-year flood peaks, respectively.

Based on the velocity contour maps, the locations of greatest potential for erosion on the left bank are upstream of the Groat Road bridge and between the High Level Bridge and the Walterdale Bridge.

5 HISTORICAL AIR PHOTO ANALYSIS

The North Shore Promenade and the Touch the Water Promenade are both located along the left bank of the North Saskatchewan River. The stability of the left bank was assessed based on historical air photos and field observations. Historical air photos were obtained from AEP to assess the rates of erosion on the left bank of the river. Photos from 1962, 1982, 2001 and recent satellite imagery from 2015 were analyzed. **Figure 5-1** and **Figure 5-2** show the georeferenced air photos. **Figure 5-3** shows the approximate location of the bank delineated on each air photo. The bank lines were overlaid on a single image to illustrate the lateral stability of the left bank along the reach. Given that there is no consistent trend in bank position over time, much of the differences are likely due to distortion and scale effects.

6 HYDROTECHNICAL CONSIDERATIONS FOR PROPOSED FEATURES

6.1 Erosion

In general, the left bank of the North Saskatchewan River is not susceptible to signification bank erosion. The historical air photo analysis of the reach shows that over the last approximately 60 years that the left bank has remained relatively stable. Upstream of the Groat Road Bridge, the left bank may be susceptible to some erosion because it is located on the outside of a meander. There is some existing bank protection in the form of broken concrete at the toe of the bank in this area. This bank protection is keeping the bank stable and more resistant to erosion. Dub has indicated that the existing concrete blocks armouring this bank should be replaced with an alternative material on this section of the river. Between the Groat Road Bridge and the High Level Bridge, the channel is fairly straight with the left bank being on the inside of a mild meander. The left bank is well vegetated and therefore appears to be stable. At the toe of the slope, some deposition of fine sediment was observed. The standard procedure is to use rock riprap as protection as it is a proven robust material and is durable over time. Other options for bank protection include gabion walls, sheet pile walls, bioengineering measures or a combination of the aforementioned options.

Recommendations:

1. **Replace existing concrete block armouring upstream of Groat Road Bridge. The recommended replacement would be rock riprap with bioengineering features.**
2. **All features on the bank should be assessed for erosion potential and potential mitigation measures should be incorporated.**

6.2 Scour

Dub bas proposed features that extend over the channel including overlooks, and suspended promenades, which may require vertical supports similar to bridge piers. Local scour can be caused around piers when flow with a vertical velocity gradient impinges on an obstacle and is forced to diverge in the horizontal plane (Transportation Association of Canada, 2004). Pier scour is a common cause of pier failure. The depth of the local scour will be dependant on the structure geometry, hydraulic conditions, and other factors including accumulation of ice and debris. Riprap aprons can be utilized to protect against the development of local scour holes around bridge piers.

Some features will require physical erosion protection in the form of bank hardening. As banks are hardened, this increases the scour potential at the toe of the protection. Typical scour protection for bank protection includes the placement of a rock riprap apron, which will launch during a scour event. On the North Saskatchewan River in the Edmonton area, bedrock is typically close to the surface, which limits the scour potential throughout the reach.

Recommendations:

1. **Proposed support structures should be assessed to determine potential local scour depth and scour mitigation measures including riprap.**
2. **Proposed bank hardening features should be assessed to determine potential scour depth and scour mitigation measures including riprap.**

6.3 Flood

Water levels along the entire reach for 2-, 5-, 10-, 25-, 50-, and 100-year return periods have been determined and are provided in **Appendix A**. **Figure 4-1** shows the locations of the referenced cross sections.

In general, the flood levels provided can be used as a guideline for assessing the risk associated with placing features at certain elevations along the bank. If a feature is inundated during a flood event, there is a high probability of damage to some components of the feature because of the forces associated with the water, debris or ice. If a feature is inundated during a flood event, hydrodynamic forces of the flow against the feature will be placed on the feature.

Recommendations:

1. **All proposed features should be designed with consideration of the flood peak elevations and associated risks of flood damage.**
2. **Hydrodynamic forces during peak floods should be assessed on all features extending into the river channel.**

6.4 Ice

Forces on Vertical Support Structures

Calculated estimates of the ice forces on the proposed vertical support structures are required to verify their structural stability. In general, ice forces are a function of the adopted ice thickness, the ice strength, the size of the ice floes and their kinetic energy, and the shape/width of the vertical support structure.

Recommendation: Vertical support structures should be designed in accordance with CSA guidelines for ice loads on bridge piers.

Ice Floes

Ice floes moving along the river during break-up or freeze-up could impact or run up against features along the bank. Some design features could be at risk of being damaged from the impact of the ice floes. For instance, ice scarring is a common feature on northern rivers where ice floes leaves mark or scars on vegetation including trees.

Ice Levels

Freeze-up ice levels were determined as per the process outlined in **Section 4.2**. **Appendix B** shows the modeled top of ice elevations including an additional 0.5 m of freeboard.

Recommendation: All proposed features should be designed with consideration of the typical freeze-up ice levels and associated risks.

6.5 Debris

During spring runoff, the channel will likely carry some debris (mostly woody debris) which could become lodged on certain features.

Recommendation: Regular maintenance should be performed to remove any debris from features after spring runoff.

6.6 Beach and Island Enhancement and Stability

There are specific areas along the study reach that are naturally prone to deposition. Dub has identified potential locations for establishing access to the waters edge including:

1) The existing island upstream of the Menzies Bridge.
2) A beach downstream of Walterdale Bridge near the Rossdale Generating Station.

The existing island had been a stable natural feature on the river over the last sixty years based on the historical air photo assessment so during lower flows this feature could be accessed by the public safely. Downstream of the Walterdale bridge, natural fine sediment deposition has occurred on the left bank forming a small natural beach.

Recommendation: The proposed beach feature should have additional sand and gravels added to construct the beach area.

6.7 General Considerations

The aforementioned presentation is intended to provide a description of river engineering and hydrotechnical features of the North Saskatchewan River in the study area. We understand that specific features will be proposed along these two promenades, and we will be prepared to apply river engineering assessments to each concept proposed in later phases to ensure that each features is developed in manner that has considered risks associated as part of their design and operation in the river environment.

7 REFERENCES

CAN/CAS-S6-00, Canadian Highway Bridge Design Code.

Chow, V. Te. 1959. Open-channel hydraulics. McGraw-Hill, Inc., New York, NY, USA.

IDG, 1995. "North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase II - Upper Reach)". Submitted to AEP by I.D. Group (Alberta) Inc., Edmonton, Alberta.

Kellerhals, R., Neill, C.R., and Bray, D.I. "Hydraulic and Geomorphic Characteristics of Rivers in Alberta". Research Council of Alberta. 1972.

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Philips Planning and Engineering Limited, 1994. "North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase 1 - Lower Reach)". Submitted to AEP by Philips Planning and Engineering Ltd., Edmonton, Alberta.

Transportation Association of Canada, 2004. Guide to Bridge Hydraulics: Second Edition. Thomas Telford Ltd., London, Ontario.

8 CLOSURE

DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Ltd. in accordance with generally accepted engineering practices and is intended for the exclusive use and benefit of Dub Architects Limited and their authorized representatives for specific application to the Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from Northwest Hydraulic Consultants Ltd. No other warranty, expressed or implied, is made. Northwest Hydraulic Consultants Ltd. and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than Dub Architects Limited.

Sincerely,

Northwest Hydraulic Consultants Ltd.

Chris Schneck

Chris Schneck, M.Sc., E.I.T.
Project Engineer

Reviewed by: 3 June 2020

PROFESSIONAL ENGINEER
EUGENE K. YAREMKO
ALBERTA

Gene Yaremko, M.Sc., P.Eng.
Principal

PERMIT TO PRACTICE
NORTHWEST HYDRAULIC CONSULTANTS LTD.
Signature 66607
Date 3 June 2020
PERMIT NUMBER: P 654
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Figures

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STUDY LIMIT

BRIDGE

ROAD

nhc
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Data Sources: Esri basemap imagery

SCALE 1:15,000

0 125 250 500 750 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

SITE PLAN

FIGURE 2-1

REH, Path: P:_Projects (Active)\1004400 Touch the Water\03_GIS\Figure 2-1 - Site Plan.mxd

1) Looking at concrete bank armouring upstream of Groat Road Bridge.

2) Looking at existing outfall on left bank upstream of Groat Road Bridge.

3) Looking at left bank downstream of Groat Road Bridge.

4) Looking at left bank between Groat Road and Menzies Bridge.

5) Looking at upstream end of island on left bank.

6) Looking at existing outfall on left bank upstream of Menzies Bridge.

Note:

1. Photos taken by NHC during site visit on August 14 and 15, 2019.
2. See Figure 2-4 for photograph locations and orientations.

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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment **SITE PHOTOS 1**		
1004400	June 2020	**Figure 2-2**

7) Looking at concrete bank armouring downstream of High Level Bridge.

8) Looking at vegetated riprap on left bank at Walterdale Bridge.

9) Looking at left bank downstream of Walterdale Bridge.

10) Looking at left bank downstream of Walterdale Bridge.

11) Looking at existing boatlaunch on left bank.

12) Looking at left bank at the downstream end of the project area. .

Note:

1. Photos taken by NHC during site visit on August 14 and 15, 2019.
2. See Figure 2-4 for photograph locations and orientations.

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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment **SITE PHOTOS 2**		
1004400	June 2020	**Figure 2-3**

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PHOTO LOCATION
STUDY LIMIT
BRIDGE
ROAD

Data Sources: Esri basemap imagery

SCALE 1:15,000

0 125 250 500 750 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

PHOTO LOCATIONS

FIGURE 2-4

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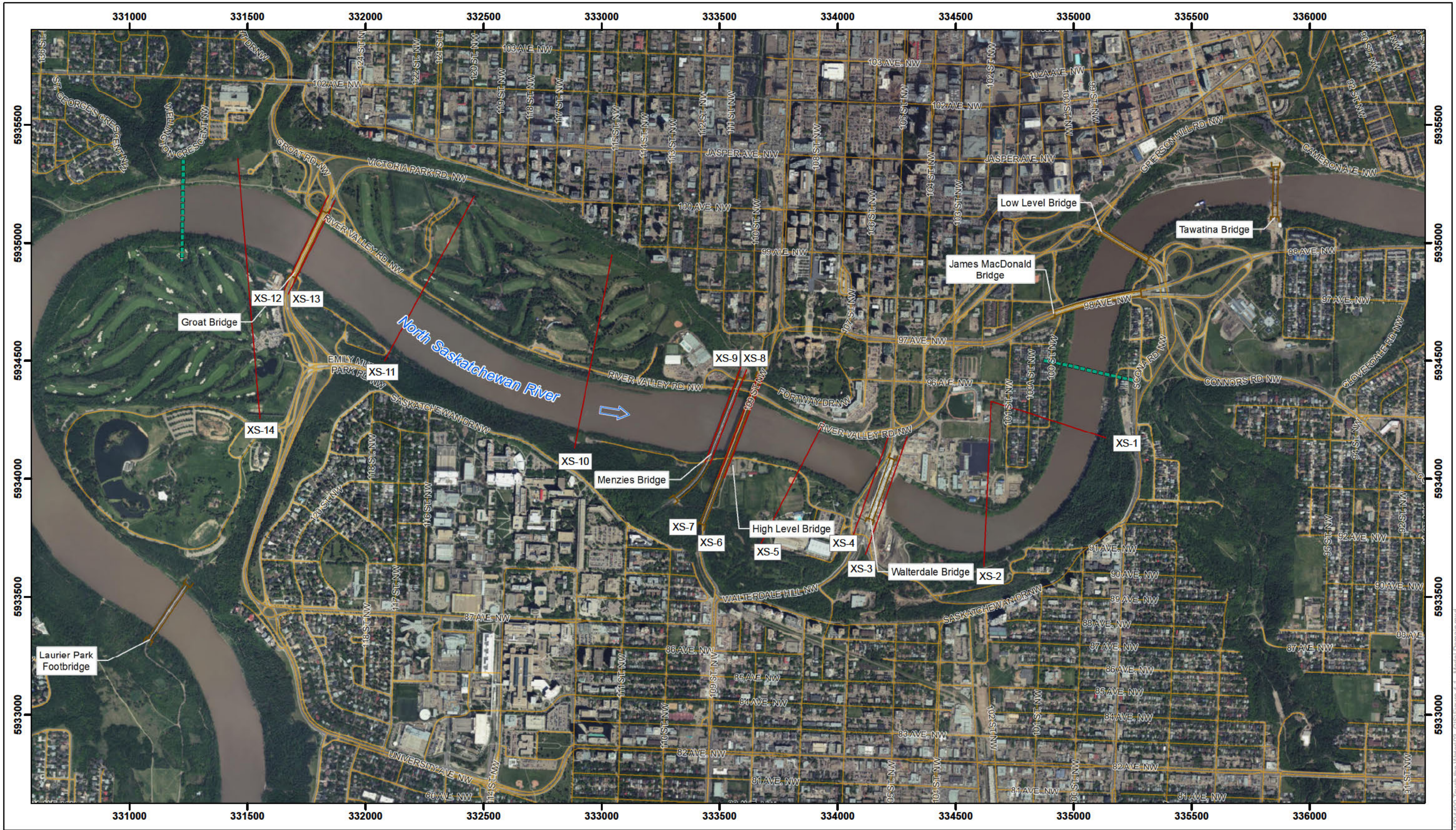

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- Cross Sections
- STUDY LIMIT
- BRIDGE
- ROAD

Data Sources: Esri basemap imagery

SCALE 1:15,000

0 125 250 500 750 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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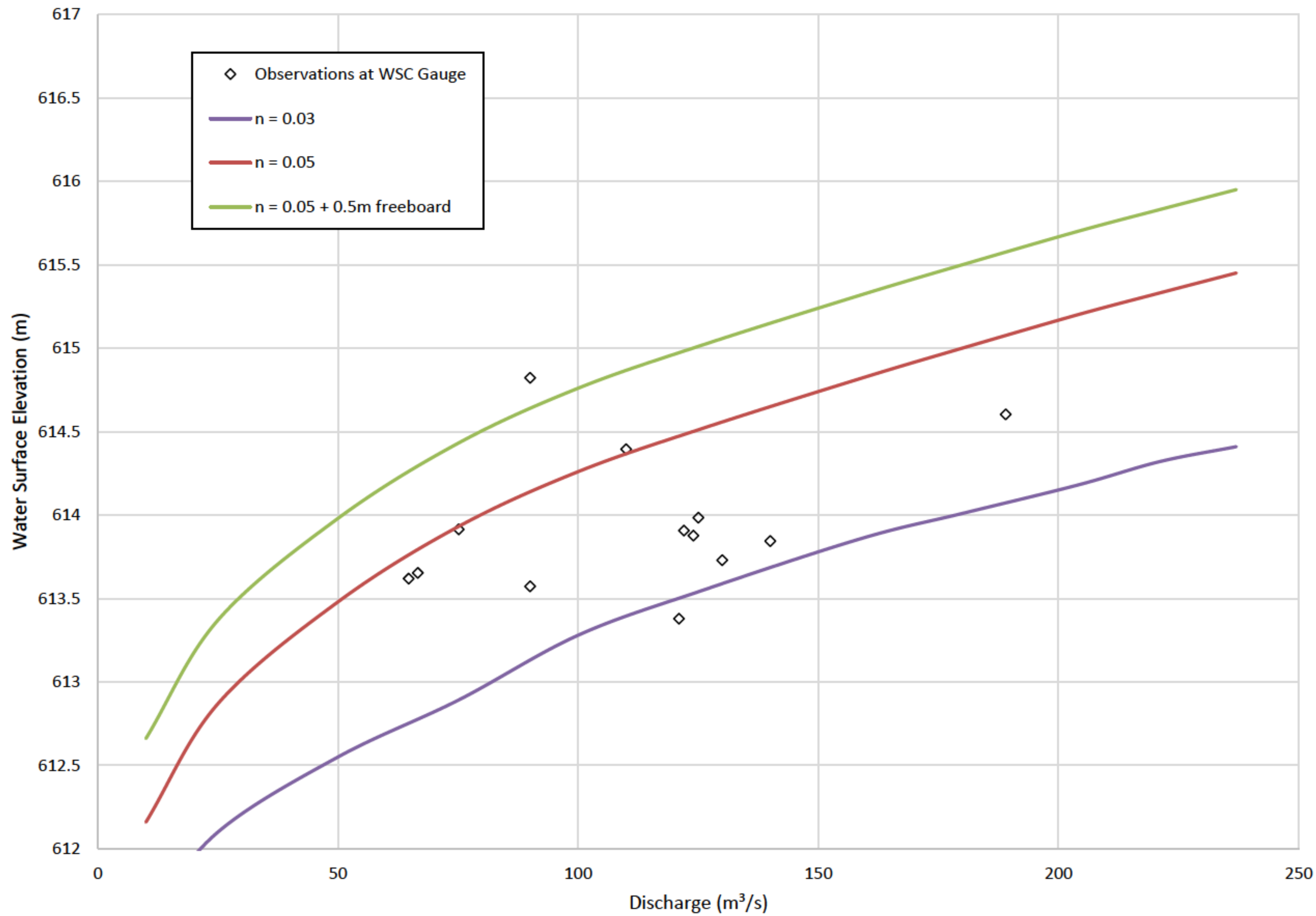
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

CROSS SECTION LOCATIONS

FIGURE 4-1



P:_Projects (Active)\1004400 Touch the Water\07_Reporting

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FREEZE-UP RATING CURVE

10044400	June 2020	**Figure 4-2**

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Notes:

1. Basemap: Esri World Imagery (2015).
2. 2-year peak discharge of 1270 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000

0 125 250 500 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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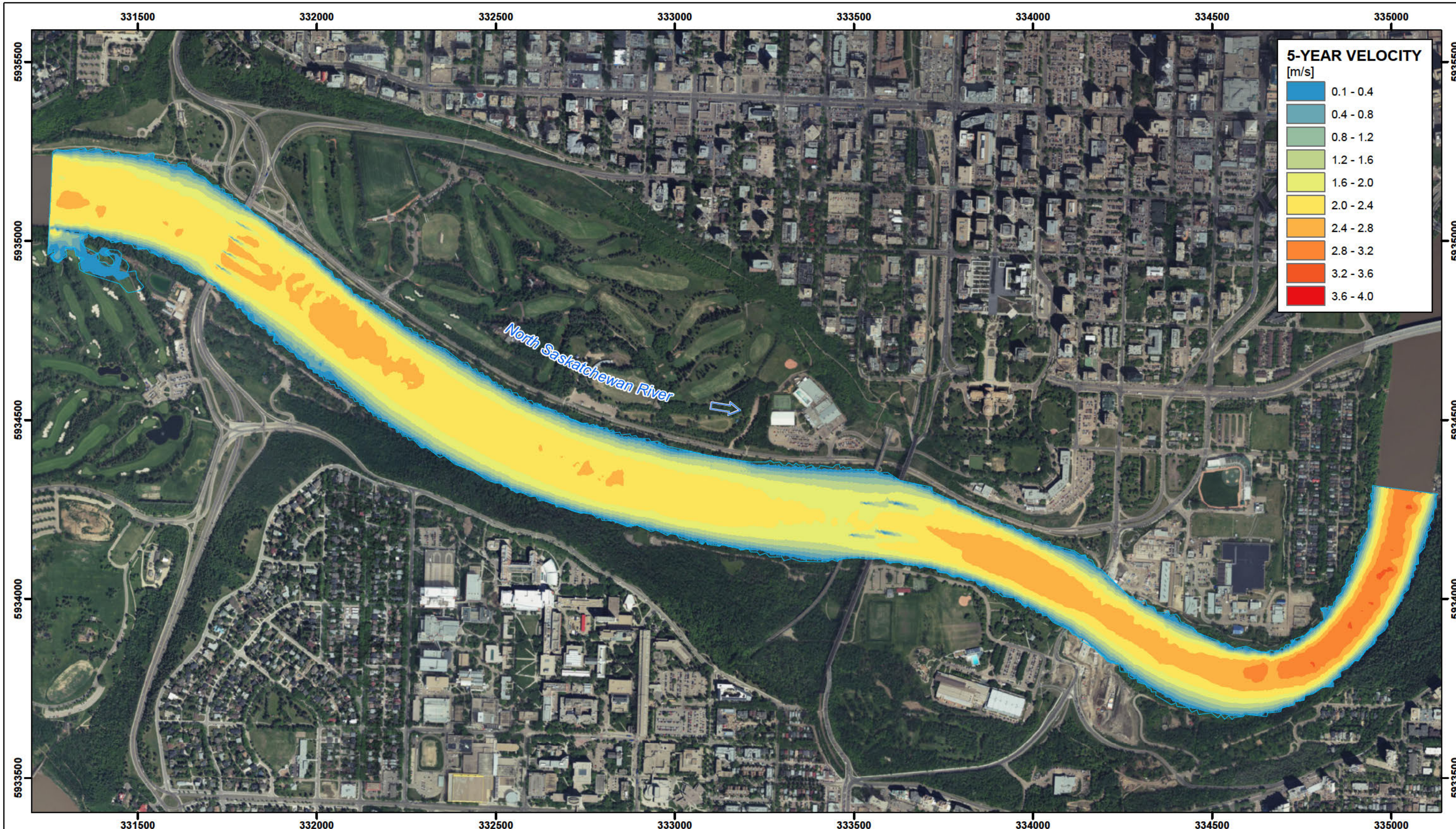
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

2-YEAR VELOCITY CONTOUR

FIGURE 4-3

REH, Path: P:_Projects (Active)\1004400 Touch the Water\09_Arc Figures\Figure 4-3_2-yr Velocity Contours.mxd



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Notes:

1. Basemap: Esri World Imagery (2015).
2. 5-year peak discharge of 2230 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000
0 125 250 500 M
N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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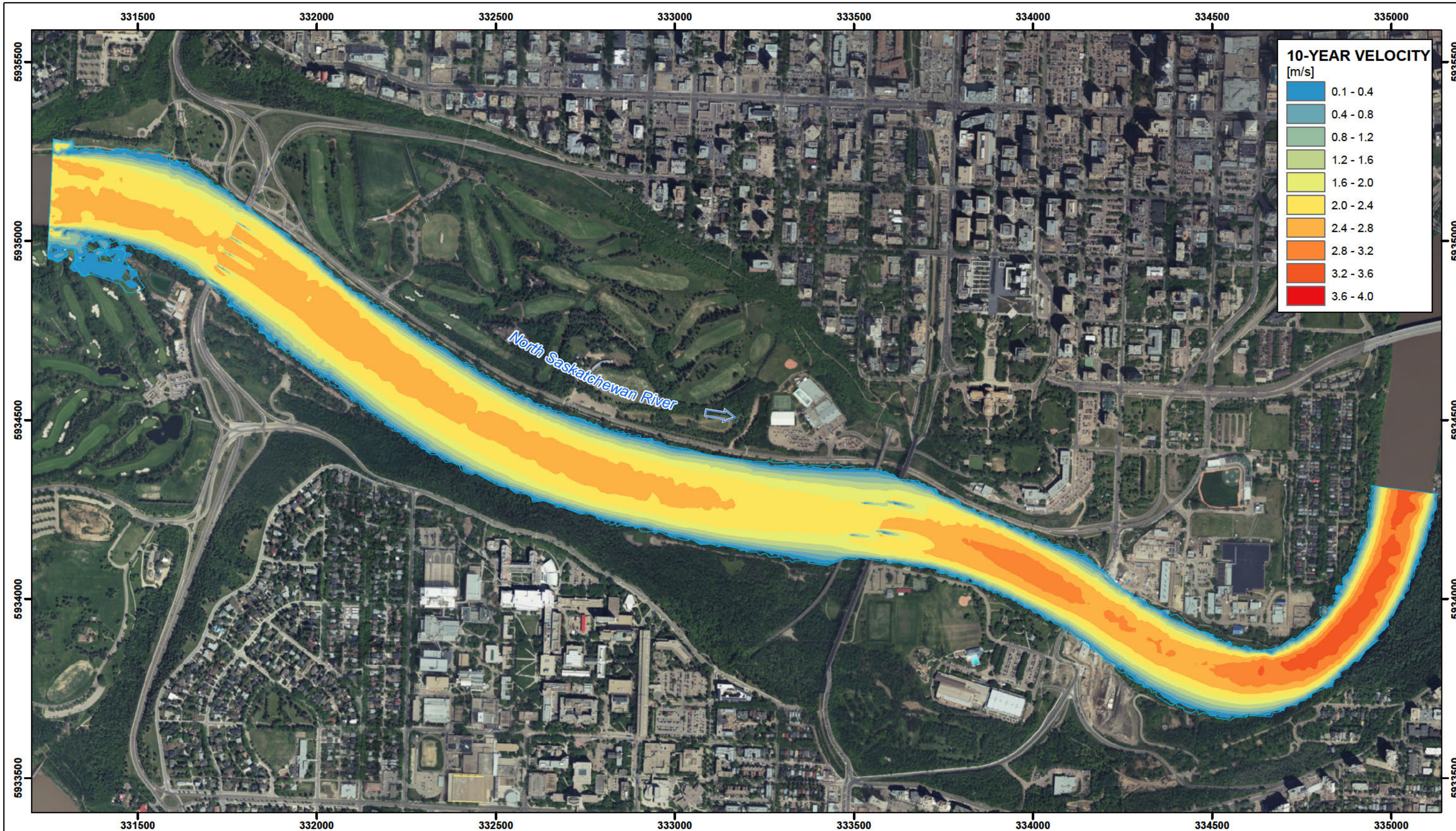
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

5-YEAR VELOCITY CONTOUR

FIGURE 4-4

REH, Path: P:_Projects (Active)\1004400 Touch the Water\09_Arc Figures\Figure 4-4_5-yr Velocity Contours.mxd



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Notes:

1. Basemap: Esri World Imagery (2015).
2. 10-year peak discharge of 2940 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000

0 125 250 500 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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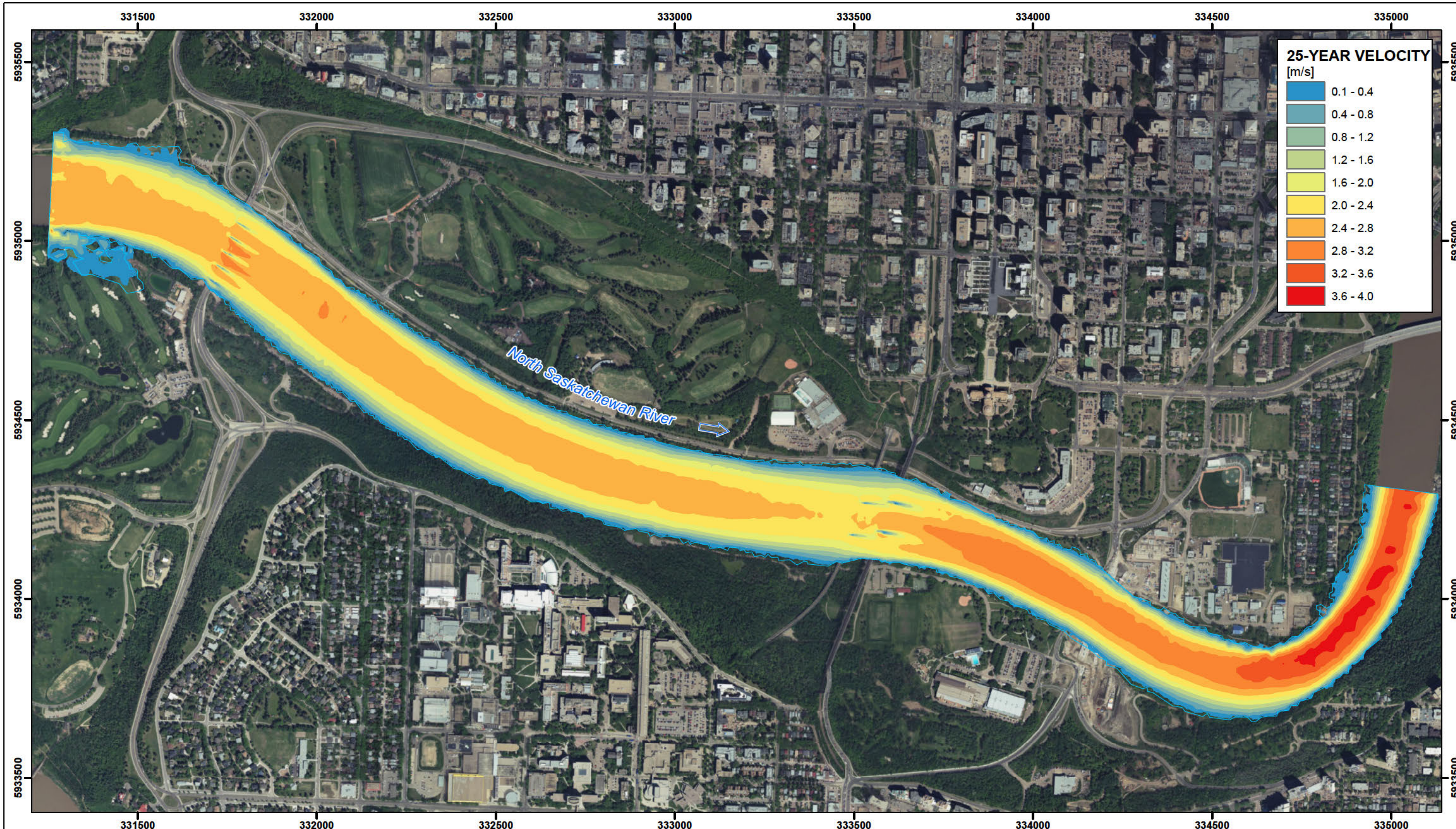
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

10-YEAR VELOCITY CONTOUR

FIGURE 4-5

REH, Path: P:_Projects (Active)\1004400 Touch the Water\09_Arc Figures\Figure 4-5_10-yr Velocity Contours.mxd



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Notes:

1. Basemap: Esri World Imagery (2015).
2. 25-year peak discharge of 3870 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000

0 125 250 500 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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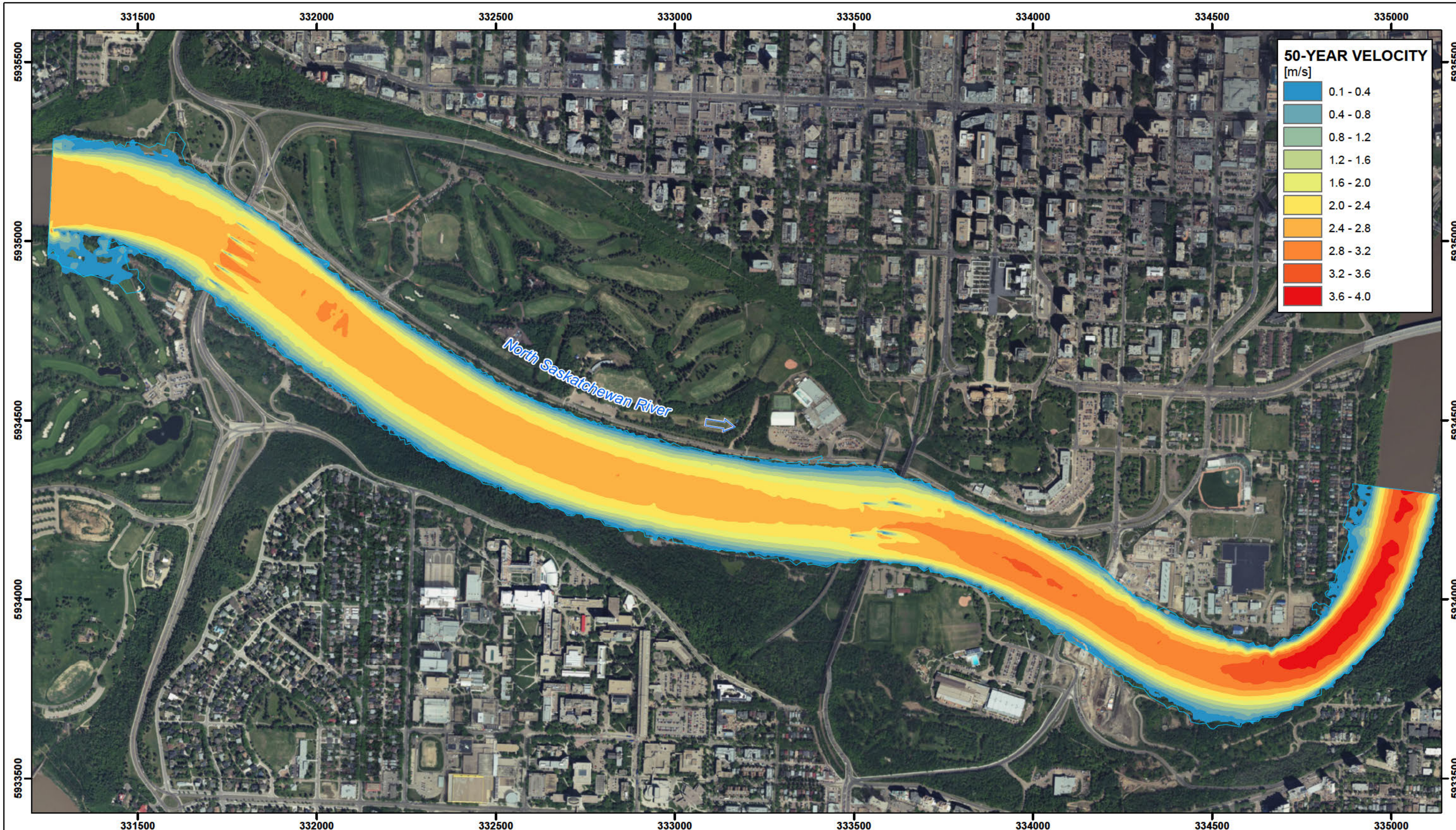
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

25-YEAR VELOCITY CONTOUR

FIGURE 4-6

REH, Path: P:_Projects (Active)\1004400 Touch the Water\09_Arc Figures\Figure 4-6_25-yr Velocity Contours.mxd



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Notes:

1. Basemap: Esri World Imagery (2015).
2. 50-year peak discharge of 4570 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000

0 125 250 500 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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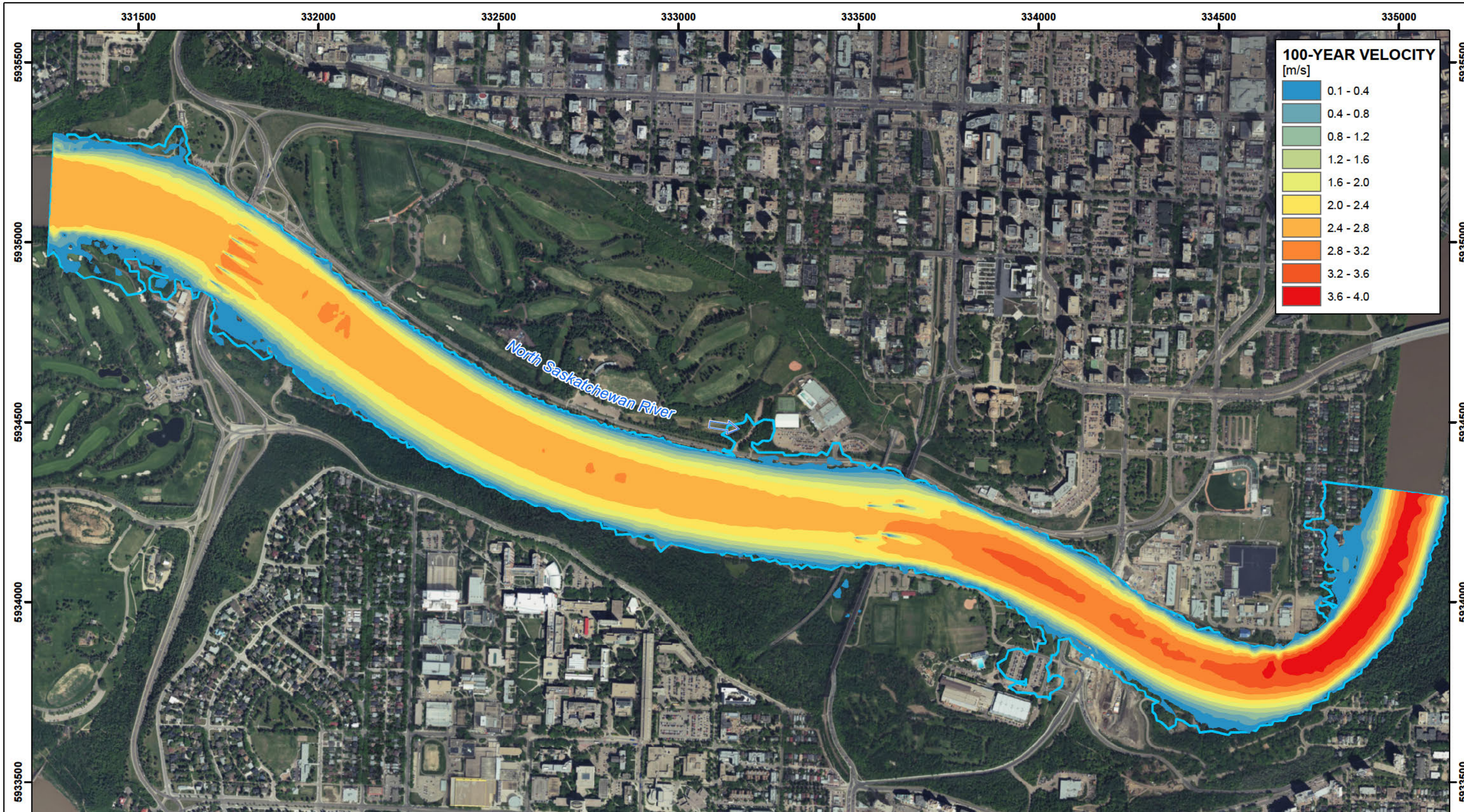
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

50-YEAR VELOCITY CONTOUR

FIGURE 4-7



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Notes:

1. Basemap: Esri World Imagery (2015).
2. 100-year peak discharge of 5270 cms modelled using TELEMAC2D.
3. Inundation extents are shown in blue.

Data Sources: Esri basemap imagery

SCALE 1:10,000

0 125 250 500 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

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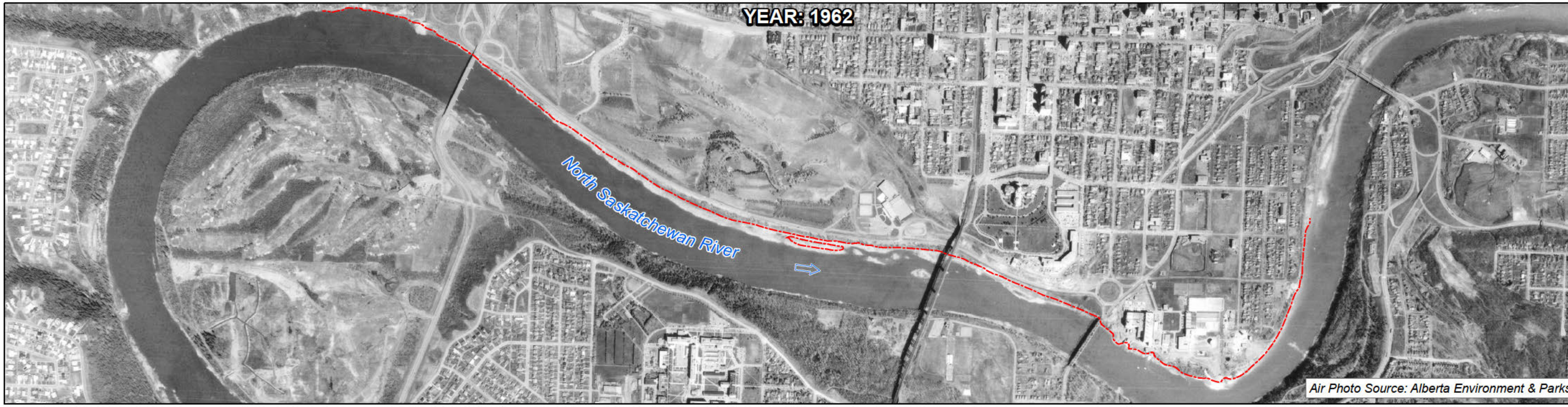
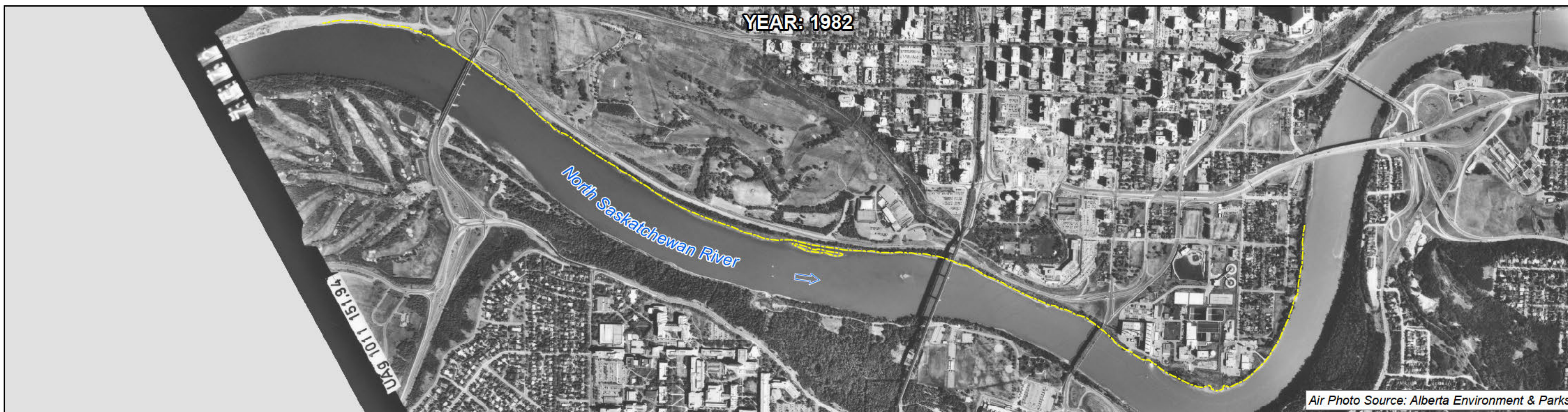
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

100-YEAR VELOCITY CONTOUR

FIGURE 4-8





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SCALE - 1:15,000

0 125 250 500 750 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: METRES

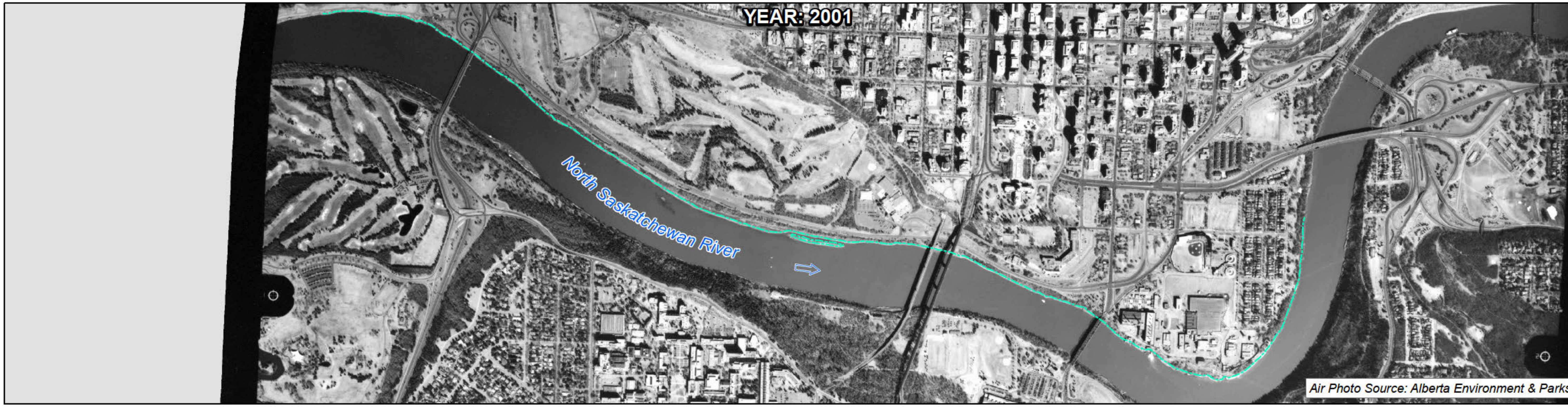
Job: 1004400 | 3 June 2020

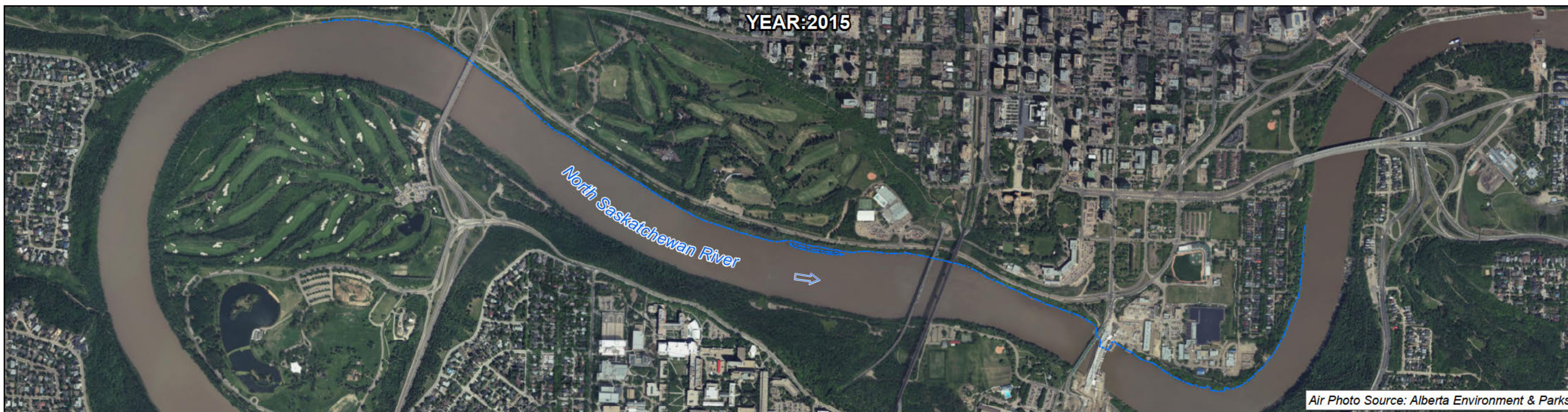
Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

HISTORICAL AIR PHOTO ANALYSIS

FIGURE 5-1

REH, Path: P:_Projects (Active)\1004400 Touch the Water\03_GIS\Figure 5-1 - Air_Photo_Analysis.mxd





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SCALE - 1:15,000

0 125 250 500 750 M

N

Coordinate System: NAD 1983 UTM ZONE 12N
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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

HISTORICAL AIR PHOTO ANALYSIS

FIGURE 5-2

REH, Path: P:_Projects (Active)\1004400 Touch the Water\03_GIS\Figure 5-2 - Air_Photo_Analysis_2.mxd

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Data Sources: Esri basemap imagery

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Units: METRES

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Touch the Water Promenade and North Shore Promenade Hydrotechnical Assessment

LATERAL STABILITY ANALYSIS

FIGURE 5-3

REH, Path: P:_Projects (Active)\1004400 Touch the Water\03_GIS\Figure 5-3 - BankLineAnalysis.mxd

Appendix A: Water Levels

Table A1. 100-Year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	622.56
2	622.79
3	623.00
4	623.11
5	623.12
6	623.41
7	623.45
8	623.48
9	623.49
10	623.55
11	623.78
12	623.9
13	623.95
14	624.04

Table A2. 50-Year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	621.44
2	621.69
3	621.91
4	622.02
5	622.05
6	622.34
7	622.37
8	622.40
9	622.41
10	622.48
11	622.74
12	623.90
13	623.95
14	624.04

Table A3. 25-year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	620.25
2	620.53
3	620.76
4	620.87
5	620.91
6	621.20
7	621.23
8	621.26
9	621.27
10	621.36
11	621.65
12	621.81
13	621.86
14	621.96

Table A4. 10-year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	618.71
2	619.02
3	619.27
4	619.36
5	619.43
6	619.70
7	619.74
8	619.76
9	619.77
10	619.88
11	620.23
12	620.42
13	620.47
14	620.58

Table A5. 5-year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	617.45
2	617.78
3	618.05
4	618.12
5	618.22
6	618.48
7	618.51
8	618.54
9	618.54
10	618.68
11	619.09
12	619.31
13	619.36
14	619.48

Table A6. 2-year Flood Peak Water Surface Elevations

Cross Section	Water Surface Elevation (m)
1	615.58
2	615.95
3	616.23
4	616.28
5	616.40
6	616.64
7	616.66
8	616.69
9	616.70
10	616.88
11	617.45
12	617.73
13	617.77
14	617.91

Appendix B: Freeze-up Ice Levels

Table B1. 100-Year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	616.51
2	616.58
3	616.65
4	616.66
5	616.85
6	617.23
7	617.25
8	617.32
9	617.32
10	617.70
11	618.02
12	618.11
13	618.11
14	618.16

Table B2. 50-Year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	616.40
2	616.46
3	616.53
4	616.54
5	616.77
6	617.19
7	617.21
8	617.27
9	617.27
10	617.60
11	617.92
12	618.01
13	618.01
14	618.06

Table B3. 25-year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	616.27
2	616.33
3	616.40
4	616.42
5	616.69
6	617.15
7	617.16
8	617.21
9	617.21
10	617.50
11	617.81
12	617.90
13	617.91
14	617.96

Table B4. 10-year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	616.09
2	616.14
3	616.22
4	616.24
5	616.63
6	617.06
7	617.07
8	617.09
9	617.09
10	617.34
11	617.65
12	617.74
13	617.75
14	617.80

Table B5. 5-year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	615.92
2	615.98
3	616.05
4	616.08
5	616.56
6	616.93
7	616.93
8	616.94
9	616.95
10	617.18
11	617.49
12	617.59
13	617.59
14	617.65

Table B6. 2-year Freeze-up Ice Levels

Cross Section	Top of Ice Elevation with Freeboard (m)
1	615.63
2	615.68
3	615.77
4	615.80
5	616.38
6	616.64
7	616.64
8	616.65
9	616.65
10	616.88
11	617.22
12	617.33
13	617.33
14	617.39