

Preliminary Hydrotechnical Design Report

Bow River Louise Bar: Flood Reduction and Recreational Wave



Integrated Services | Innovative Solutions



Prepared for: O2 Planning and Design Inc. on Behalf of the City of Calgary
May 2025

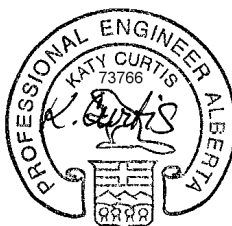
PRELIMINARY HYDROTECHNICAL DESIGN REPORT

BOW RIVER LOUISE BAR: FLOOD REDUCTION AND RECREATIONAL WAVE

Prepared for O2 Planning and Design, May 2025



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EXECUTIVE SUMMARY

The *Louise Bar – Bow River: Flood Reduction and Recreational Wave* project in the City of Calgary aims to enhance flood resilience while improving public spaces across five key components, referred to as nodes: the Louise Bar, the Recreational Wave and Wave deck, the Landing, the South Slopes, and the North Channel. The project is from 14 St. Bridge to the LRT Bridge in west downtown. Key objectives are:

- **Flood Reduction: The Louise Bar** - The primary project focus is on reducing flood risk by partially removing and reshaping the remaining portion of the vegetated Louise Bar, under Louise Bridge (10 St NW) to improve flow conveyance through the bridge and decrease flood risk to adjacent neighbourhoods. The final configuration of the bar will also create the necessary hydraulic conditions for the recreational wave node and will provide seating areas and river access opportunities.
- **Recreational Opportunities: The Recreational Wave and Wave Deck** - The Recreational Wave is a centerpiece feature designed to meet public demand for improved river recreation. It will use adjustable Obermeyer gates for safe and efficient operation within a Bow River flow range of 50 m³/s to 280 m³/s. At flows above 280 m³/s, the City's safe boating advisory, the gates will lower to prevent an unsafe wave condition and potential gate damage from debris.
- **Enhancing the Public Realm: The Landing** - The Landing provides critical egress opportunities for wave users and improves the public realm with a beach area downstream of the wave. The beach will be built with gravel, cobbles, and riprap (or stepped blocks).
- **Enhancing the Public Realm: The South Slopes pathway** - Enhancing the steep south riverbank will improve safety, aesthetics, and public access. Excavated material from the Louise Bar and The Landing will create a stable, vegetated slope armoured with riprap and feature an engaging, varied pathway.
- **Enhancing the Public Realm and Aquatic Habitat: The North Channel** - This node was proactively created to provide fish habitat compensation for river work at other nodes that may cause a harmful alteration, disruption and destruction (HADD; DFO 2023) of fish habitat. A side channel will be excavated through a gravel bar along the north bank, featuring fish habitat enhancements like boulder clusters. Excavated material from the channel will be repurposed on the north riverbank to create a formal trail network. If the generated habitat exceeds the offsetting need for this project, the excess may be banked for different City of Calgary projects.

Historical Context: The Bow River near the near Louise Bridge has been heavily impacted by human activities, including channel excavation, bank alteration, water level control structures, and bridges.

Design Stage and Next Steps: The design is at the preliminary phase and will proceed to detailed design, tender, and construction upon City approval of each stage.

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1 INTRODUCTION

Montrose Environmental Solutions Canada Inc. (Montrose; formerly Matrix Solutions Inc.) was retained by O2 Planning + Design (O2) on behalf of the City of Calgary to provide hydrotechnical design, environmental assessments, and lithology mapping for the preliminary design for the project: *Bow River Louise Bar – Flood Reduction and Recreational Wave*. Lithology mapping is available in Appendix A.

A vegetated gravel bar below the Louise Bridge along 10 Street NW in downtown Calgary will be reshaped to increase flood conveyance through the bridge and decrease flood risk through downtown and the Kensington neighbourhood. Known as the Louise Bar, it surrounds one of the four bridge piers. There are no near-future plans for bridge replacement; the bridge was built in 1921 and rehabilitated in 1995. Bar reshaping has been discussed at the conceptual level since at least 2017, in a city-wide Calgary rivers morphology assessment (KCB 2017). A biophysical impact assessment (BIA) is underway that describes the ecology of this area (Matrix 2023).

An adjustable recreational wave that will be active during target flow conditions is also included. The recreational wave has been under discussion with various stakeholders since at least 2019, when an initial design report for the wave was first drafted (Surf Anywhere 2019). The Louise Bar reshaping will create the necessary hydraulic conditions for the wave.

The project extends about 1.2 km from the 14 St. SW bridge to 300 m upstream of the Peace Bridge, near the west end of downtown on the Bow River (Figure 0). The LRT Bridge, just downstream of the Louise Bridge, is in this reach.

The hydrotechnical design is based on numerical (1D and 2D), morphodynamic, and physical modelling. Morphodynamic modeling was conducted from 2022 to 2024 by the University of Ottawa (U of O), while physical modeling took place in 2023 and 2024 at the National Research Council – Ocean, Coastal and River Engineering (NRC-OCRE) Research Centre, in partnership with the U of O. Modeling details are provided separately by others.

The project is guided by the City of Calgary, with O2 leading the consulting team. The team also includes Applied Ecohydraulics, Surf Anywhere, and Montrose. Its multidisciplinary composition and collaborative design process are outlined in Figure A. Applied Ecohydraulics leads the wave design, with input from the Consulting Team. A brief design overview for the wave is provided herein, with full details under separate cover.

The team developed the overarching vision statement: *“A safe, vibrant urban waterfront connecting people to the Bow River. Through design, we will reduce flood risks, create diverse and interesting opportunities for river recreation, and incorporate nature in the city”*. This vision statement contains several hydrotechnical aspects, including:

- *A safe, vibrant urban waterfront.* Hydrotechnical design is critical to ensure the safety of people, infrastructure, and the environment.
- *Through design, we will reduce flood risks.* The primary driver for the works is reducing the increased flooding risk caused by the bar at Louise bridge.

- *Create diverse and interesting opportunities for river recreation.* The recreational wave is the primary piece of infrastructure that will fulfill this project goal.

The design is at the preliminary phase and will proceed to detailed design, tender, and construction upon City approval of each stage.

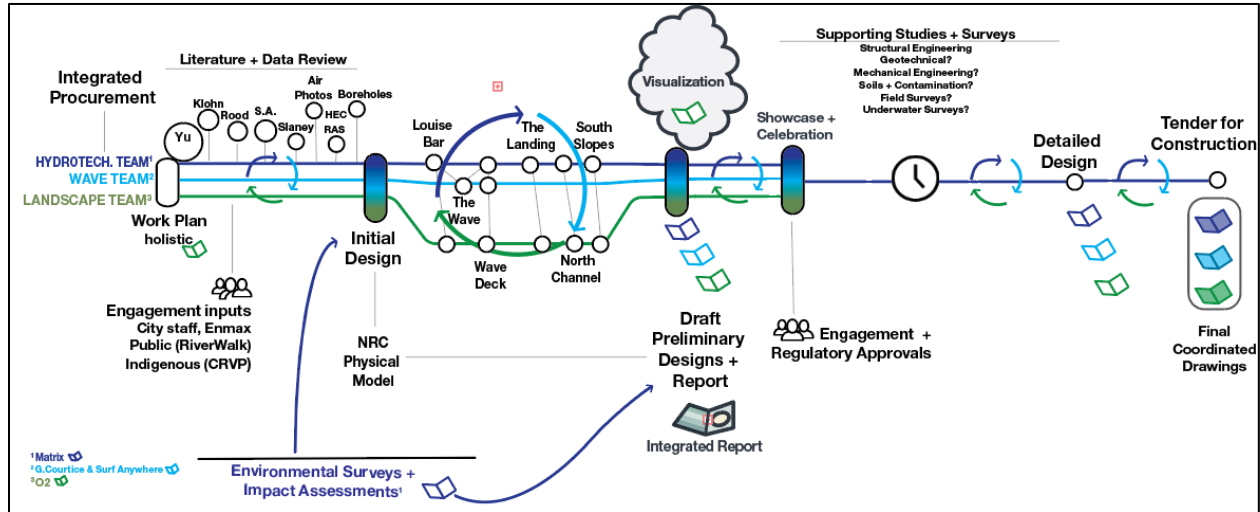


Figure A Team Composition and Process Schematic (per O2)

1.1 Project Goals

The project goals include:

1. Reduce flood risk to downtown by reshaping a vegetated gravel bar underneath the Louise Bridge.
2. Construct a robust, high-quality, and low-risk wave, integrated with the bar modifications.
3. Create places where Calgarians and tourists can congregate, be outside, and enjoy nature in the underdeveloped west end of downtown Calgary.

1.2 Scope of Report

The scope of this report addresses the hydrotechnical aspects of the project, and includes:

- Hydrotechnical site conditions: analysis of site characteristics
- Hydrotechnical assessment: evaluation of design considerations
- Preliminary hydrotechnical design: recommendations for the design

1.3 Overview of Project Nodes

The project team has identified five key work areas, referred to as nodes in this report (Figure 0). These nodes are discussed in detail in the primary project report by O2, but are outlined briefly below to provide hydrotechnical context.

1.3.1 The Louise Bar

The Louise Bar is the central component of the work. The bar has existed under the Louise Bridge since at least 1953, based on review of old air photos. Until the 2013 flood, it was relatively small and had little impact on flood levels. However, the 2013 flood enlarged the bar and therefore increased flood levels and risk to downtown. Morphodynamic modelling of the bar suggests that, if left unmodified, it will continue to grow – even without accounting for the influence of vegetation (Yu et al. 2022). This risk is further compounded by the establishment of vegetation on the enlarged bar since 2013, which has affected flow conveyance at the bridge in several ways:

1. The bar occupies capacity at two of five bridge arches, raising water levels (Figure B).
2. Channel roughness (Manning n) has increased due to vegetation growth, raising water levels.
3. Vegetation makes it less likely that the bar will naturally shrink, as it anchors the bar in place.
4. Vegetation on the bar will trap sediment over time, enlarging the bar.

To address the above four items, and provide the necessary flow split and hydraulic head for the wave (Section 1.3.2), the design at the bar will reduce the footprint and raise and realign the remaining portion to generate the required hydraulics for the wave. The raised portion will be armoured with riprap to resist erosion during the 1:100-year flood and will include stone seating areas and river access points. The bar will also include a potential emergency helicopter landing pad, as part of the downtown heliport reactivation at the Peace Bridge.

Figures B, C, 3, and 4 provide an overview of recent (2013 and newer) conditions at the Louise Bar



Figure B Vegetation on Louise Bar (September 18, 2024)



Figure C North Channel and Upstream Tip of Louise Bar (September 18, 2024)

1.3.2 The Recreational Wave and Wave Deck

The recreational wave is a secondary driver in this design, with strong support from groups including the Alberta Whitewater Association, the Alberta River Surfing Association, internal stakeholders at the City of Calgary, and public stakeholders (e.g., for tourism). The wave will be fully controllable over a range of river flows, using Obermeyer gate structures that raise off the riverbed to ensure a high-quality wave at varying river flow rates (Table 4).

A standing wave¹ has existed along the river's south bank between the Louise Bridge and LRT Bridge since at least 2013, when the record flooding exposed a historical wooden pile wall in the riverbed (Section 5.2.1). In recent years, the wave size has decreased, and it is no longer surfable. The wave was popular when it was usable.

1.3.3 The Landing

The landing node is downstream of the wave on the south bank and includes a cobble and gravel beach. It will be the natural egress point for wave users. This area is currently a mix of vegetation and eroding bare soils; the erosion is partly caused by the public accessing the river at non-designated access points. The landing will provide a clear access point to the river and will enhance the public realm.

1.3.4 The South Slopes

The South Slopes node extends along the river's south bank from the 14th Street Bridge to the Louise Bridge at 10th Street. The current bank vegetation is of low quality, and concrete debris is present.

The South Slopes will incorporate a riprap armoured toe with a vegetated upper bank. There will be pedestrian pathways, connecting to the existing multi-use path. River access points will be built at key locations to link with the multi-use pathway system. The riprap toe will be non-linear and include boulder clusters to enhance fish habitat.

1.3.5 The North Channel

The North Channel node provides fish habitat compensation for river works at other nodes that may cause a harmful alteration, disruption and destruction (HADD; DFO 2023) of fish habitat. If this node provides surplus habitat, it can be banked for future City projects.

A vegetated gravel bar adjacent to the north bank means the node is mostly dry and disconnected with the river's main channel except during floods above a 1:5-year return period. A semi-permanent graminoid marsh (wetland) exists on the vegetated gravel bar (Matrix 2023). Pedestrian usage is frequent throughout the area. A small channel, for fish habitat, will be excavated through the gravel bar. River sediments (e.g., sands, gravels, cobbles) will be excavated and re-contoured on adjacent areas, including to build pathways. Fish habitat features (e.g., riffles, pools, boulder clusters, and overhead cover) will be added to enhance the aquatic habitat.

¹ A standing wave is stationary in location relative to the riverbank and is created when water is constricted flowing over an obstruction. A standing wave is a form of hydraulic jump.

2 DESIGN BASIS AND AVAILABLE INFORMATION

The basis and available information used for the preliminary hydrotechnical design is as follows.

2.1 Design Standards and Guidelines

The assessment and design recommendations presented in this report are based on the following design guidelines:

- City of Calgary *Design Guidelines for Bridges and Structures* (The City 2021)
- Transportation Association of Canada (TAC) *Guide to Bridge Hydraulics* (TAC 2001)

2.2 Available Information and Literature Review

The key reports and information used to inform the design include:

1. ***Calgary Rivers Morphology and Fish Habitat Study (Klohn Crippen 2017)***: provides a conceptual design for reshaping the Louise Bar and documents the substrate size at Louise bar: $D_{50} = \sim 100$ mm at the surface and $D_{50} = \sim 50$ mm subsurface.
2. ***Mitigation of Flood Hazard and Environmental Impacts from the Louise Bar and Recreational Wave (Rood 2020)***: provides the river history for the Louise Bar area and assesses the potential impacts of reshaping the bar and building a wave on hydraulics, geomorphology, aquatic habitat, flood hazard, navigation, and recreation. Rood concludes that a gravel bar will consistently form at Louise Bridge.
3. ***Impact Evaluation of Instream Bar Management Using Morphodynamic Modelling² (Yu et al. 2022)***, completed by the University of Ottawa, modeled and compared three scenarios for Louise bar: (1) do nothing, (2) complete bar removal, and (3) bar reshaping, (partial removal). The study concluded that reshaping the bar was the most stable bed form and would lower the 1:100-year flood peak water level by about 0.07 m compared to the “do nothing” scenario.
4. ***The City of Calgary’s River Morphology Risk Mitigation Program (Slaney et al. 2019)*** assessed the cost to benefit ratio of addressing four morphologic risks to infrastructure: valley wall failures, avulsions, erosion, and sedimentation. The study found that the most resource-efficient option is usually intervening in areas prone to sedimentation (i.e., gravel bars), where riparian colonization reduces flood conveyance by increasing channel roughness.
5. ***Extensive physical modelling completed by the NRC-OCRE “nature-based solutions” program (NRC-OCRC 2024)***. Details of this modelling are under separate cover. The physical modelling enabled rapid iteration of the proposed design and testing of erosion protection measures at each project node. The model was calibrated by simulating the 2013 flood event and comparing the modelled geomorphic change to the observed geomorphic change (i.e., from pre- and post-flood bathymetry). The model was used to test three conceptual Louise Bar alignments under the 1:10-year, 1:35-year, and 1:100-year return period flows.

² Morphodynamic modelling is the study of bathymetric response (i.e., channel bed changes) to fluid dynamical processes, and the interaction that each has on the other (Wright and Thom 1977).

6. **Louise Bridge drawings and historical inspections** from The City of Calgary (detailed in Section 3.2). Used as a direct indicator of local scour depths in the wave area.
7. **Historical aerial and ground-based imagery** (City of Calgary, various dates; Glenbow Archives, various dates) provide historical context on the morphological and human changes to the Bow River from the 1920s to the present. Georeferenced historical aerial imagery is available from The City for select years from 1924 to 2023.
8. **Bow River Hydrology Assessment** (Golder 2020a): provides flood magnitudes for return periods from 1:2-year to 1:1,000-year that were used for modeling.
9. **Post-flood bathymetry and DEM (City of Calgary, 2020)**: LiDAR and bathymetry data were combined into a single digital elevation model (DEM) for 1D and 2D numerical modelling and physical modelling.
10. **City's 2D model results for this project (2023)**: used to confirm that the flow split between the wave channel and the river's main branch is suitable for wave operation. The results also refined the designed location of the upstream tip of the bar to maintain an appropriate flow split.
11. **The City's and Montrose's experience restoring aquatic side channel habitat along the Bow River** includes The City's experience at Quarry Park, Bowmont West, Elbow Island Park, and the Inglewood Bird Sanctuary, as well as Montrose's experience on the North Channel near St. George's Island and at Jack Tennant Memorial Bridge in Cochrane.
12. **The City and Montrose's Experience and knowledge of the Bow River** including flow history, geomorphology, and proven construction and isolation methods were considered during preliminary design and will be incorporated into the detailed design and execution planning stages.
13. **City of Calgary Flood Damages Report (Draft; CoC 2022)** modelled a future scenario where the bar increases in height and the south channel infills. This increased the 1:100-year water level by 0.54 m and increased flood damages by \$86 million. This modelling used a higher Manning roughness value than current conditions for the bar to represent a fully vegetated bar.
14. **Hydraulics of Repelling Groynes and their Application to the Bow River After the June 2013 Flood (Oosting et al. 2015)**: Assesses the efficacy of repelling groynes (pointed upstream and sloped downward from the bank towards the river) and recommends a design approach for the City of Calgary based on observed and modelled hydraulic characteristics. This project tested river groynes on the south slopes in the physical modeling.
15. **Borehole and Geotechnical data (provided by The City, various dates)**: Enabled lithology layer mapping by Montrose that was considered during the physical modelling by NRC-OCRE: if large amounts of scour were observed in areas with a known clay layer, the physical model was adjusted to reflect the more resilient substrate conditions.
16. **Implications of Ice on the Morphology of the Bow River (NHC 2016)**: An extensive overview of winter hydraulic and ice regimes on the Bow River, including the formation, lodging, and breakup processes of ice, and their impact on bed material mobilization. This study should be considered during detailed design to ensure the project is resistant to ice damage and does not increase ice jam severity.

3 HYDROLOGY

A detailed hydrology study for the Bow River was completed by others as part of the draft *Bow, Elbow, Highwood, and Sheep River Hydrology Assessment* on behalf of Alberta Environment and Parks (Golder 2020a). This report provides naturalized flow conditions from the 1:2-year to the 1:1,000-year return periods, i.e., flow conditions without any attenuation of flow from upstream reservoirs. For the purposes of this project, floods above the 1:100-year return period are not assessed.

The annual flow hydrograph and flow statistics for the Bow River are displayed in Figure D. More detailed hydrology is available in Figure 1.

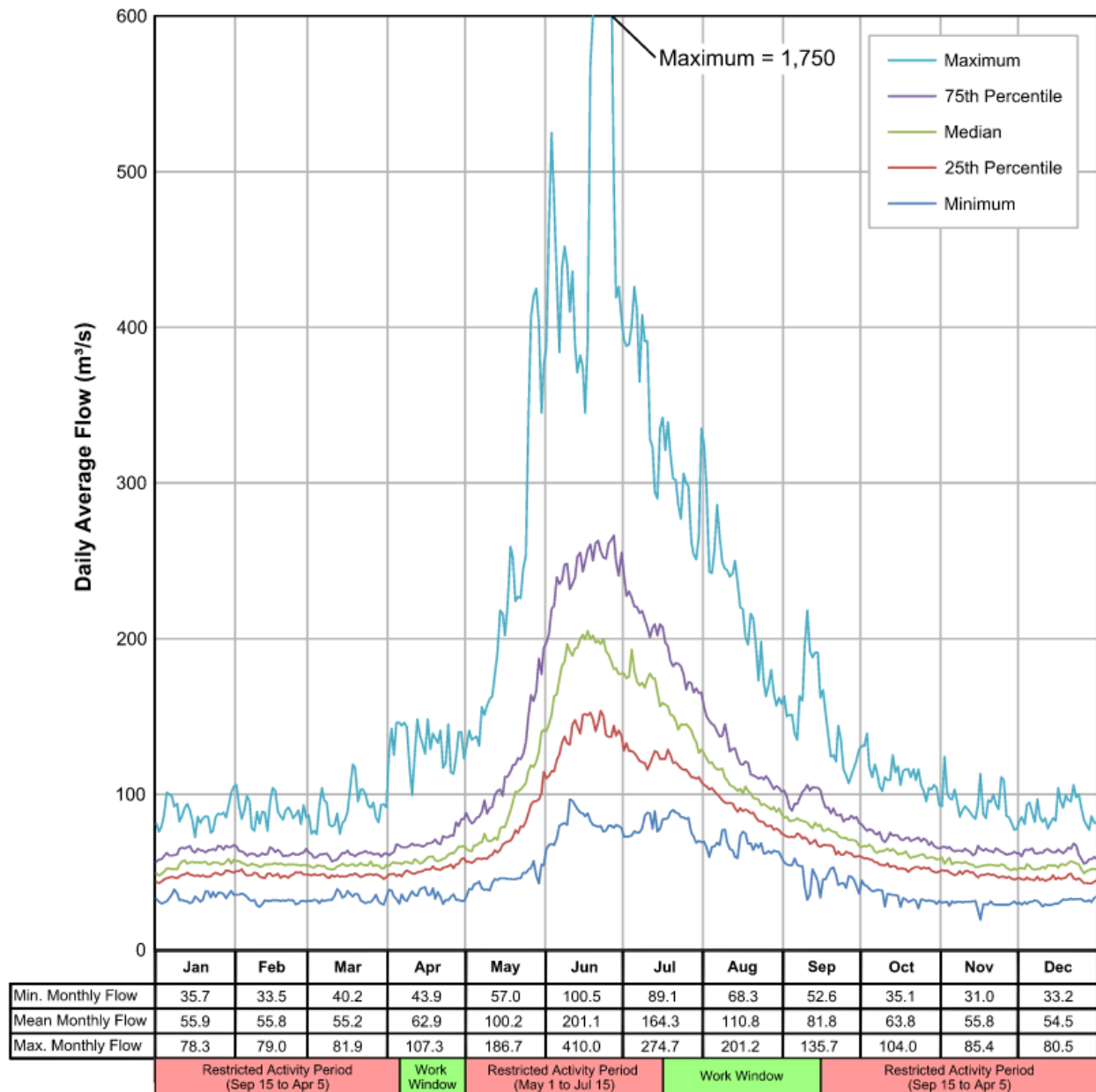


Figure D Annual Hydrographs and Monthly Flow Statistics (1955 to 2022)

3.1 1:100-Year Flood Magnitude

The design flood in Alberta and in the City of Calgary is the 1:100-year flood. The naturalized 1:100-year flood used for design is 2,090 m³/s (Golder 2020a). This flow is conservative, as the peak flood flow rate does not account for regulation from upstream reservoirs on the Bow and Kananaskis Rivers. Additional flood regulation will also result from the Ghost Reservoir and Dam relocation and expansion, if completed.

4 MORPHOLOGY

4.1 Morphological History

Historical aerial photography and site observations illustrate over a century of morphological change in the project area. The Bow River in this reach has been heavily altered by human activities, including log drives, channel realignments, infrastructure development, and gravel extraction. In the late 1800s, the Eau Claire and Bow River Lumber Company built a diversion dam and operated a nearby sawmill and hydropower plant, significantly changing local flow patterns and channel form. These structures remained in place until the mid-20th century, during which time additional modifications, such as a cofferdam and the infilling of side channels, further constrained the river corridor.

Beginning in the 1960s, bar development became a defining feature of the project area, particularly with the formation of a central mid-channel bar beneath the 10th Street Bridge and the expansion of the left-bank Poppy Plaza bar. These bars gradually vegetated until the 2013 flood, which scoured much of the vegetation, deposited new sediment, and caused localized erosion along the right bank. While normal river processes of erosion and deposition continue to shape the area, the long-term morphological trend reflects a system that has been historically constrained and simplified.

4.2 Lithology Mapping

Montrose assessed historical borehole data along the Bow River completed for various projects, including the design/construction of the 14th Street Bridge, the Louise Bridge, and the LRT bridge. These data were used to develop a conceptual model of the stratigraphic layers that are present in and near the river. This lithology mapping is available in Appendix A. Key takeaways of the lithology mapping are as follows:

- Through the project area and in the river channel, substrates predominantly consist of gravels, underlain by clay, and then sandstone.
- In some locations in the project area the gravel substrate has been mobilized away from the underlying clay. This clay layer is generally resistant to scour and protects against bed lowering.
- Based on comparisons between LiDAR and bathymetry before and after the 2013 flood, the clay layer acts as a stable riffle at approximately 0+600. This generally prevents headcutting and channel slope changes from progressing through the project area – an important consideration for operational performance of the wave and wave channel.

4.3 Morphological Changes at Project Site

The Bow River at the project site was heavily altered by human activities in the early 1900s up to about the 1960s. The river was relatively stable without major disruptive instream alterations (human or otherwise) from the 1960s onward until the 2013 flood caused rapid growth of the Louise Bar. Perhaps the single largest difference in the channel morphology in the project area from the 1920s to 2025 was just downstream of the Louise Bridge, where a historical log driving and hydropower channel was infilled in the 1960s and further developed as parkland in the 1980s. Additional discussion on specific changes to the river is provided in Section 5.2.

This project seeks to work with the existing morphological patterns while providing a stable, functional channel form that respects natural processes. It will not detrimentally alter the river system. Instead, by addressing historical constraints and enhancing sediment dynamics and bank stability, the project represents an improvement over the legacy condition.

5 HYDROTECHNICAL SITE CONDITIONS, CONSIDERATIONS, AND MODELLING

The river's morphology, hydrology, flow regimes, history, and future land-use plans are critical to the hydrotechnical design of any project. These factors provide essential insight into the river's behavior and its potential response to modifications, particularly in terms of flow dynamics. The following sections outline key site conditions and considerations that influence the hydrotechnical design.

5.1 General River and Site Conditions

Figure 7 depicts the design surface and nodes, Figures 2 through 4 show key site photographs. Figures 5 and 6 show historical aerial imagery at the project area. The entire design is located in the floodway³ per the draft provincial flood hazard map in Figure E below. The works outlined in this report are in an Outdoor Recreation Area and are permitted under Calgary Land Use Bylaw 1P2007 (The City 2023).

Extreme open water flood events typically occur from May to July during intense precipitation, rapid snowmelt at the headwaters, or a combination of both. The entire project area is inundated during the 1:100-year flood (Figure F).

Flows during the winter months are relatively low and regulated by upstream dams. The river's steep slope, gravel bars, deep thalweg, and numerous warm-water inflows contribute to the development of open leads and a reduction in water levels after freeze-up, primarily due to the ice smoothing out (NHC 2016).

³ The floodway represents the area of highest hazard where design flood flows are deepest, fastest, and most destructive.

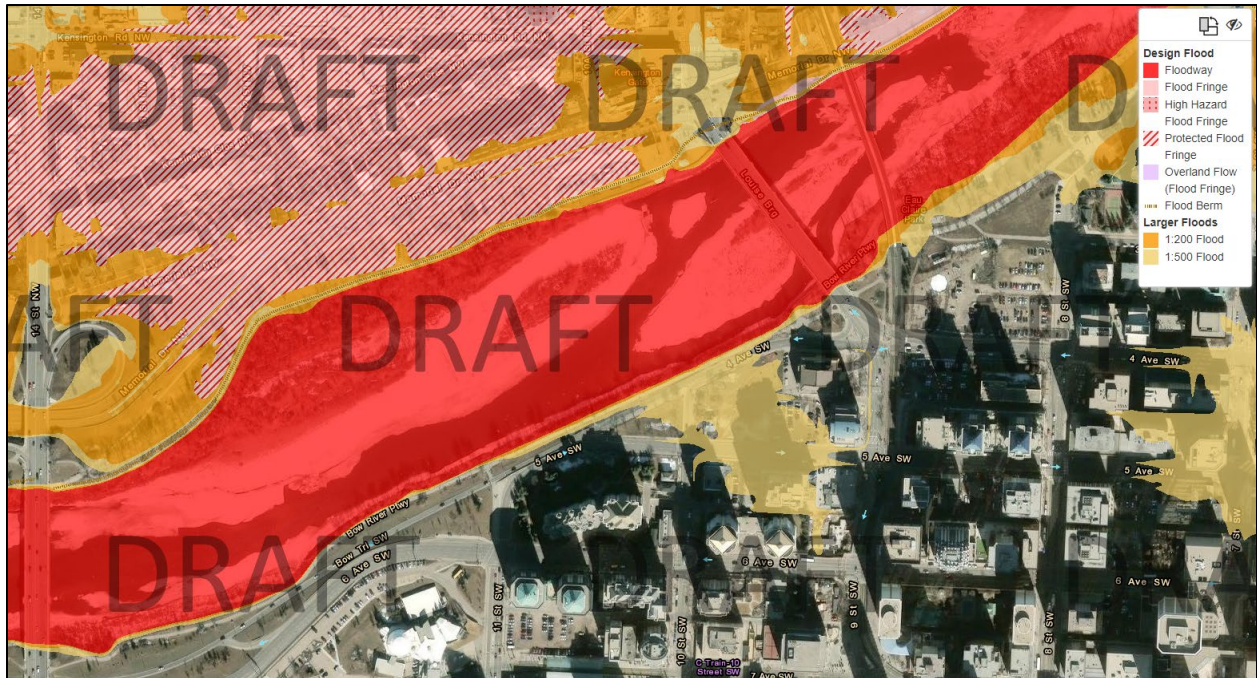


Figure E Floodway and Flood Fringe (Government of Alberta 2024)



Figure F 1:100-Year Flood Inundation (Government of Alberta 2024)

5.2 Summary of Historical Aerial Photographs and Bridge Information

5.2.1 Historical Aerial and Ground Photographs

Historical aerial and ground-based imagery from 1906 to 2023 shows river changes and provides evidence for certain historical river features still present, such as wooden piles from the diverter channel for the Calgary Power hydroelectric plant and sawmill, and remnant concrete from previous bridges; Figures 5 and 6). Figure presents G the earliest available historical aerial imagery from 1924, and includes key areas of change labelled in yellow, and referred to in the below bullets.

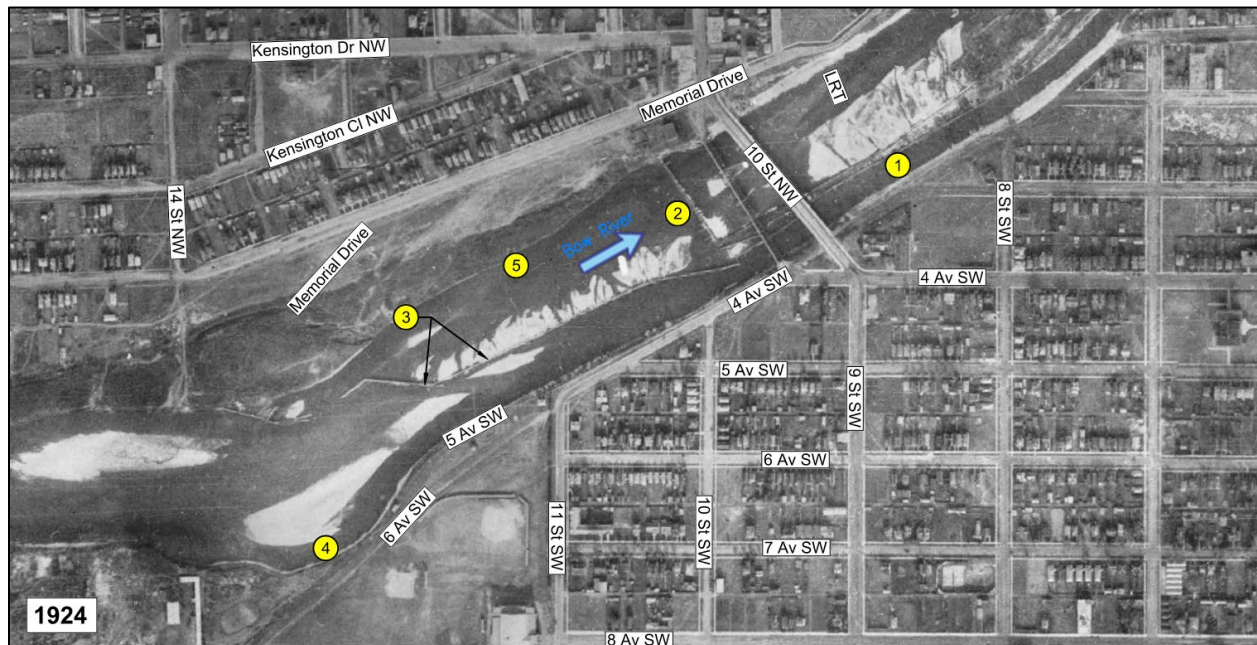


Figure G Historical Imagery with Key Areas of Change

Key observations are outlined thoroughly on Figures 5 and 6. They include:

- The original Bow Marsh Bridge, built in 1888 just upstream of 10th Street NW, was replaced with a steel bridge in 1906.
- Several mid-channel structures appeared in the 1924 imagery upstream of the Louise Bridge. These include the 1906 steel bridge, the weir structure and south sub-channel, and remnants of the 1888 Bow Marsh bridge. The Bow River was split roughly 40:60 between the south subchannel and the main channel, separated by a wooden pile wall. Logs were floated into the south channel for processing at the Eau Claire sawmill. The weir also raised water levels in the south channel to supply water to the Eau Claire Hydroelectric Plant.
- By the 1948 imagery, the 1906 steel bridge and the guide structures to the south sub-channel were removed, but the wooden pile wall against the south sub-channel remained. By 1957, the weir was partially breached, and the south sub-channel was partially infilled. The weir was fully removed, and the sub-channel was fully infilled, by 1984 (Figure G; Items 1, 2, and 3).

- Portions of the river's south bank were infilled from 1948 to 1957 to construct 5th and 6th avenue SW (Figure G; Item 4).
- An instream berm appears on the 1948 imagery upstream of 10th street. Montrose speculates that the berm was used for gravel mining.
- Between 1957 and 1984, a gravel bar formed at the toe of the north bank. This bar has continued to stabilize and vegetate since 1984 (Figure G; Item 5)).
- By 1984 the Louise Bar was starting to form and had some vegetation. In 1997 the bar was roughly the same size as it was in 1984, perhaps with more vegetation. After the 2005 flood, the bar grew slightly downstream of the Louise Bridge but not laterally. After the 2013 flood, the bar grew substantially in all directions and caused flows below the 1:2-year flood to be split on either side of the bar. The 2013 flood removed most vegetation from the bar that had been present since 1984. By 2022, the bar was almost fully vegetated again, with similar extents to the post 2013 flood condition.

The overall takeaway from the historical data is that the Bow River through downtown is a heavily modified reach of the river and no longer in a natural regime. The project works described in this report will not degrade a natural system, but rather operate within an altered urbanized setting shaped by historical modifications. Figures 2, 5, and 6 present historical aerial and ground-based images as well as outline key changes to the river over time.

5.2.2 Bridge Design Drawings and Inspections

Pier details for the hydraulic model were based on bridge design drawings for the Louise and LRT bridges. Borehole data from various geotechnical investigations, including the original bridge designs, was also used to determine the lithology and presence of an erosion-resistant clay layer below the river. The following historical data, bridge drawings, and inspections were reviewed:

- 1920 drawing showing the 1906 steel girder Louise Bridge and the current concrete-arch bridge, completed in 1921.
- 1967 drawing showing an inspection of the Louise Bridge south pier.
- 1979 report for the *Geotechnical Investigation – Proposed Memorial Drive Widening at 14th Street NW*, located at the project's upstream boundary, near the North Channel node.
- 1980 report for the *Geotechnical Investigation for Construction of the Proposed Bow Trail Connectors*.
- 1980 report for the *Proposed Northwest LRT – Drilling to Bedrock in the Hillhurst Area*.
- 1982 report on the *Proposed Bow Trail Connectors between 8th and 21st Street SW*.
- 1985 report for the *Northwest LRT Bow River Crossing Geotechnical Evaluation*.
- 1987 drawing for the Louise Bridge south pier rehabilitation, including the installation of a new concrete footing protected by Class 3 riprap ($D_{50} = 800$ mm) placed all around the pier.
- 1993 report for the *Bow River Watermain Crossing showing borehole logs*.

- 2010 report for the *Calgary Soldier Memorial Geotechnical investigation*.
- 2013/2014 underwater inspection report noting about 1 m of scour at the south pier's upstream nose but no undermining.

5.3 Modelling

5.3.1 Modelling Summary

Several different models were completed to assess the hydraulic and morphodynamic characteristics of the Bow River in the project site, including:

- **1-D HEC-RAS model:** created as part of the Bow River Flood Hazard study and modified by Montrose to include updated terrain geometry representative of the proposed project nodes. The model was used to determine flood water levels through the project area and confirm that there would be no increase to flood levels because of the project and is further outlined below.
- **2-D HEC-RAS model:** created by the City of Calgary and modified by Montrose to determine the optimal placement of the upstream tip of the reshaped Louise Bar such that an appropriate flow split between the main channel and the wave channel (i.e., to ensure proper functioning of the recreational wave) was achieved. This model was also used to estimate localized velocities at the proposed nodes to help determine armouring requirements (Figure H).

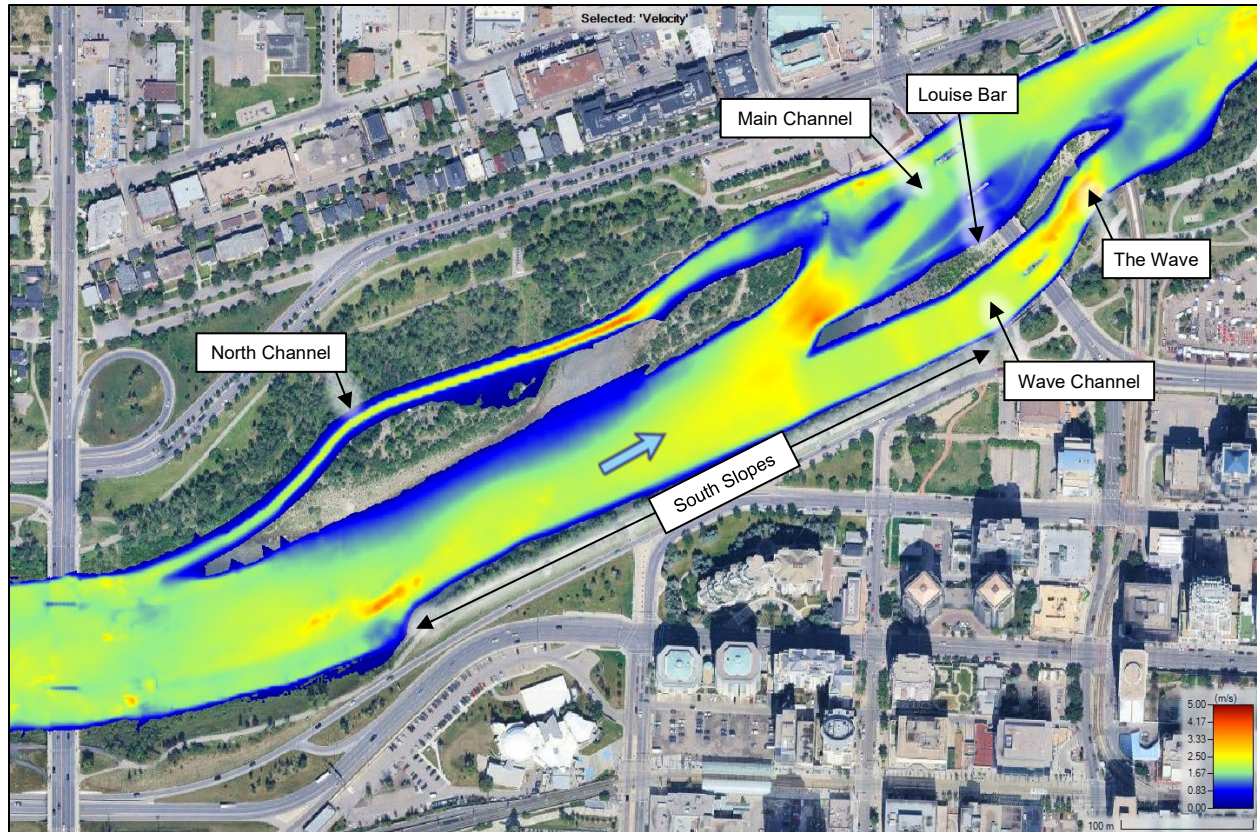


Figure H Modelled Velocities at the Safe Boating Advisory Flow ($280 \text{ m}^3/\text{s}$)

- Physical scale model (1:30 scale):** created by NRC-OCRE in partnership with the City of Calgary and in close collaboration with the University of Ottawa. A 1 km reach of the Bow River was modelled at an undistorted 1:30 scale in NRC-OCRE's research laboratory in Ottawa, Ontario; the model extended from the 14th Street Bridge to just downstream of the LRT Bridge. The model included a mobile bed composed of scaled granular material, which allowed for an investigation of hydrodynamic conditions as well as geomorphic changes that would likely be caused by the project. Results from this model were used to inform alterations to the digital elevation model, which was iteratively modelled in numerical software (HEC-RAS, by Montrose; and Delft3D, by the University of Ottawa) to develop the final digital elevation model of the project. Additional detail on the physical model is available under separate cover.
- Morphodynamic model:** created by the University of Ottawa to determine the effect of the planned gravel bar and wave modifications on sediment transport characteristics through the project area. The results of this modelling show that there is some deposition expected in both the North and Wave Channel after the design flood, but likely not enough to affect the functionality of the wave. Some bar growth and infilling of the North Channel would be expected after a design flood, though it is suspected that the morphodynamic modelling overestimated the total deposition in the project site based on field measurements collected during the 2013 flood.

5.3.2 Existing Conditions

The baseline water levels, without the proposed project alterations, were determined using the draft Bow and Elbow River Hazard Study hydraulic model (Golder 2020b) supplemented with a detailed digital elevation model (DEM) of the riverbed, developed from bathymetric LiDAR surveys (The City 2020). This DEM represents the bar at roughly its current size, as it has not changed since 2020.

The 2020 base model does not account for the channel roughness increase due to vegetation growth on the bar. Montrose added cross-sections to the model through the project area and adjusted the channel roughness values to reflect this vegetation growth, providing a more accurate representation of current flood water levels at and upstream of the Louise Bar.

5.3.3 Digital Elevation Model Development – Proposed Conditions

The development of the proposed conditions DEM involved several iterative steps, incorporating learnings from the physical and numerical modelling. The DEM development generally proceeded as follows:

1. **Initial Modifications:** The 2020 DEM was modified using terrain modification tools in HEC-RAS 6.4.1 to represent the proposed hydrotechnical conditions across the five project nodes.
2. **Numerical and Physical Modelling:** The DEM developed in step 1 was modelled numerically in HEC-RAS and physically in the 1:30-scale I model to evaluate its performance under simulated flood flows.
3. **Iterative Adjustments:** Based on physical modeling results, iterative changes were made to the DEM using HEC-RAS tools to test different node configurations. Each modified DEM iteration was recreated in the physical model. This process resulted in a final “proposed hydrotechnical DEM”.
4. **Landscape Architecture Refinements:** O2 refined the proposed hydrotechnical DEM into a proposed landscape DEM to include landscape architecture details, such as curves and transitions, which the HEC-RAS tools could not produce. These refinements followed criteria from the consulting team and incorporated hydrotechnical parameters and modeling results.
5. **Morphodynamic Modeling Refinements:** The U of O completed updated morphodynamic modelling on the proposed landscape DEM. Minor adjustments were made based on this modeling.
6. **Finalization:** The finalized DEM, incorporating hydrotechnical, landscape architecture, and morphodynamic adjustments, is documented on Figures 7 to 10. Design water levels are based on this final proposed conditions DEM.

5.3.4 1:100-Year Flood Water Levels

The 1:100-year flood water levels for existing and proposed conditions are as follows:

TABLE 1 1:100-year Flood Water Levels

Condition	Design Flow (m ³ /s)	Water Level at 14 th Street bridge (0+000)	Water Level at Louise Bridge (0+800)	Water Level Downstream of Louise Bridge (1+000)
Current ¹	2,090	1050.3 m	1049.2 m	1047.8 m
Proposed		1050.3 m	1048.8 m	1047.8 m

¹The current condition model and water levels are derived from the Montrose modified 2020 draft model, i.e., the model reflects the bar’s present vegetated condition.

The proposed works will lower the 1:100-year flood water level by up to 0.5 m at the Louise Bridge. Flood levels decrease approximately 300 m upstream of the Louise Bridge and about 110 m downstream of the LRT bridge due to excavation for the Landing (Figure I). Water levels downstream of the LRT Bridge remain unchanged.

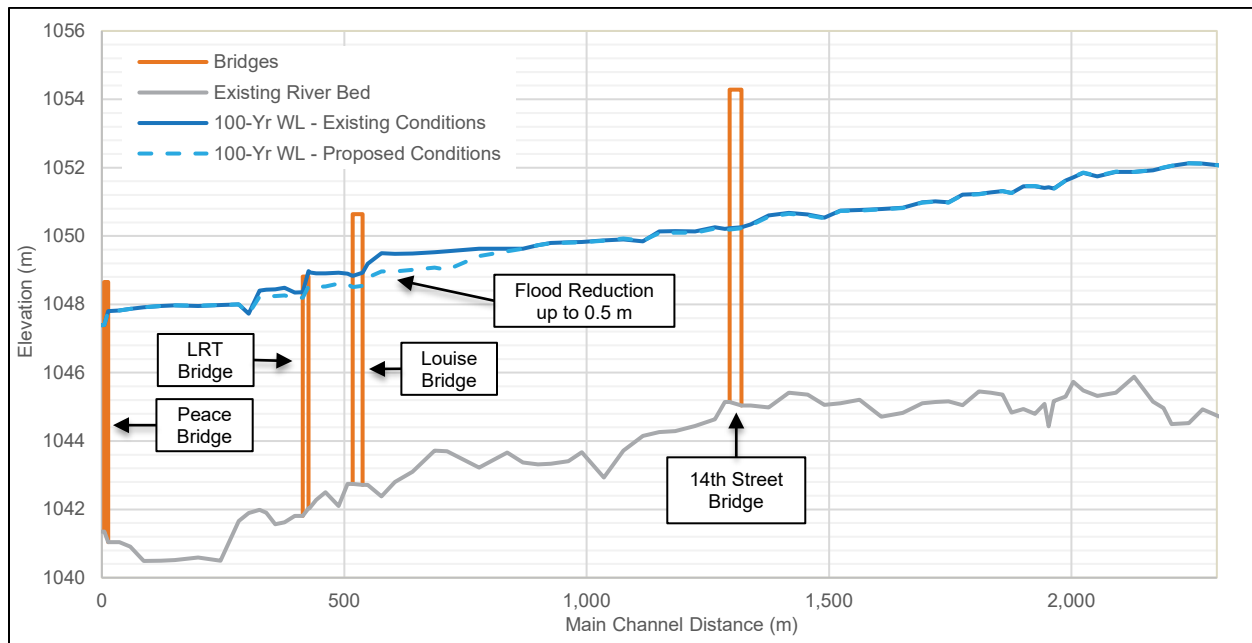


Figure I Water Surface Profiles from 1D Hydraulic Model (Current and Proposed Conditions)

5.4 River Ice

A general description of expected river ice conditions on the Bow River through downtown, based on observed site conditions by Montrose, Wim M. Veldman Consulting Inc., and a 2017 report on river ice in the Bow River through Calgary (NHC 2017), include:

- **River ice formation** – primarily frazil ice, generated in turbulent river reaches during low air temperatures, and border ice, formed along the banks and gravel bars. Frazil ice may accumulate on the border ice or the riverbed, forming larger masses of ice. Ice formed on the riverbed is called anchor ice.
- **Mid to late winter river ice cover and river conditions** – the Bow River occasionally develops complete ice cover, influenced ice lodgement at a constructed ice anchorage about 450 m downstream of the LRT bridge. If lodgement does not occur, typically during warm winters with limited ice production, a complete ice cover may not form.
- **Break-up** – break-up on the Bow River is relatively mild and classified as thermal, driven by warming temperatures. During break-up, open leads form, and water levels drop. High ice events or severe ice runs have not occurred historically. Ice floes tend to be small and disintegrated.

- **Freeze-up** – NHC (2017) identified the maximum freeze-up ice levels at the Louise Bridge occurred during the winters of 1959-1960 and 1995-1996. The ice level profile downstream of Louise Bridge during the winter of 1995-1996 suggests the bridge constricted the channel, likely affecting upstream ice levels (Figure J). Historically, ice jamming at the Louise Bridge has occurred, possibly worsened by the Louise Bar.

Based on the proposed project modifications, the overall impact on river ice conditions is expected to be neutral to slightly beneficial. Reshaping the Louise Bar will improve channel conveyance, which may reduce the risk of ice lodgement and jamming upstream of the Louise Bridge. Additionally, the creation of two distinct flow paths through the project area may further reduce the likelihood of localized ice jams, as ice transport can redistribute between channels if one becomes obstructed. While the project is not specifically designed to address river ice dynamics, the modifications are not expected to increase the risk of ice-related issues and may offer incremental improvements to ice movement and breakup conditions during typical winter periods.

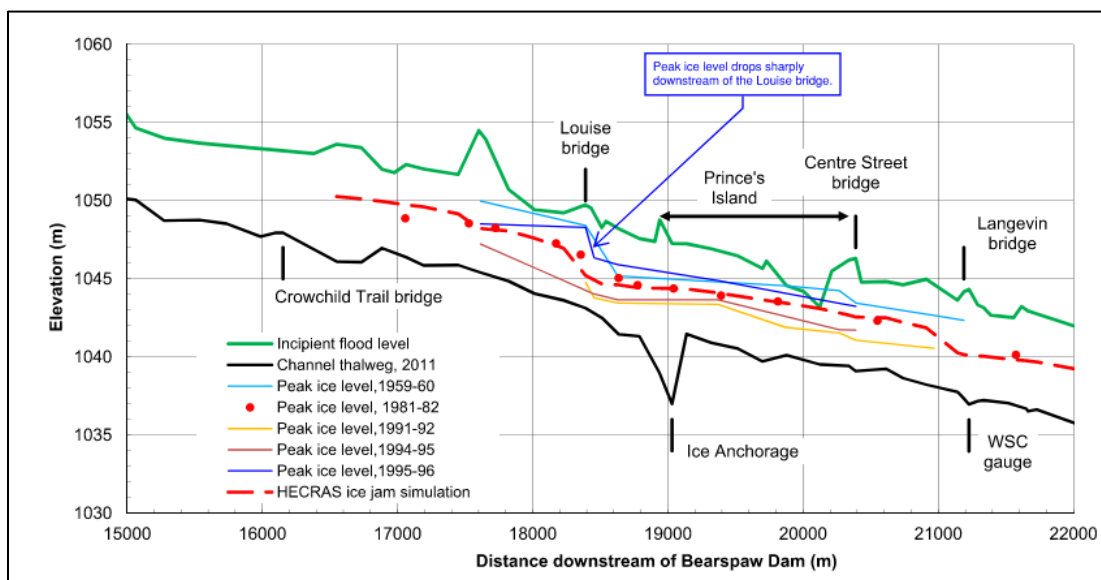


Figure J Maximum Freeze-Up Levels on Bow River (Adapted from NHC 2017)

5.5 Debris

Under a separate scope, following the record 2013 flood, Montrose conducted an underwater bridge inspection program for The City of Calgary in 2013 and 2014. These inspections did not note debris accumulation at the Louise Bridge or LRT bridges. However, the reports did mention debris accumulation at the upstream nose of the 14th Street Bridge's north pier. There is some potential for debris, and anecdotally, The City is aware of debris accumulating downstream of the project area at erosion protection riprap groynes (Figure K).

Since the Bears paw and Ghost reservoirs upstream tend to trap large woody debris, and bank erosion in the city upstream of the project is limited by bank protection and other control structures (e.g., bridges), large debris is likely to originate primarily from tree fall along the riverbanks downstream of Bears paw Reservoir.



Figure K Woody Debris Downstream of Project (2022 Imagery from City of Calgary)

6 HYDROTECHNICAL DESIGN

There are several design parameters that are common across each of the nodes, as outlined in Table 2. Preliminary hydrotechnical design details in the subsequent sections will be further refined during the detailed design phase.

TABLE 2 Hydrotechnical Design Parameters for all Nodes

Category	Description
Flood Design Criteria	Refer to Section 3.3 for flood magnitudes. All nodes, except the North Channel, are designed to remain stable during the 1:100-year flood event. Collectively, the 1:100-year flood level must not exceed existing conditions. Some nodes may require repair or maintenance after a large flood (e.g., to uncover architectural features buried by deposition on the Louise Bar), but no bulk failure should occur. The North Channel is fully inundated during the 1:100-year event and will function as part of the Bow River main channel. Excavating this channel should be effective for several years, depending on future high flows and sediment loading in the Bow River.
Net Flood Level Impact	0 m or less. Any increases to flood levels caused by an individual node (e.g., the south slopes, which reduce the conveyance area of the river) will be offset by the north channel, bar excavation, and deepened wave channel.
Ice Jams	Avoid increasing ice jam risk and, if possible, reduce its likelihood.
Material Reuse	Excavated river materials will be reused and armoured with riprap, where necessary, to balance cut and fill on the north and south side of the river and prevent off-site material transport. Hauling material off site would be costly and would impact the sediment balance of the reach.
Public Safety	Each node must provide recreational access, minimize hydraulic risks, and improve riparian and riverbank health where possible.
Environmental Goals	Each node has been considered from an environmental perspective. Strategic fish habitat placement (e.g., boulder clusters) and vegetated riprap with an undulating toe will be

Category	Description
	incorporated at the detailed design stage. The North Channel node is included specifically for fish habitat offsetting or credit banking. Additionally, the river through downtown is a heavily modified reach that functions under a substantially altered ecological regime. The project works described in this report are using nature-based solutions to improve hydraulic conditions. It is also likely that the project will generally increase aquatic habitat complexity.
Aesthetics	Improvements should align with goals of enhancing the public realm, including integration with existing pathways and improved river access.
Design Scour Depth	General Scour: 1 to 2 m. The design scour was assessed with calculations based on a D_{50} of 104 mm, from the sediment sampling program conducted by the city (KCB 2016). This scour is consistent with observed variations in thalweg elevation from the Bow and Elbow River Hazard Study – Channel Stability Investigation Report (Golder 2018) Local Scour: 2 to 3 m. Local scour at groynes, piers, and sharp bends will exceed general scour. For reference, the 14th Street, Louise, and LRT bridges had scour holes at the piers with a maximum depth of 1.0 m after the 2013 flood. Total Scour: 1 to 5 m. Total scour is the sum of general scour and local scour. Anecdotally, comparison of pre-2013 and post-2013 flood DEMs indicates that there was minimal scour through the project area, potentially due to the presence of the clay layer near the channel surface. While considering that often the maximum scour hole depth is infilled during the receding limb of the flood hydrograph, these observations provide a basis that scour would be on the lower end of this range.
Design Flood Velocity	Per the draft 2020 hydraulic model that was modified by Montrose to include the terrain modifications in the project area and including additional model cross sections and detailed LiDAR and bathymetry data (The City 2020). The average channel velocity will decrease (resulting from the increased flow area) through the project reach, though there will be concentrations of higher velocity flow at instream infrastructure. Therefore, it is prudent to use the highest average channel velocity through the project area for the riprap design. The bar's upstream tip is the location with the highest velocity, though the wave will experience the highest velocities. The design for the wave is handled by Applied Ecohydraulics under separate cover. The highest average channel velocity from the modified 2020 model is 3.2 m/s
Erosion and Scour Protection	Angular Class 2 riprap ($D_{50} = 500$ mm) is recommended to protect project nodes from erosion. Class 2 riprap is the standard size used on the Bow River through Calgary, but some locations (e.g., the Louise Bar's tip, the Wave abutments) may warrant larger riprap classes during detailed design due to the importance of maintaining these features and the erosion shown in the physical modelling. Riprap will be vegetated above the ordinary high-water mark to promote a natural river environment and infilled with gravels below the ordinary high-water mark to improve walkability. Where toe scour is expected (e.g., at the Louise Bar and South Slopes), riprap should be thickened to protect against undermining. The thickened riprap will launch to fill the scour hole. A buried toe trench could also be used but would require riverbed excavation, potentially requiring flow isolation and turbidity control. A launching apron could conflict with the public realm experience because submerged riprap would be difficult to walk on.
Maintenance	The design of each node prioritizes longevity and minimizes maintenance requirements. It is expected that some maintenance will be required, especially at nodes where historical trends indicate deposition is likely to continue occurring (e.g., at the North Channel and the Louise Bar/wave channel).

Node specific hydrotechnical parameters are outlined in the following sections.

6.1 The Louise Bar Node

Key **design goals** for the Louise Bar include:

- **Discourage future bar growth** by creating a morphologically stable design that discourages deposition, which could raise flood levels. Deposition has occurred since the removal of the old wooden pile structures in the 1950s. Maintenance, such as sediment removal, may be necessary to preserve the wave's channel's functionality.
- **Provide the required wave hydraulics** by establishing a stable bar that ensures the necessary flow rate and hydraulic head for the wave design.

The **preliminary hydrotechnical design** is to:

- Determine the bar geometry that meets the design goals and criteria,
- Armour the bar to stabilize it for the design flood.

During **detailed design**, additional features will be incorporated to enhance safety, provide contingency, and/or offer other benefits. For example:

- Placing riprap boulder clusters around the bar's edge to promote scour, discourage deposition in the wave channel and on the bar, provide recreational features, and enhance fish habitat.
- Determining the Calgary Fire Departments requirements for signage or additional infrastructure to warn recreational users of the wave.

Table 3 details the hydrotechnical design criteria to accomplish the design goals for the Louise Bar node.

TABLE 3 Louise Bar Hydrotechnical Design Parameters

Parameter	Value	Comment
Louise Bar – Removal Elevation	Upstream 1044 m; Downstream: 1043.5 m	As per U of O conceptual design DEM for which morphodynamic modelling was completed (Yu et al. 2022). The proposed elevation is driven by flood reduction and will provide a smooth transition to the surrounding riverbed.
Louise Bar – Crest Elevation	Upstream: 1046.5 m Downstream: 1046.0 m	Bar to be about 0.5 m above the 1:2-year water level so that the wave can operate, and so vegetation can grow on the island.
Louise Bar – Length	300 m, measured at the toe of the bar	As required to provide 1.5 m of head for the wave (criteria from Applied Ecohydraulics).
Louise Bar – Top Width	4 m nominally, 18 m at a potential emergency helicopter landing site	Minimum 4 m for constructability.
Width of Wave Channel	35 m along the channel, 25 m at the wave	Between the bar and the south bank. Width is approximate along channel and exact at the wave. 25 m width at the wave allows for multiple gate sections of varying widths. Exact number of gates and specific widths to be determined during detailed wave design.

6.2 The Wave Node

The key **design goals** for the recreational wave include:

- Provide a fun, safe wave that provides excellent recreational opportunities in downtown Calgary.
- Manage public and user safety (avoid a hydraulic jump which can trap users underwater)
- Mitigate deposition (reduce risk of material depositing around the wave structure which could negatively impact the wave gate functionality). The wave gates and associated infrastructure will be designed by others to be resistant to the effects of deposition on the moveable structure.

The **wave design** is presented under separate cover (Applied Ecohydraulics 2024). The in-river components for the wave structure will, at a minimum, include:

- Concrete foundations and abutments,
- Water level control gates,
- Pneumatic or hydraulic operating machinery.

Upstream of the wave, when the wave gates are up (i.e., the wave is active), a low-velocity backwater pool will form due to the gate structure. This setup creates the following flow and operational considerations:

- The pool will extend upstream to the start of the wave channel,
- The wave gates will be lowered gradually to prevent flow surges when the wave is “turned off” for the evening or during higher flows.

During the **detailed design stage**, Montrose will provide hydrotechnical and river engineering design measures to protect the wave structure(s) from the effects of erosion, scour, debris, ice, and high flows. Consideration for maintenance access to the wave will also be required.

Table 4 details the hydrotechnical design parameters for the recreational wave.

TABLE 4 Wave Hydrotechnical Design Parameters

Criteria	Value	Comment
Operating Head ¹	Min: 1.5 m Max: TBD m Minimum operating head provided by Applied Ecohydraulics	The operating head is the water level difference that is available to the wave (i.e., the difference in water level between the upstream end of the bar and downstream of the wave). The operating head is affected by the flow split at the bar and in this case the bar is positioned such that about 35% to 40% of the operating flow (280 m ³ /s) is directed down the wave channel. Applied Ecohydraulics confirmed that the design configuration outlined in this report meets this criterion. Maximum operating head to be determined during future phase of design (important for gate operation and safety).
Bow River Operating Flow ²	Min: 50 m ³ /s Max: 280 m ³ /s	Total Bow River Flow. Maximum wave operating flow is the safe boating advisory flow. Minimum flow to be as low as practical to maximize duration that wave can be operated. The minimum operating flow is exceeded 100% of the time in June, July, and August; and 97% of the time in September.

Criteria	Value	Comment
Wave Channel Operating Flow ²	Min: 20 m ³ /s Max: 100 m ³ /s	For a 25 m wide wave option. Based on an operating unit flow of 1 to 5 m ³ /s/m (wave width can be adjusted as part of its operational capability to refine the total wave operating flow). Assuming about 40% of the total river flow to the wave, 20 m ³ /s is exceeded 95% of the time (total river flow 95% exceedance is 50 m ³ /s).
Minimum operating headwater level	1045.0 m	Water level upstream of the wave during the minimum wave operating flow. Approximate value based on preliminary upstream end of the bar design. To be refined by Applied Ecohydraulics.
Hydraulic control elevation of wave structure with all gates lowered.	1042.5 m	Channel will infill to this elevation upstream of the wave. To be refined during detailed design by Applied Ecohydraulics.

(1) The operating head is preliminary and will be refined as the wave design progresses.

(2) The minimum Bow River and wave channel operating flow is preliminary and will be refined as the detailed wave and bar design progress (i.e., which dictates flow split between the main river channel and the wave channel).

6.3 The South Slopes Node

The key **design goals** for the South Slopes include:

- Stabilize the placed material with riprap to prevent erosion and deposition at the bar or in the wave channel.
- Incorporate a pathway and other public improvements as specified by O2.
- Not negatively affecting the wave channel

The **preliminary hydrotechnical design** for the South Slopes is to:

- Armour the slopes to the 1:2-year water level, plus 0.5 m with Class 2 riprap.
- Vegetate the riprap above the ordinary high-water mark to reduce its visibility and provide overhead cover for aquatic species.
- Incorporate three river access points, spaced roughly evenly along the South Slopes. River access points will be built from durable materials (i.e., riprap, Montana block stone as used in the East Village, or equivalent) to provide strategic public entry points to the river.

During the **detailed design stage**:

- Extend three stormwater outfalls along the South Slopes - one at the upstream end, one just west of 11 St SW, and one aligned with 10 St SW - to ensure they remain connected to the river. Alternatively, or in combination, the South Slopes could be strategically “indented” to reduce the required outfall extension length. The stormwater outfall modifications will be addressed in the next design phase.
- Boulder clusters and erosion protection designs for the river access points will be provided. This could include strategically placed deflector spurs upstream of the river access points to make access to the river easier and safer.

Table 5 details the hydrotechnical design parameters for the South Slopes.

TABLE 5 South Slopes Hydrotechnical Design Parameters

Criteria	Value	Comment
Minimum Top Width of Fill	4 m	As required for construction equipment
Minimum Top Elevation of Fill	1:2-year Flood, plus 0.5 m	As preferred by the City of Calgary, to minimize duration that pathway is inundated while balancing minimizing disturbance to vegetation above the 1:2-year water level
Side Slope of Fill	3H:1V	To facilitate the architectural features (e.g., pathway variation).

6.4 The North Channel Node

The key **design goals** for the North Channel include:

- Minimize disturbance and follow low points in the terrain,
- Ensure connectivity with the main channel of the Bow River at design low flows.

The **preliminary hydrotechnical design** is to:

- Determine the channel geometry that achieves the design goals and criteria.

During **the detailed design stage**, Montrose will:

- Enhance fish habitat along the constructed channel with features such as boulder clusters, woody debris, riffles, etc. Fish habitat that is specified will minimize the risk for displacement (i.e., by floating away and accumulating downstream),
- Assess options to discourage deposition in the excavated channel, using riprap to induce scour for example,
- Provide public access features, such as stepping stone pathways, along the created channel.

Table 6 details the preliminary hydrotechnical design parameters for the north channel.

TABLE 6 North Channel Hydrotechnical Design Parameters

Criteria	Value	Comment
Design Low Flow	33 m ³ /s	To ensure connectivity to the main channel. Equal to the 99% exceedance flow (Q99)
Design Low Flow Water Level at Inlet	1,045.7 m	Computed with the 2020 Golder Bow River HEC-RAS model at the upstream end of the design
Minimum Depth	10 cm	At the design low flow (Q99)
Geometry	5 m bottom width Maximum 2H:1V side slopes	As required for material balance and public accessibility considerations
Publicly Accessible	Yes	Per the landscape design (O2 2024)

6.5 The Landing Node

Key **design goals** for the Landing include:

- Stabilize the Landing's beach area to support long-term functionality and resistance to erosion. Erosion protection measures should be stable for the design flood, though beach substrate (i.e., gravels and cobbles) may need to be replenished if it washes away (i.e., maintenance may be required).

The **preliminary hydrotechnical design** is to:

- Balance material on the south nodes, cut material from the Landing will be used for the South Slopes fill.

During **detailed design**, Montrose will:

- Refine the erosion protection designs and specifications, once the landscaping and public realm improvement design is complete. Currently, O2 has provided preliminary design renderings of the Landing which will be finalized during the detailed design phase.
- Incorporate or reconfigure an existing stormwater outfall located in the Landing area. Note that designs for the stormwater outfall will be completed in the next phase of design.

Table 7 details the hydrotechnical design parameters to accomplish the design goals for the Landing node.

TABLE 7 The Landing Hydrotechnical Design Parameters

Criteria	Value	Comment
Geometry	Varies, per figures	As required by the landscaping design, material balance, and public use.
Slope of beach/bay area	Varies, but not more than 5H:1V	To facilitate public access and cobble/gravel "beach" area.
Erosion Protection	Strategically placed riprap or other stone "hardpoints"	Riprap or stone hardpoints will be strategically placed to provide erosion protection that meshes with the landscaping design. This could include hard point "ribs" running through the beach area to increase the stability of gravels and cobbles. River sediments at the Landing may be displaced during the design flood as it is not practical to prevent this, but the structural components (i.e., large blocky rock tiers) should be stable without requiring large repairs.

7 CONSTRUCTION COST ESTIMATE

The full project cost estimate, including architectural and structural features, is provided by O2 under separate cover. The major costs are:

- 1) Excavation, placement of excavated river gravels, hauling of surplus gravels and supply/delivery of imported riprap
- 2) Public realm improvements and landscaping
- 3) Relocation or alteration of stormwater outfalls
- 4) The wave

Montrose prepared a Class 4 construction cost estimate for costs associated with Item 1, based on material volumes from the DEM and unit price averages provided by the City of Calgary and Alberta Transportation. Unit rates for materials were reported for high, low, and average values over the last four years, resulting in estimated costs of \$2.4MM, \$2.6MM, and \$2.7MM for the low, average, and high cases respectively. These costs rely primarily on the unit price averages provided by the City of Calgary for excavation, transport, and placement of river gravels. While these unit prices are an order of magnitude lower than those published by Alberta Transportation, they are justified based on similar gravel bar removal jobs in the city.

8 CONCLUSIONS

The Louise Bar Flood Reduction and Recreational Wave project is feasible and will reduce flood water levels in the downtown area at and upstream of the Louise bridge. Deposition has occurred at this location since the removal of the old wooden pile structures in the 1950s. Therefore, maintenance, such as sediment removal, may be needed to maintain the functionality of the wave channel.

The recreational wave, south slopes, and landing nodes present a unique opportunity to develop world-class public realm improvements that would be a major driver of tourism and cultural activities in Calgary. The public realm and aquatic habitat improvements will be a net benefit to this reach of river, which has historically been heavily altered over the last 120 years.

9 RECOMMENDATIONS

The following recommendations should be considered by the city and the consulting team as the next phase of design begins:

- Design aquatic habitat features, the north channel, and the wave channel to prevent the accumulation of floating debris through the project area. If woody features are used, ensure they are well secured and do not act as strainers.
- Develop erosion prevention measures for bar and the wave, considering the bar's critical role for recreation.

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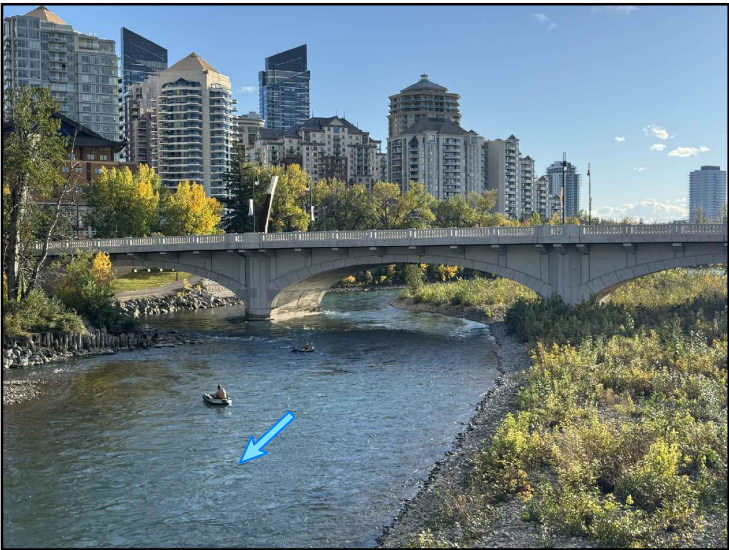
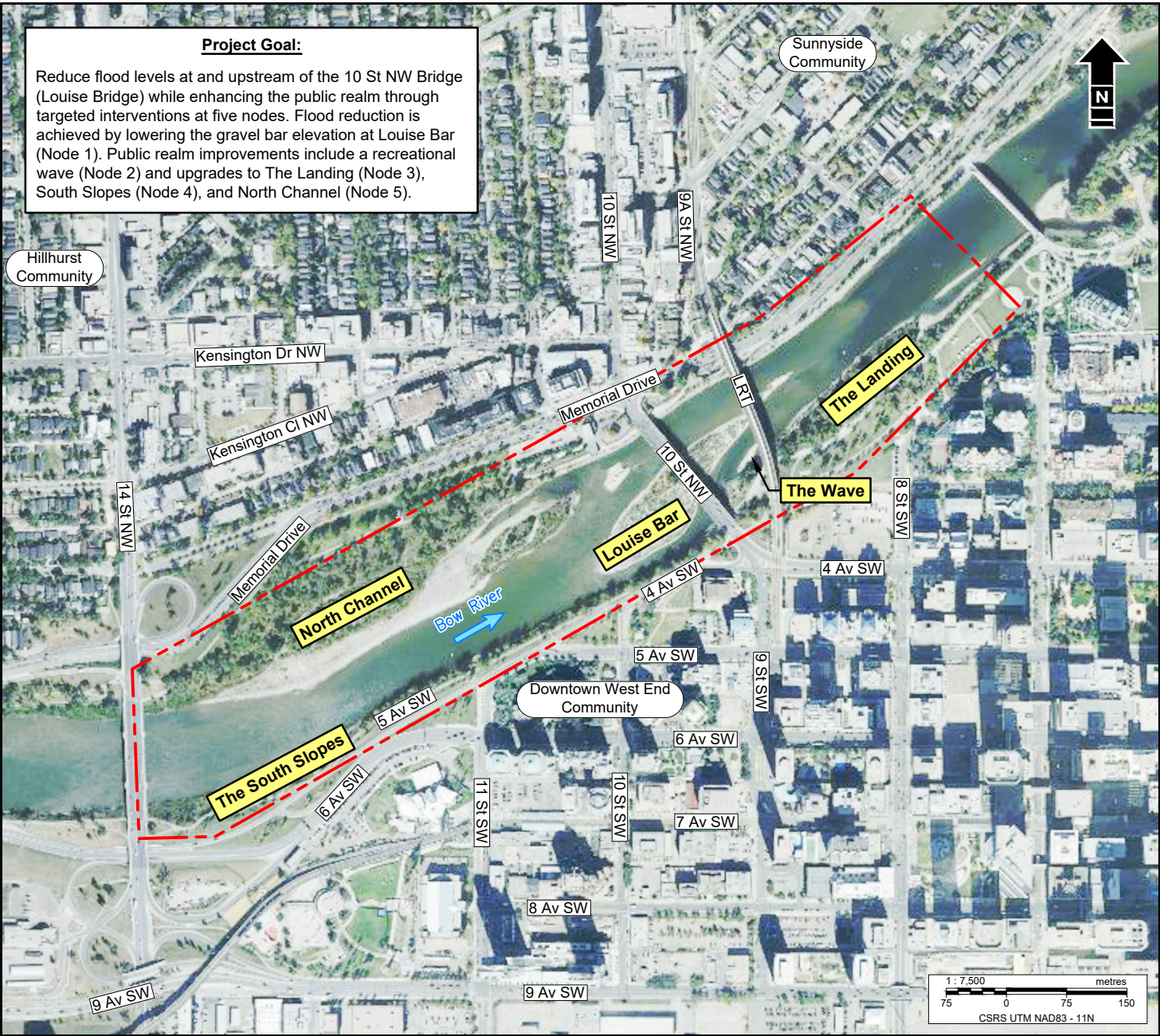
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<https://doi.org/10.1016/j.jenvman.2022.115564>

Plot 1:1 = Tabloid (L)

F:\34737\CADD\WG10 St Gravel Bar\Production\Figs\34737-GRAVEL BAR DESIGN.dwg - COVER - May 6, 2025 9:50:51 AM - Gary Evenson



Louise Bar and 10 St. NW Bridge (Per Montrose Environmental).



Louise Bar and LRT Bridge (Per Montrose Environmental).



North Channel and Upstream Tip of Louise Bar (Per Montrose Environmental).



South Slopes and Upstream Tip of Louise Bar (Per Montrose Environmental).

Louise Bar: Bow River Flood Reduction and Recreational Wave

Hydrotechnical Figure Index

Figure No.	Figure Title
1	Bow River Hydrology, Frequency Analysis, and Flow Duration Curves
2	1906 - 1930 Historical Photos and Timeline of River Activities in the Project Area
3	2013 - 2024 Site Photos Louise Bar and 10 St. Bridge
4	2024 Site Photos
5	Historical Aerial Photograph Comparison (1924 - 1984)
6	Historical Aerial Photograph Comparison (1997 - 2023)
7	Preliminary Site Plan and Digital Elevation Model
8	Main Channel Profiles
9	Main Channel Profile and South Slope / Wave Channel Sections
10	North Channel Profile and Section



Birds-Eye View of Proposed Gravel Bar Realignment and Recreational Wave Project (Per O2).

Roles and Responsibilities:

O2 Planning + Design: Lead consultant. O2 is responsible for landscape architecture, riparian restoration, and public realm design.

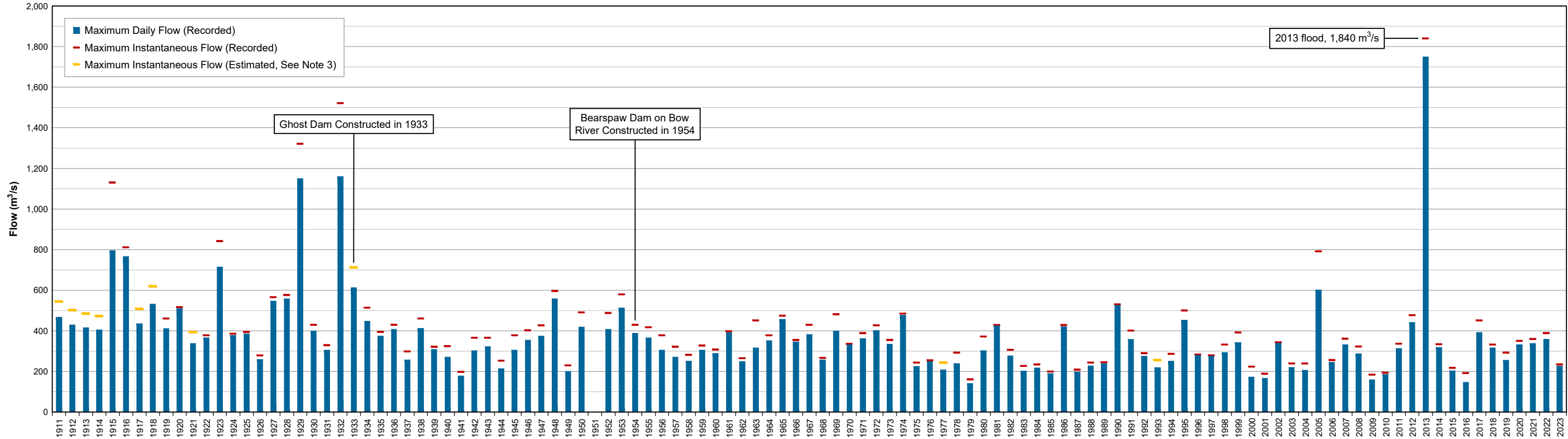
Montrose Environmental: Hydrotechnical and Environmental Consultant. Lead for numerical hydraulic modeling and hydrotechnical engineering design, aquatics and fish habitat assessments, terrestrial, and vegetation assessments.

Applied Ecohydraulics: Wave Design Consultant. Lead for specifics related to the wave design, as well as providing support and input for hydraulic modeling and evaluations.

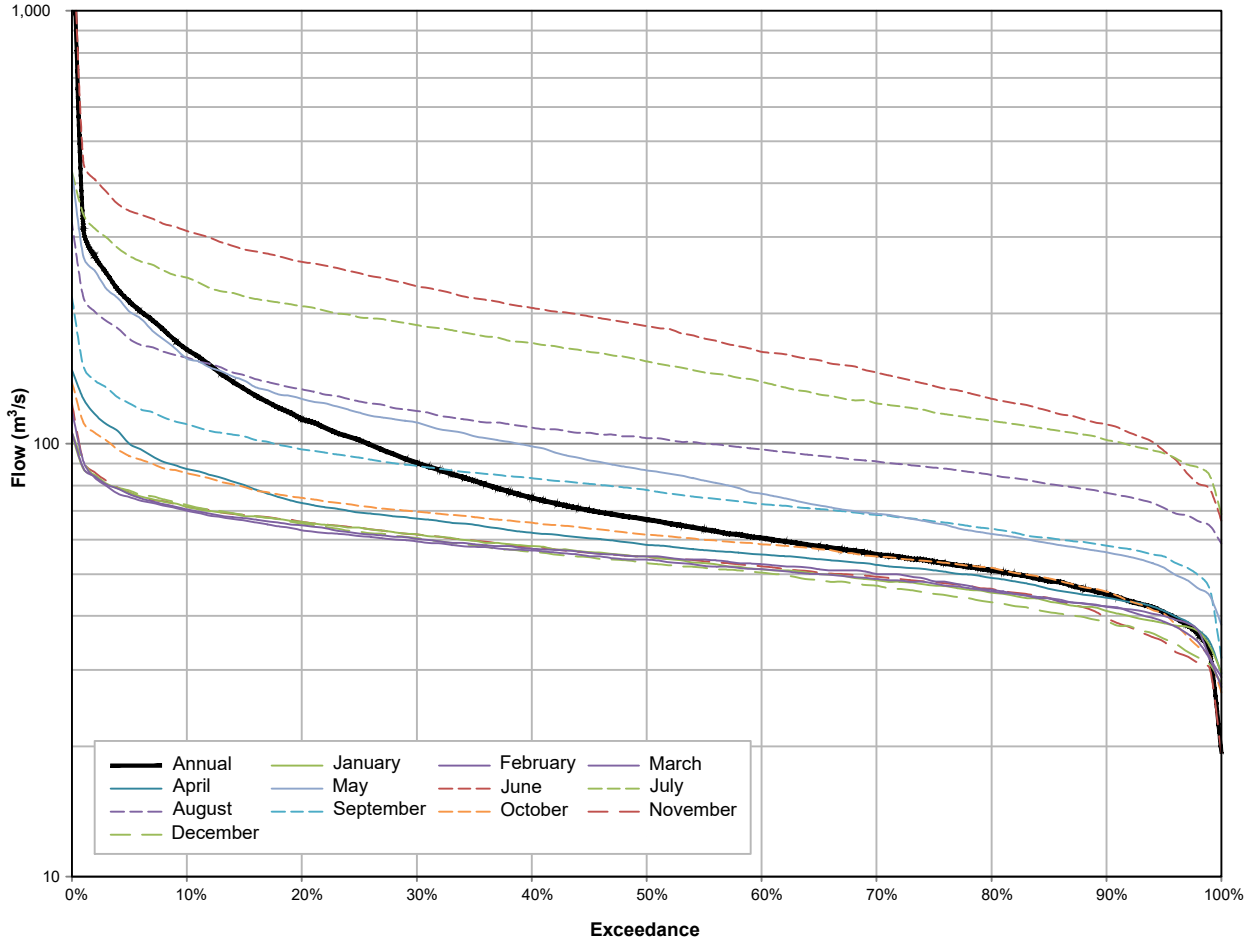
Surf Anywhere: Wave Design Consultant. Lead for determining project aspects sought and desired by specialized river recreation activities. Input based on extensive experience with river recreational wave design and operations.



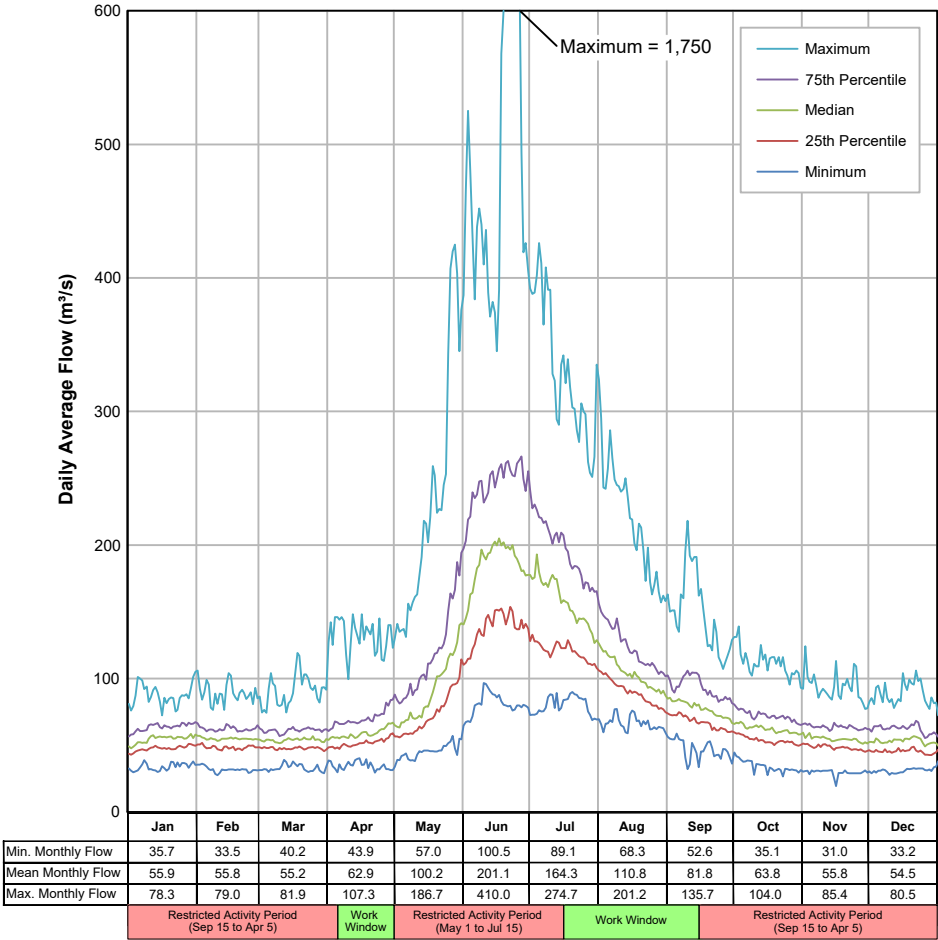
Bow River at Calgary (05BH004) Flow History



Flow-Duration Curve (1955 - 2022)



Annual Hydrographs and Monthly Flow Statistics (1955 – 2022)



Flood Frequency Analysis (Golder, 2020⁴)

Return Period (Year)	Flow (m³/s)
2	401
5	627
10	845
20	1,120
35	1,400
50	1,610
75	1,880
100	2,090

Notes:

- Flow record are taken from Water Survey of Canada (WSC) hydrometric station 05BH004 (Bow River at Calgary)
- Drainage area at WSC Station 05BH004 is 7,890 km².
- When not available, maximum instantaneous flow is estimated from maximum daily flow by applying the linear regression ratio of maximum instantaneous flow to maximum daily flow.
- Golder Associates. 2020. Bow and Elbow River Hazard Study, Hydraulic Model Creation and Calibration Report.
- Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.



O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

Bow River Hydrology, Frequency Analysis, and Flow Duration Curves

Date: May 2025 Project: 34737-522 Submitter: K. Seasons Reviewer: K. Curtis

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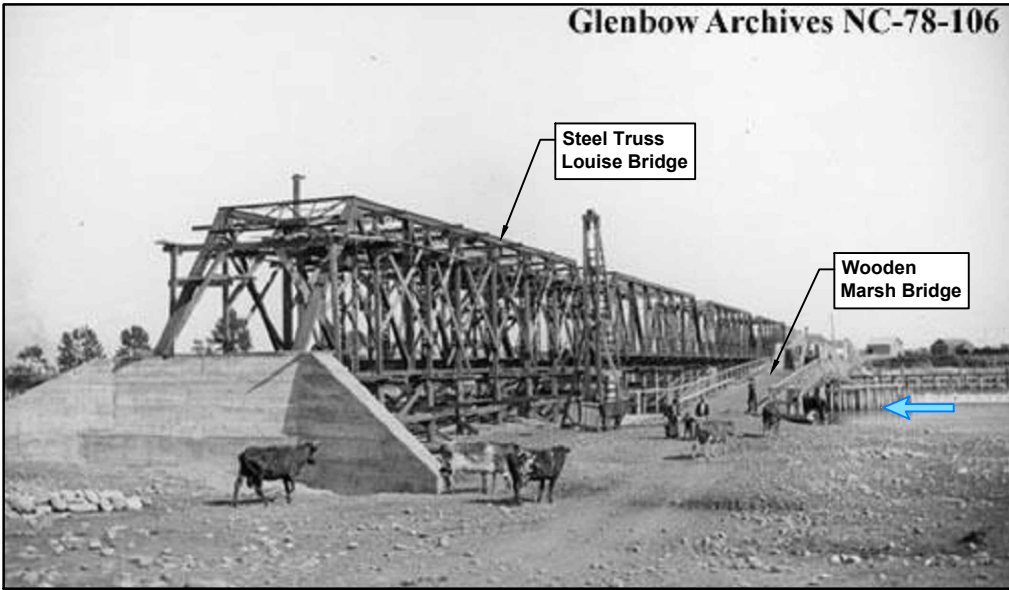


Photo 1: 1906 – Construction of the steel truss Louise Bridge. Previous wooden Marsh Bridge on right.

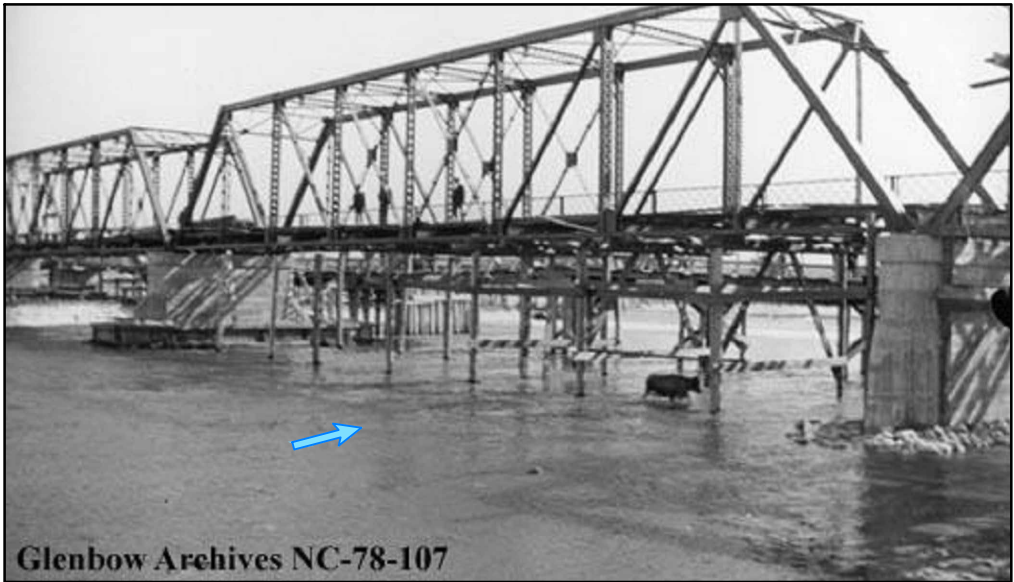


Photo 2: 1912 - 1914 – Steel truss Louise Bridge in service.

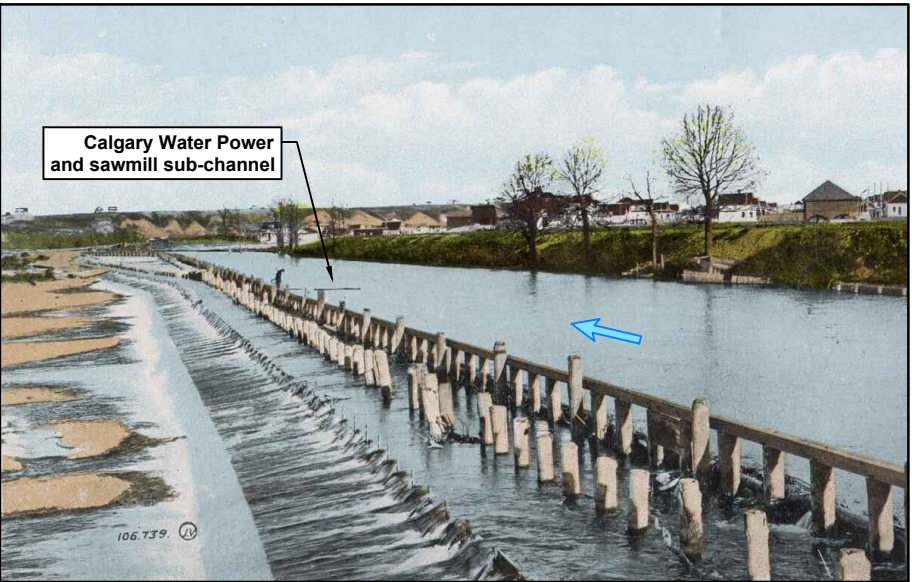


Photo 3: 1911 – Bow River sub-channel along the South bank, downstream of the Louise Bridge, was used to drive logs to the Eau Claire Lumber Mill and increase flow to the Calgary Water Hydroelectric Power Plant at Prince's Island.

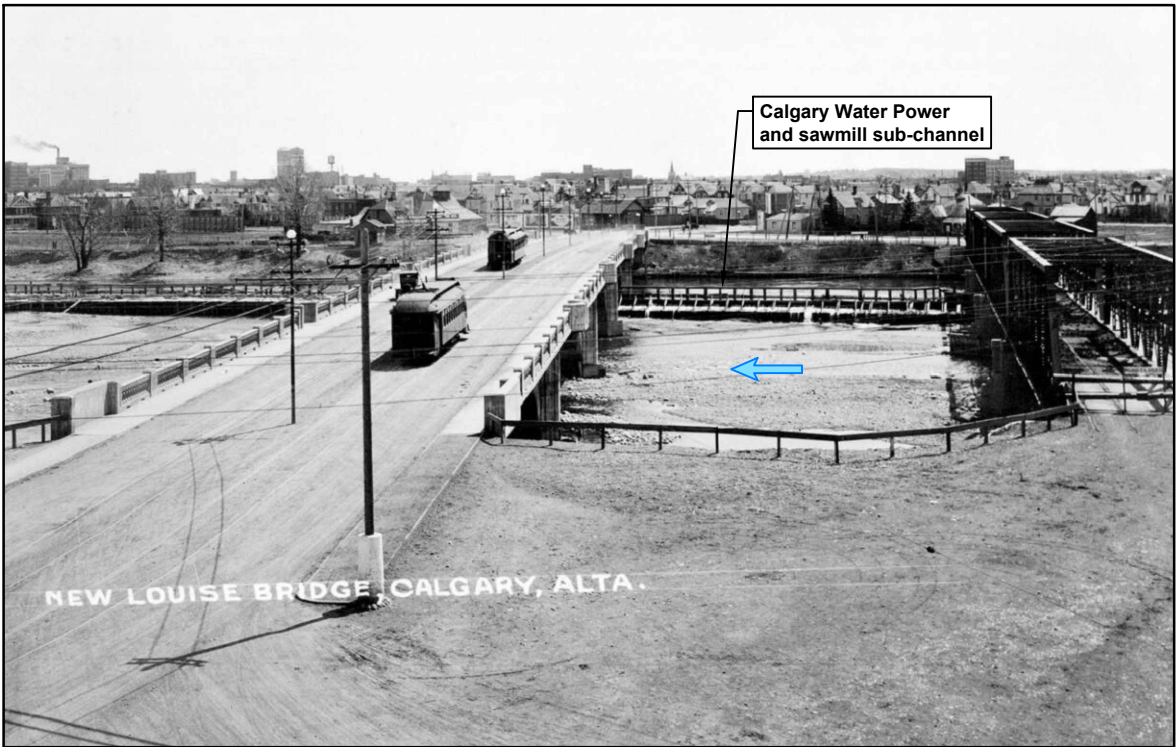


Photo 4: 1922 (estimated) – Concrete-arch Louise Bridge. Previous steel truss bridge on right.

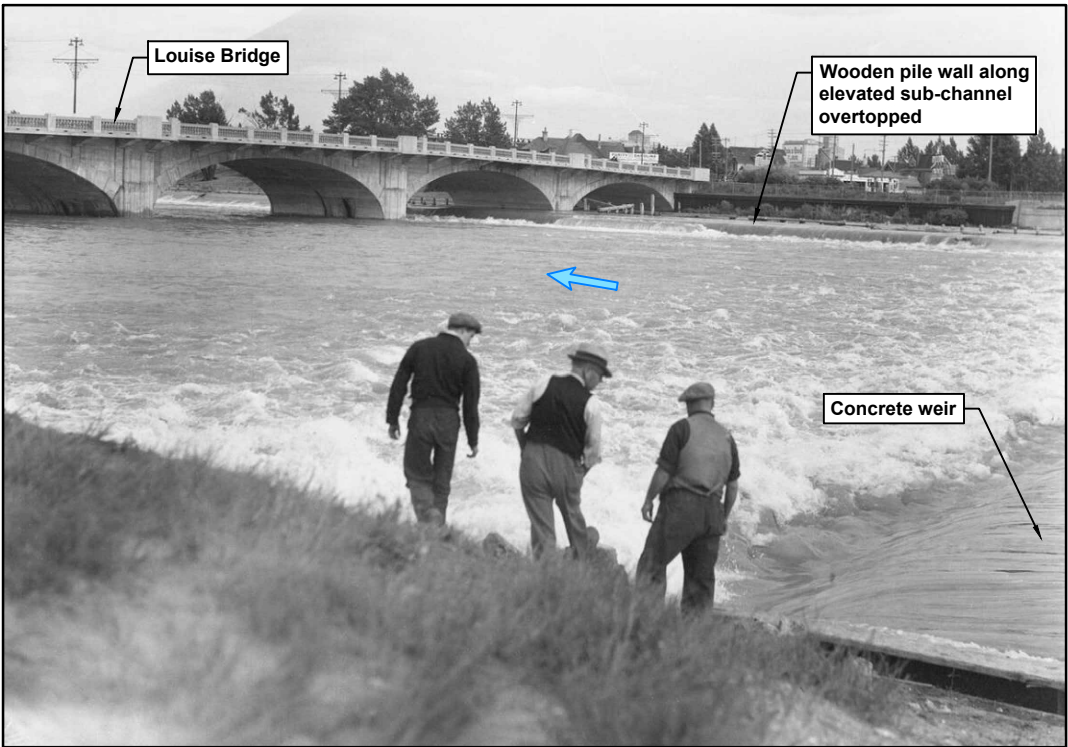


Photo 5: 1925 to 1930 (estimated) – Calgary Water Power weir and Louise Bridge.

Timeline:

- **1887** – Marsh Bridge, the first bridge over the Bow River in the 10th Street area, was constructed.
- **1890** (approx.) – The Calgary Water Power Company and Eau Claire Sawmill built a 4-meter-high weir across two-thirds of the river upstream of Louise Bridge to raise the water level and divert flow into an elevated channel along the south bank, contained by wooden walls. The channel carried logs and increased flow to the sawmill and hydroelectric plant on Prince's Island.
- **1906** – Steel Louise Bridge constructed; a steel truss bridge located downstream of the Marsh Bridge and upstream of the current concrete Louise Bridge. The Marsh Bridge was later removed.
- **1921** – Current concrete Louise Bridge constructed (also called the new Hillhurst Bridge). Previous steel truss Louise Bridge was removed after 1924.
- **1950 to 1962** (approx.) – Calgary Water Power and Eau Claire Lumber Co. subchannel filled in and weir structure removed.
- **1987** – LRT bridge constructed downstream of the Louise Bridge
- **1990** (approx.) – rehabilitation of the south pier of the Louise Bridge.
- **2012** – Ice jam event damaged the pathway under the Louise Bridge and caused flooding of the basements / parkades of nearby buildings on the south side of the river.
- **2013** – Flood of record on the Bow River. Caused the gravel bar under the Louise Bridge to grow. The bar size has remained the same since 2013, but vegetation has colonized on the bar.

Key Considerations:

- The Bow River through the project area has been modified over the years as part of the industrial growth of the City of Calgary.
- Historical remnants of industrial works and structures are still present along the river banks through the length of the project area (e.g., wooden piles).
- The Bow river has been narrowed through the project area since at least the 1950s when a sub-channel from the former Calgary Water Power Plant was infilled.

References:
1. Historical photos from Glenbow Archives, various dates.

Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Legend

➡ Flow Direction



O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

1906 - 1930 Historical Photos and Timeline of River Activities in the Project Area

Date: May 2025 Project: 34737-522 Submitter: K. Seasons Reviewer: K. Curtis

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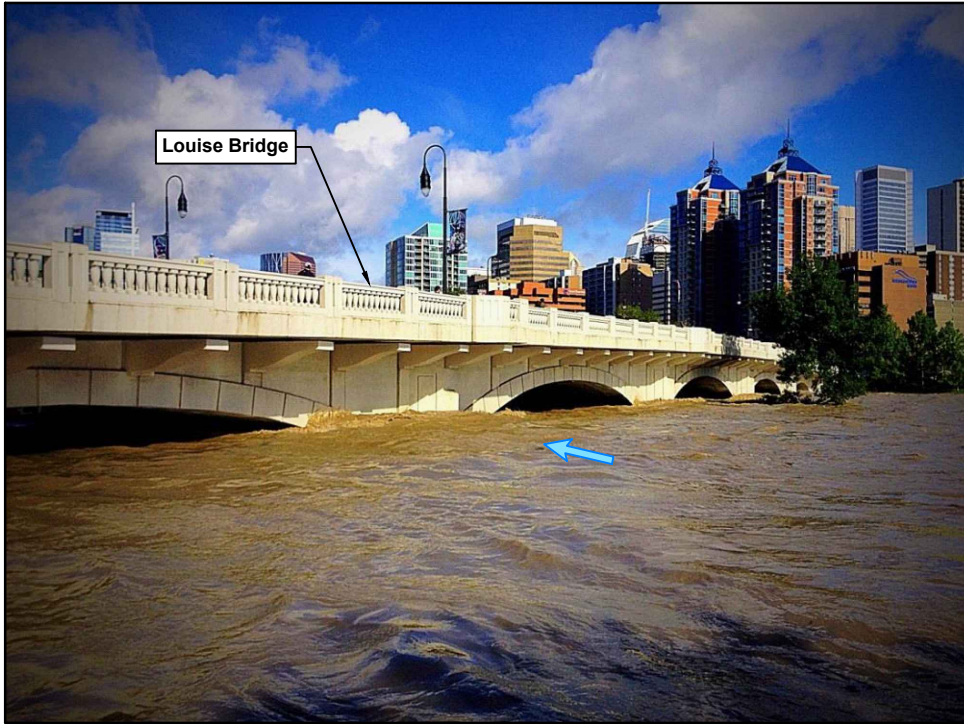


Photo 6: 2013 – One day after the peak of the record flood. Photo from Rood 2020.

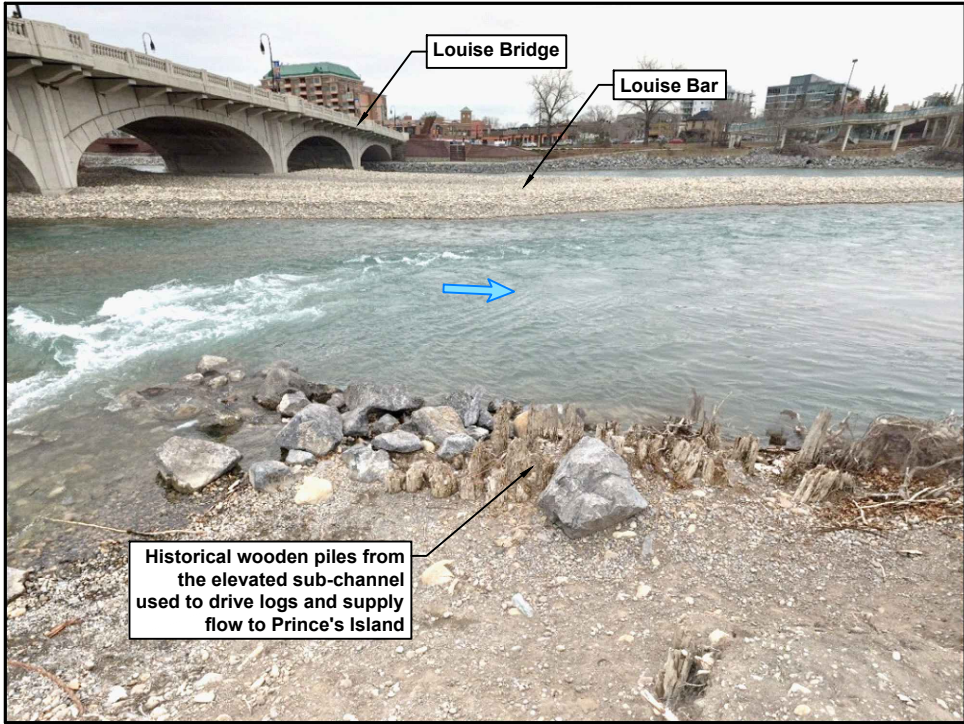


Photo 7: April 2016 – Louise bar and historical infrastructure along south bank at proposed wave location.

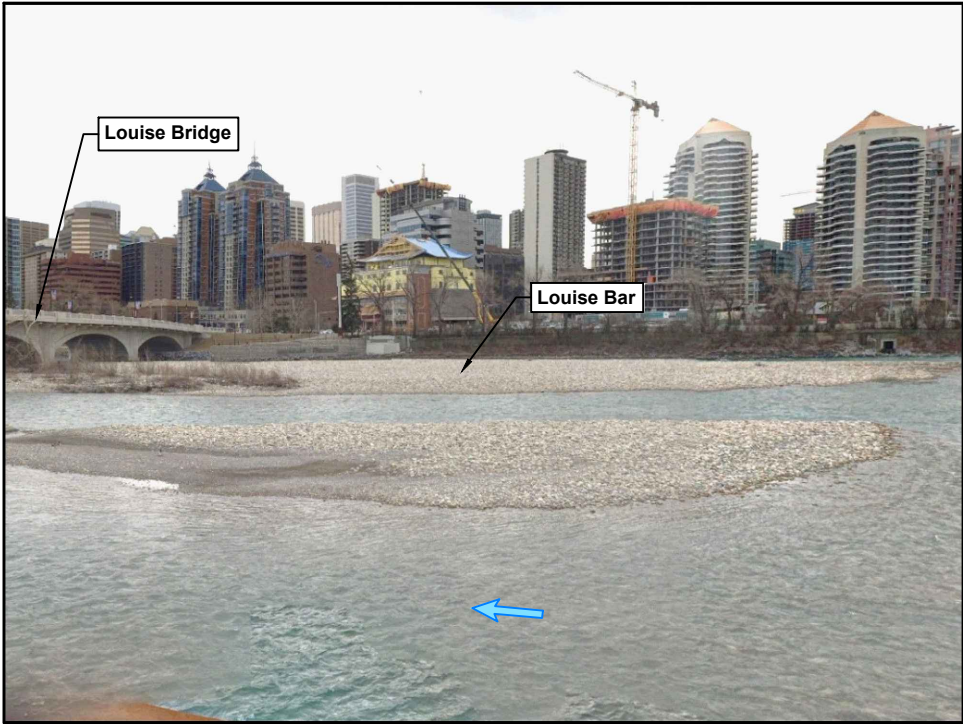


Photo 8: April 2016 – Louise bar upstream of the Louise Bridge is mostly bare of vegetation after the 2013 flood.

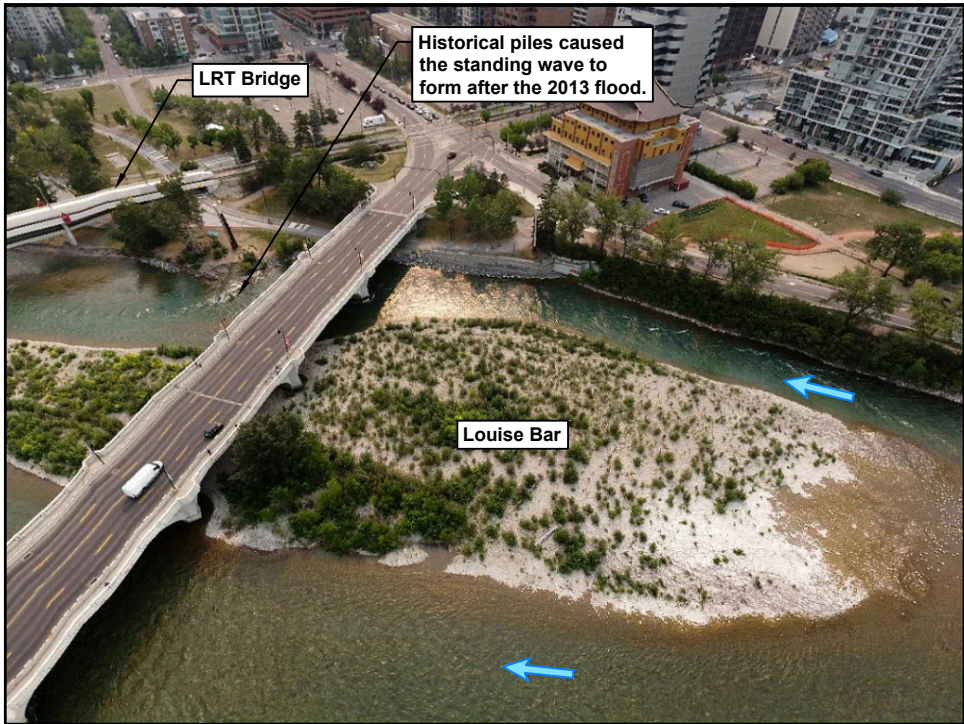


Photo 9: July 2021 – By 2021, vegetation was well established on Louise Bar.



Photo 10: July 2023 – Vegetation continuing to grow on Louise Bar downstream of Louise Bridge in 2023 (Matrix 2023).



Photo 11: September 2024 – Well established and tall vegetation on Louise Bridge upstream of Louise Bridge in 2024 (Matrix 2024).

Key Considerations:

- Gravel bars in the project area were stable until the 2013 flood, which resulted in redistribution of river sediments and enlargement of the Louise Bar.
- Vegetation has almost fully colonized the enlarged Louise Bar since the 2013 flood, which has led to decreased flow conveyance capacity through the Louise bridge arches.
- The gravel bar must be reduced in size to reduce the flood risk to adjacent communities.

References:

1. Except where noted, photos are from publicly accessible Google Maps Street View.
2. Rood, Stewart. 2020. "Louise Island in the Bow River at Calgary: Mitigation of a Growing Flood Hazard and Prospective Environmental Impacts from the Urban Surf Beach and River Waves Project."
3. Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.

Legend

→ Flow Direction



O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

**2013 - 2024 Site Photos
Louise Bar and 10 St. Bridge**

Date:	May 2025	Project:	34737-522	Submitter:	K. Seasons	Reviewer:	K. Curtis
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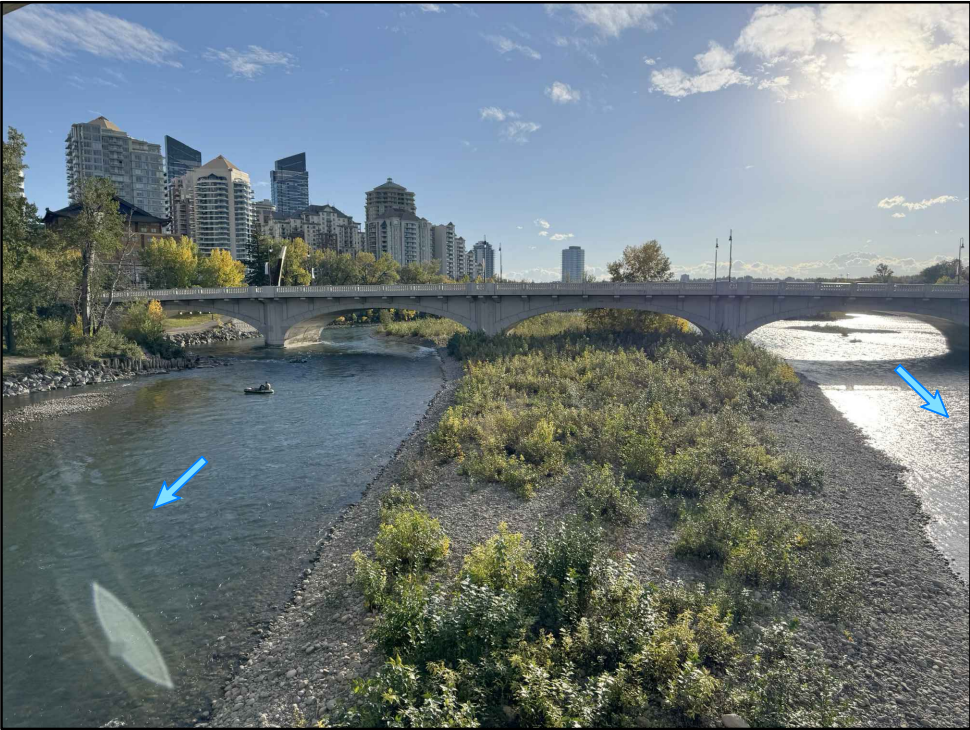


Photo 12: Vegetation on Louise Bar viewed from the LRT Bridge. September 18, 2024.

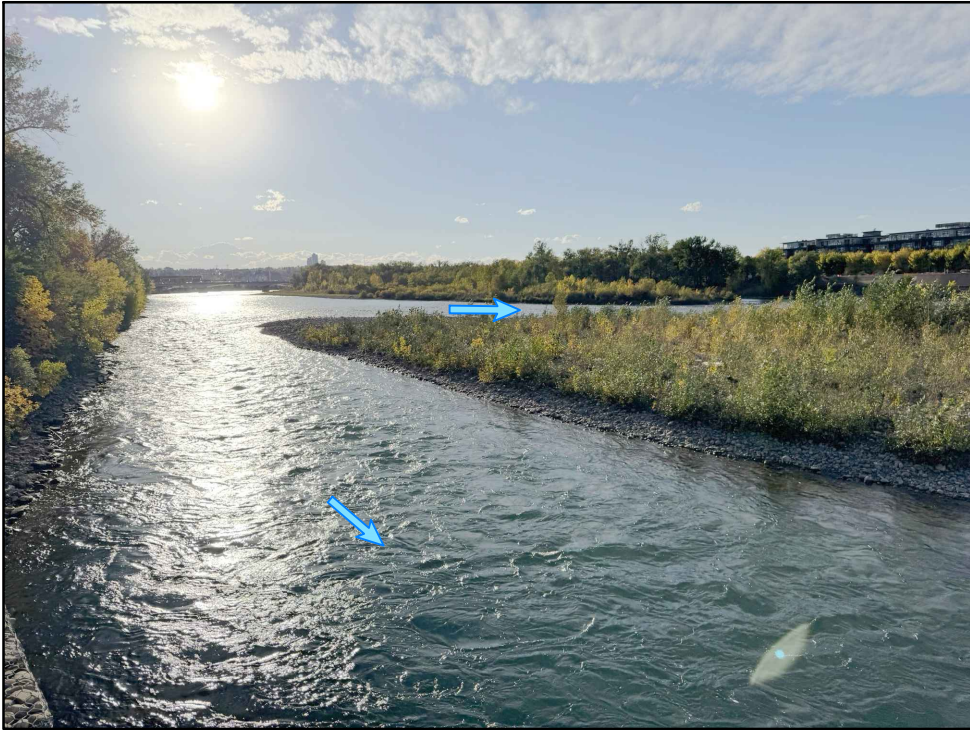


Photo 13: South sloped and upstream tip of Louise Bar. September 18, 2024.



Photo 14: North Channel and Upstream Tip of Louise Bar. October 9, 2024.



Photo 15: Louise Bar is obstructing two of the bridge spans. September 18, 2024.

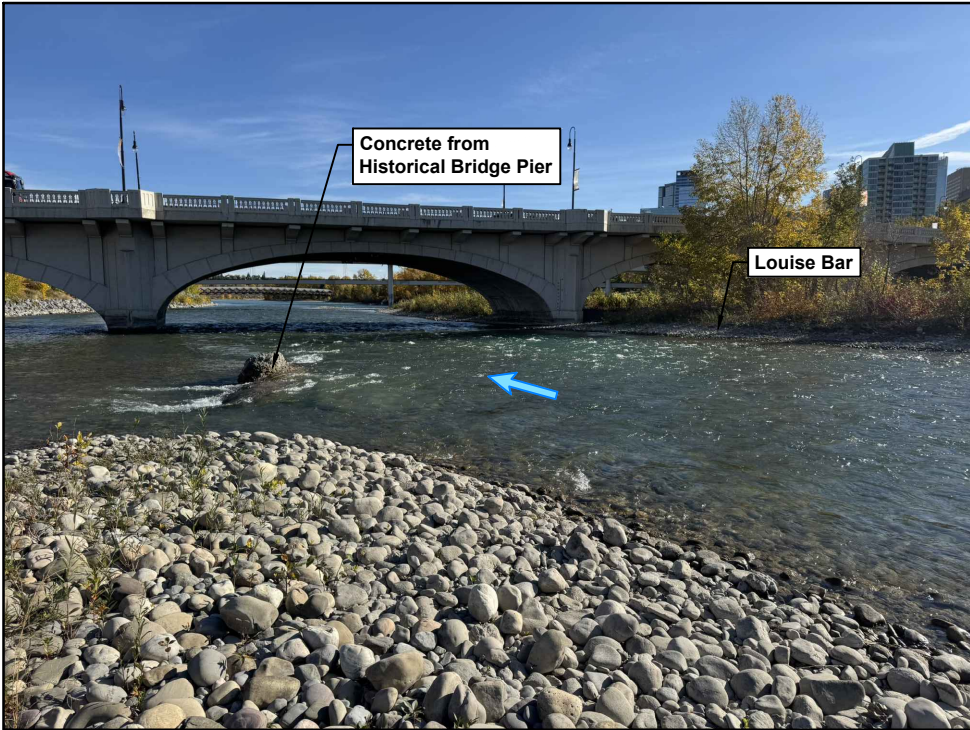


Photo 16: Pier from historical bridge remains in the river. October 9, 2024.



Photo 17: North Channel Area. October 9, 2024.

Legend

→ Flow Direction

- References:
1. Photos taken by Matrix Solutions Inc.
 2. Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.

Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

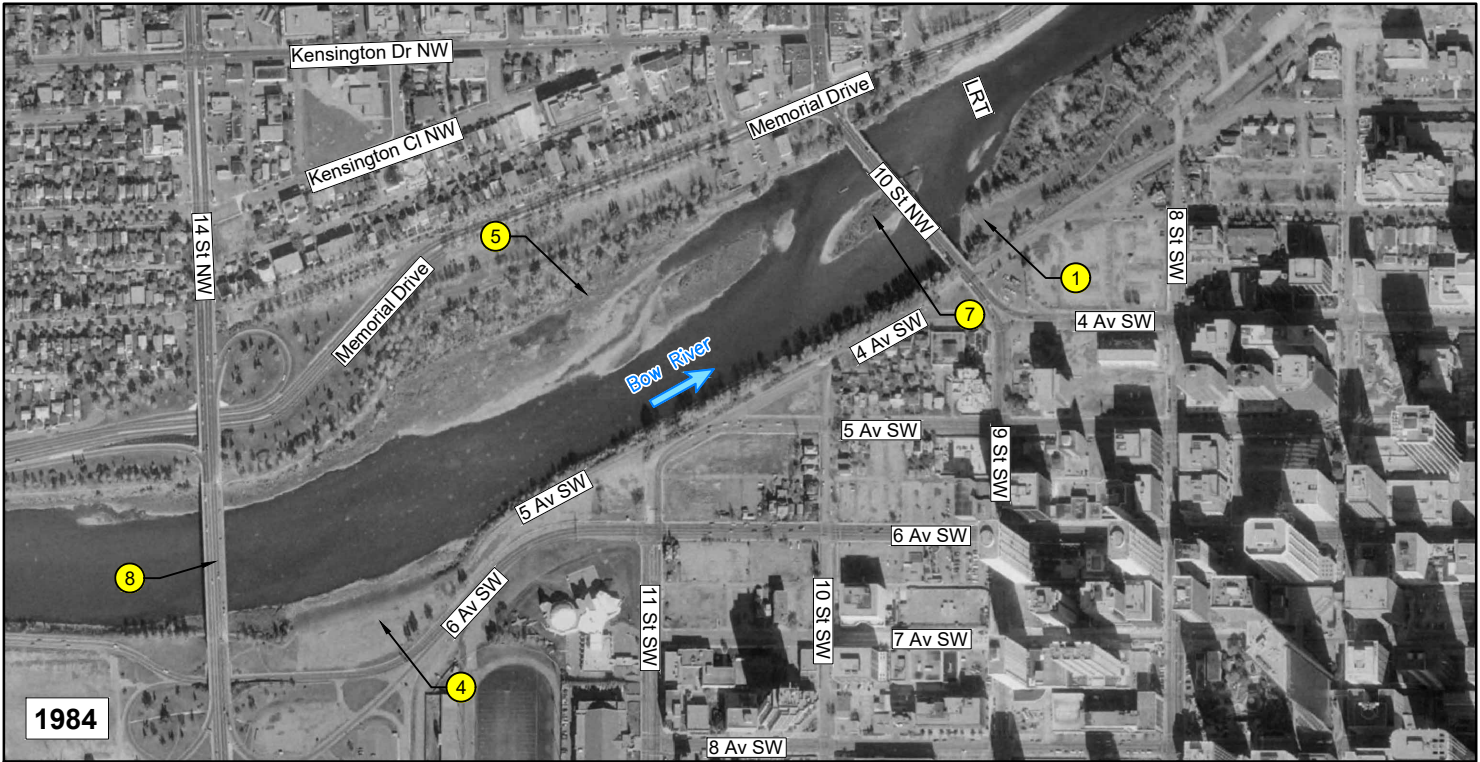
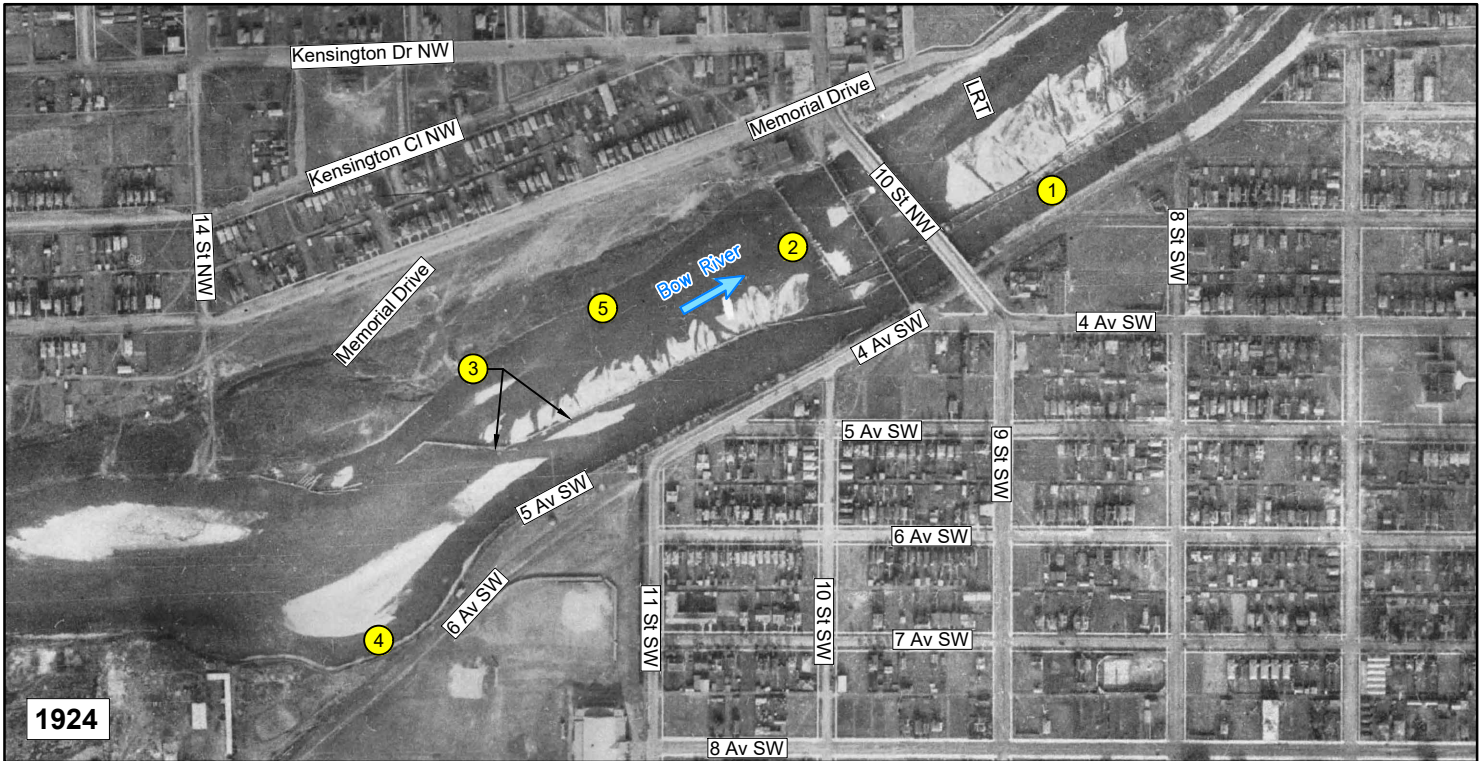


O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

2024 Site Photos

Date:	May 2025	Project:	34737-522	Submitter:	K. Seasons	Reviewer:	K. Curtis
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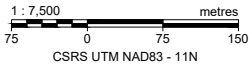
Notes:

- ① A sub-channel along the South bank drove logs to the Eau Claire Sawmill and supplied water to the Calgary Water Power hydroelectric plant on Prince's Island. The elevated channel, contained by wooden piers on the north side, was infilled by 1984.
- ② In 1924, several in-stream structures were present upstream of the Louise Bridge: the old steel truss Louise Bridge (replaced by the current Louise Bridge in 1921) and a weir that raised water levels to divert flow into the sub-channel. The weir was partially breached by 1957 and fully removed by 1962.
- ③ Log-guide structures directing logs to the south sub-channel were removed by 1948.
- ④ This portion of the river was infilled by 1957 for the construction of 5th and 6th Avenue SW.

- ⑤ A gravel bar along the north bank began to develop by 1948 and was vegetated by 1984.
- ⑥ An in-stream berm was present in 1948, purpose unknown but possibly for gravel mining.
- ⑦ Louise Bar appeared in the 1957 photo, downstream of the intact portion of the breached weir. By 1984, the bar was vegetated.
- ⑧ 14 St (Mewata) Bridge NW was built in 1954.

Legend

➡ Flow Direction



References:

1. Aerial Photographs from the City of Calgary dated October 7 to 18, 1924; May 7, August 8 & 31, 1948; September 25, 1957 and September 30, 1984.

Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

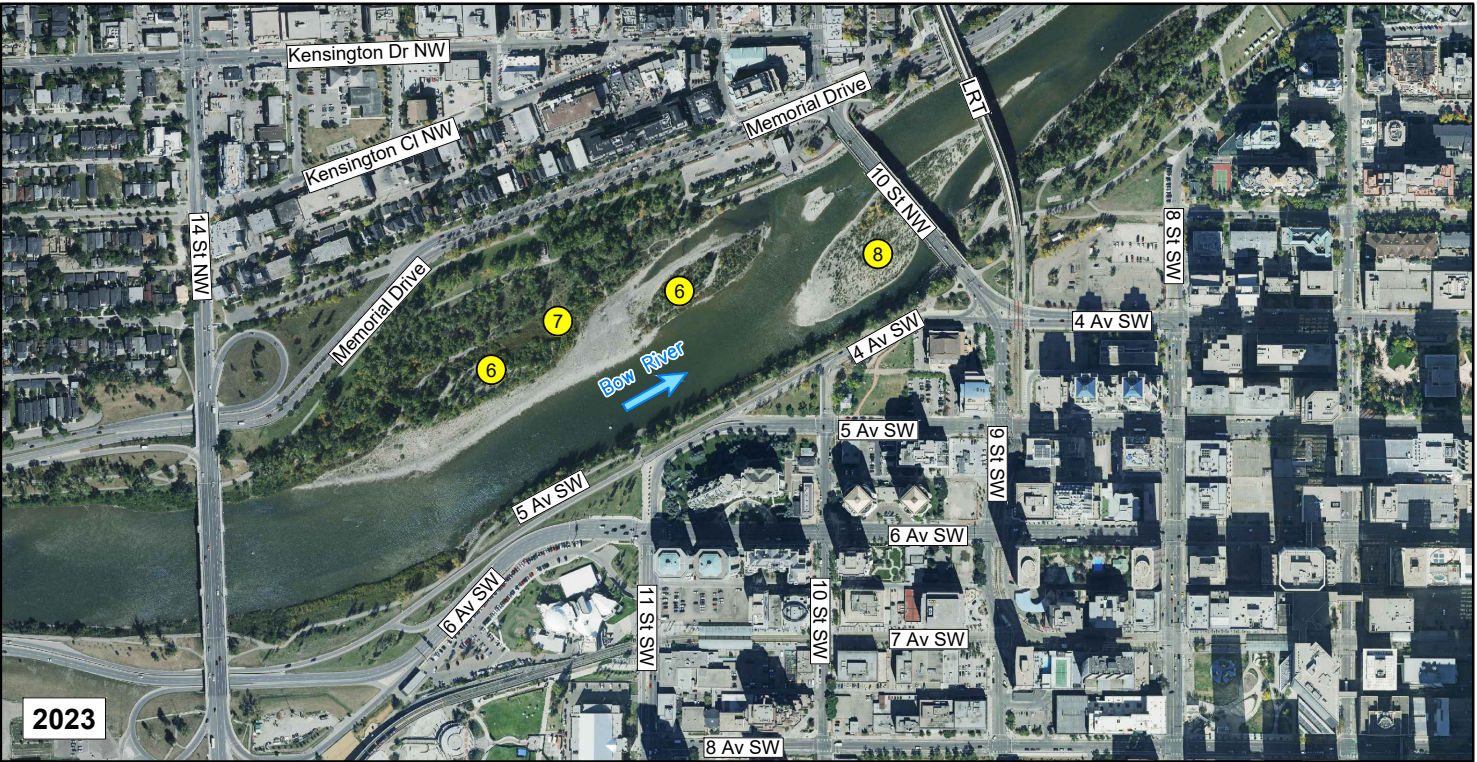
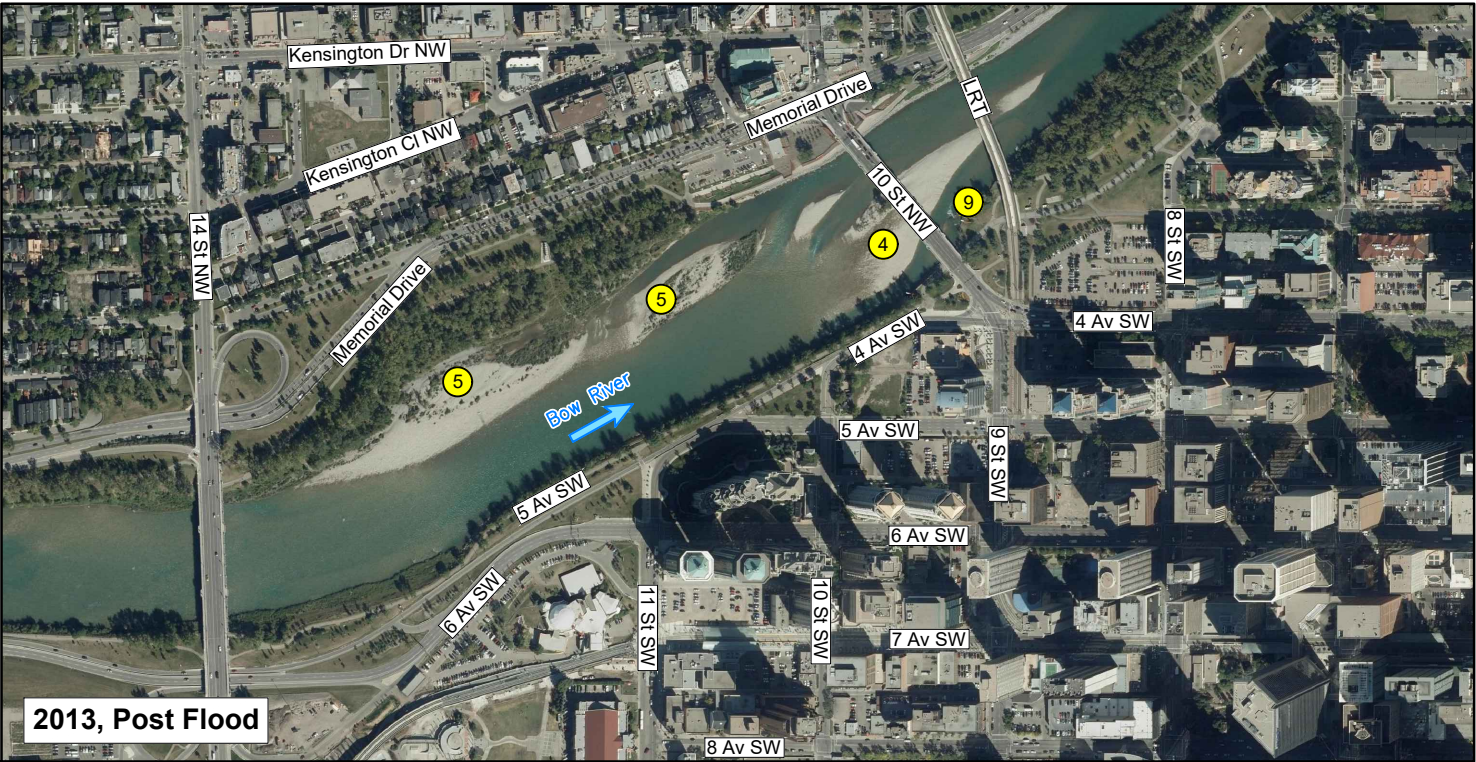
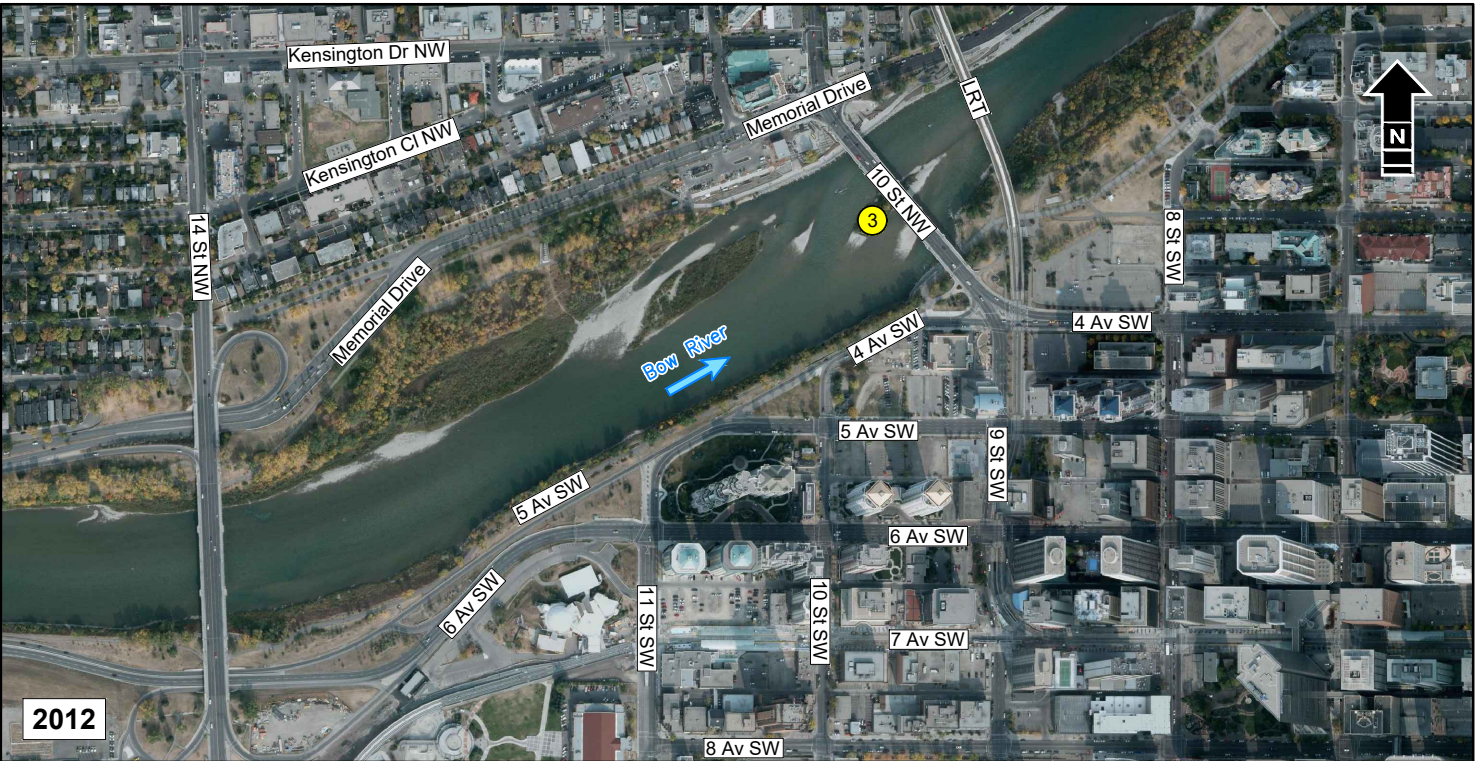
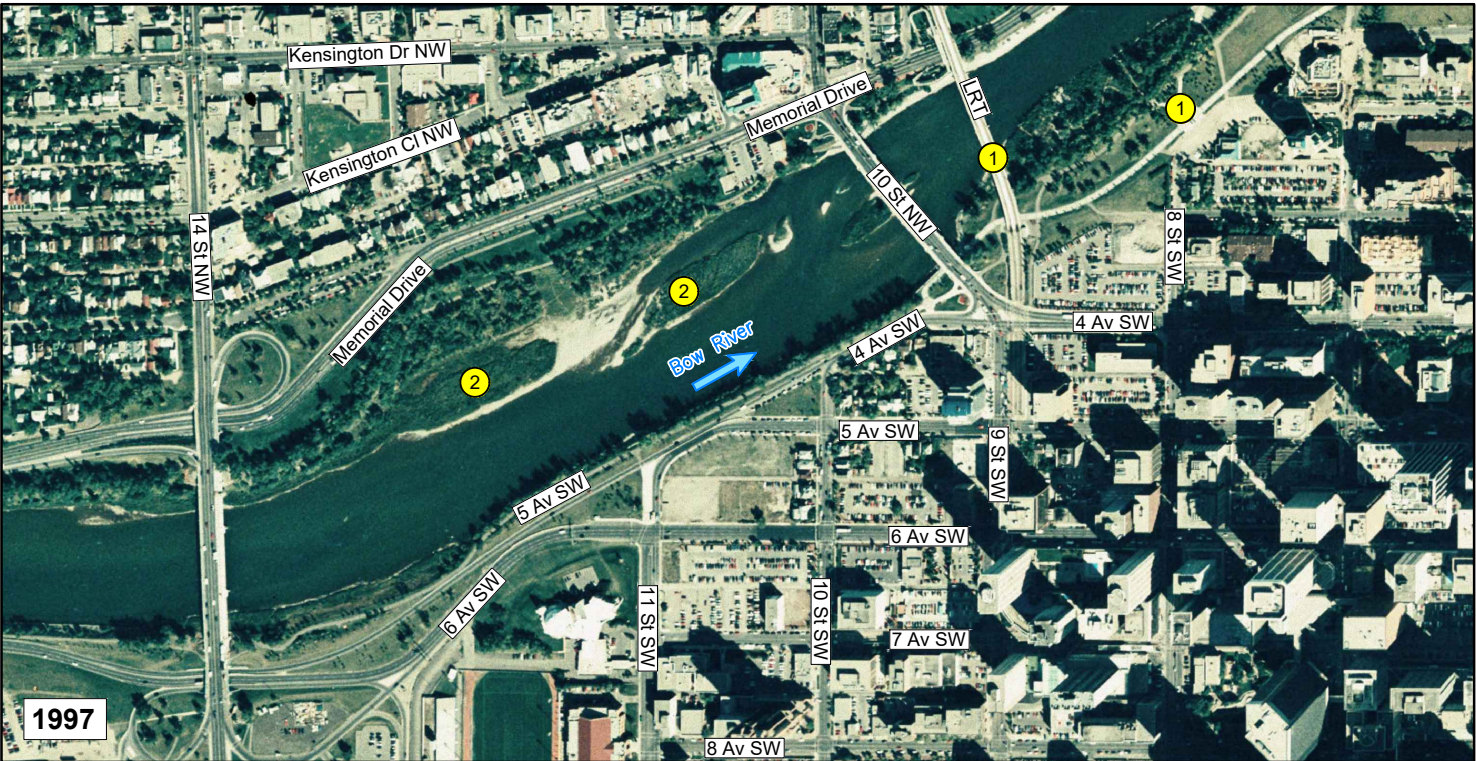


O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

Historical Aerial Photograph Comparison
(1924 - 1984)

Date: May 2025 Project: 34737-522 Submitter: K. Seasons Reviewer: K. Curtis

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Notes:

- 1 Helipad and LRT Bridge in place by 1997.

2 North gravel bars continue to vegetate.

3 Louise Bar well vegetated and has not changed in size since at least 1984.

4 2013 flood cause Louise Bar to enlarge in length and width. Vegetation on the bar was mostly lost during the flood.

5 Vegetation on the north bars was mostly lost or buried in river sediments during the flood.
- 6 Vegetation has re-established on the north bars.

7 Wetland has formed on the north bar since the 2013 flood.

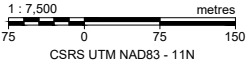
8 Louise Bar has maintained its shape since the 2013 flood, but has been colonized by vegetation.

9 Historical wooden pile wall was exposed in river bed and formed a standing wave after the 2013 flood.

References:

1. Aerial Photographs from the City of Calgary dated September 9, 1997; September 23, 2012; August 11, 2013 and June 26, 29, August 14 & September 16, 22, 2023

Legend
→ Flow Direction



Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

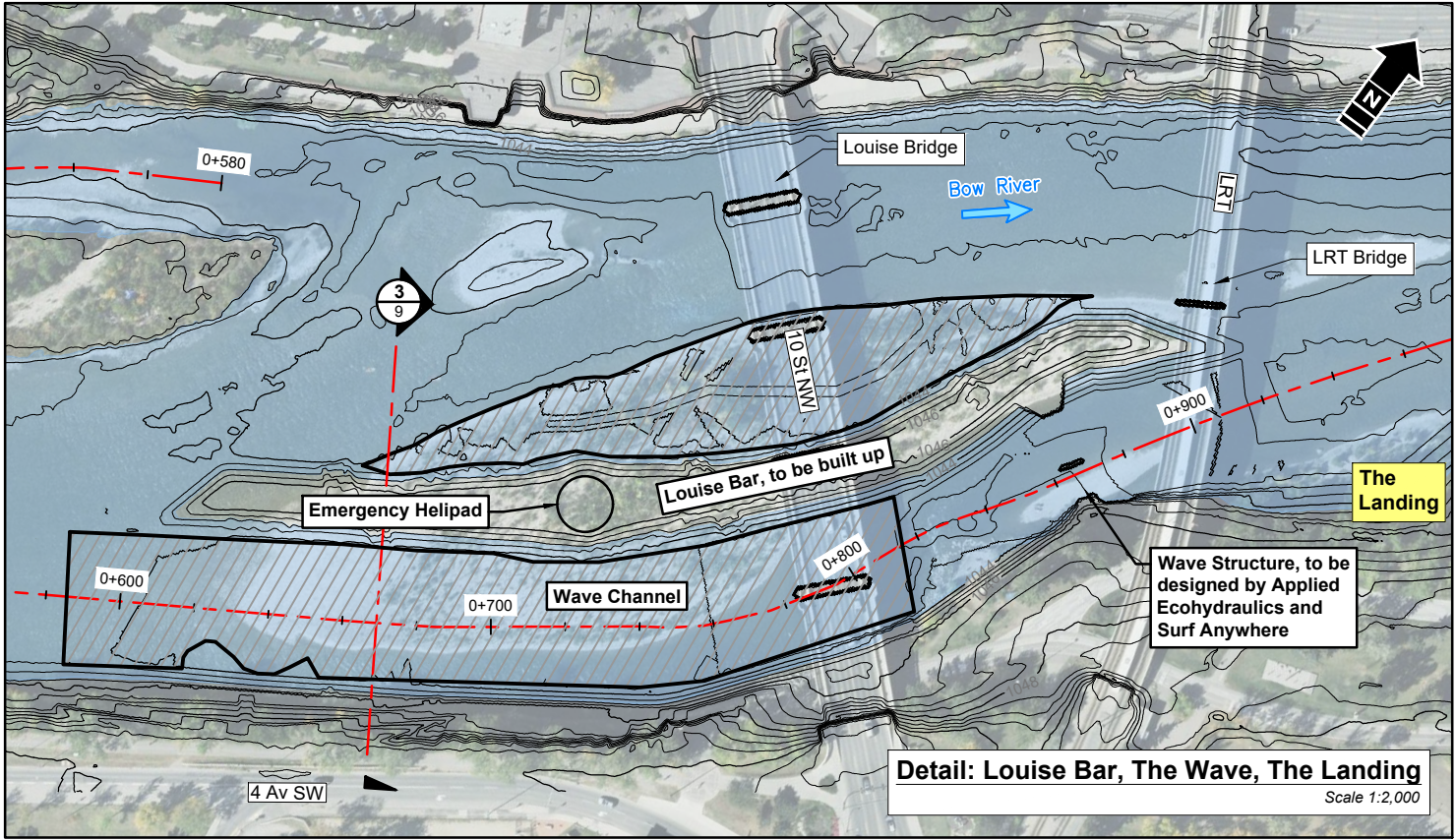
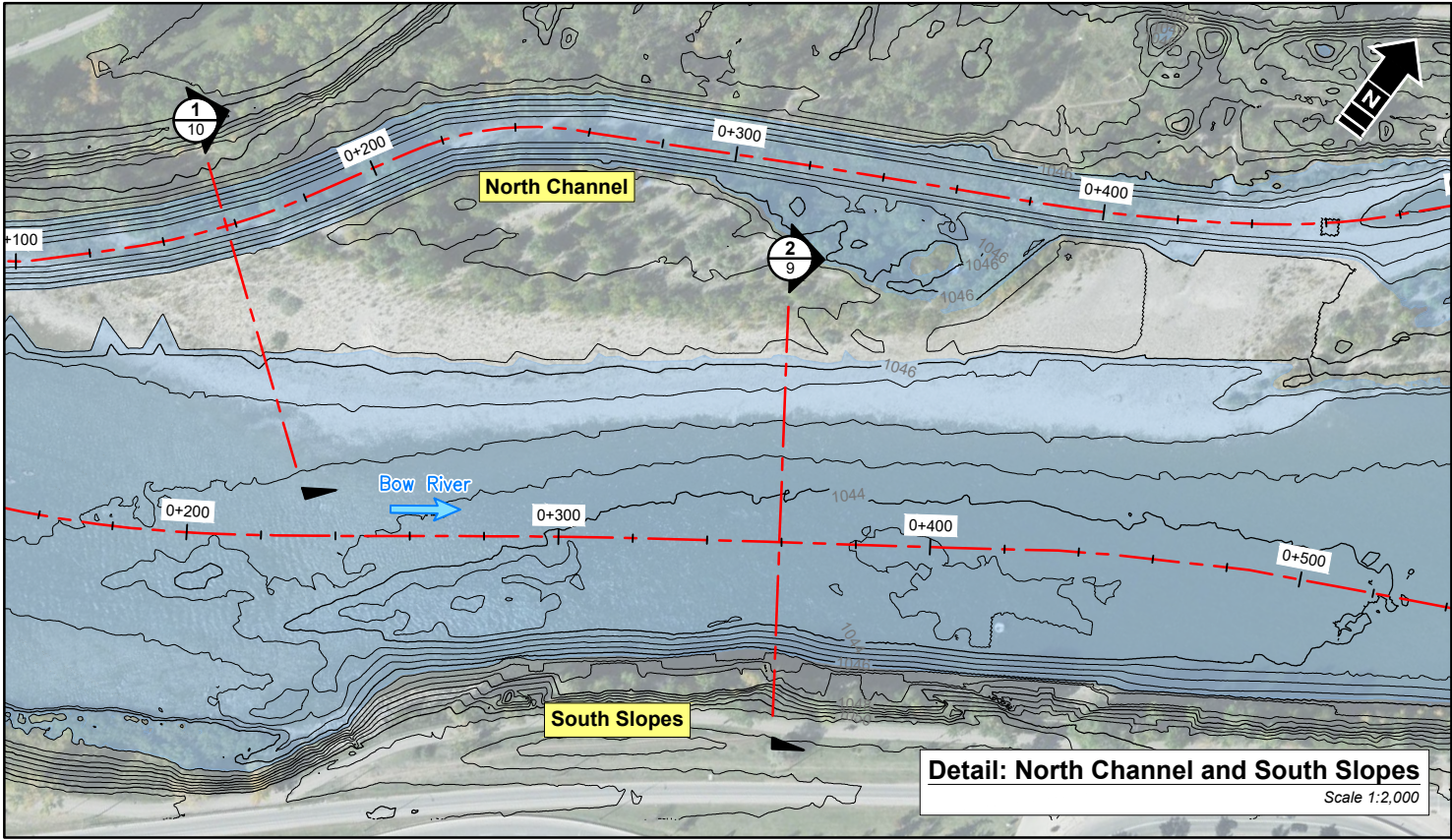
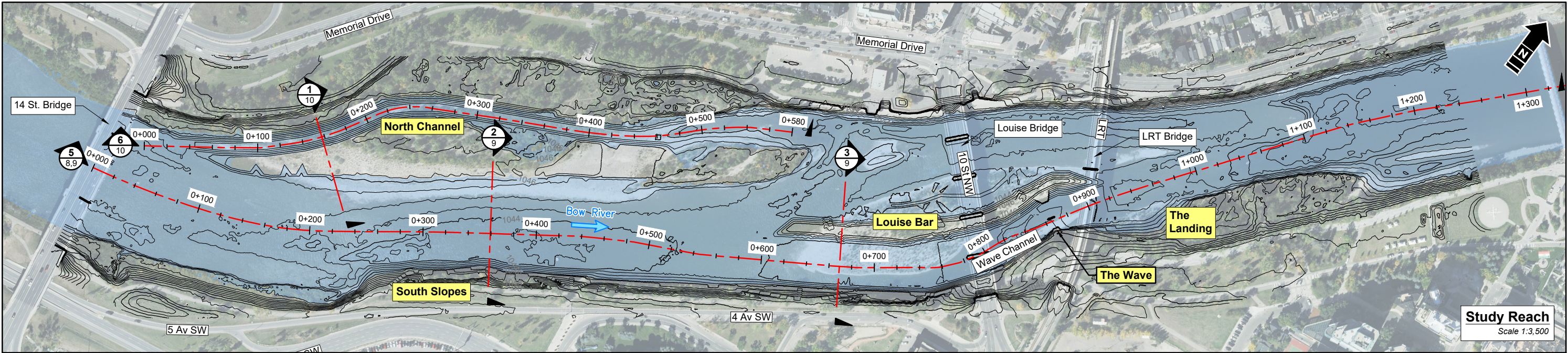
O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

**Historical Aerial Photograph Comparison
(1997 - 2023)**

Date: May 2025	Project: 34737-522	Submitter: K. Seasons	Reviewer: K. Curtis
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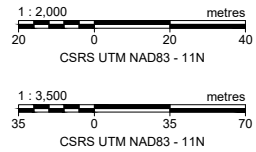
Figure 6



- Legend**
- Flow Direction
 - Node Labels
 - Louise Bar Lowering and Wave Channel Deepening
 - Safe Boating Advisory Boundary (at 280 m³/s). Wave not operational above this flow.
 - Topographic Contour 2.0 m Interval
 - Topographic Contour 0.5 m Interval

- References:**
- Aerial Photographs from the City of Calgary dated June 26 & 29, August 14, September 16 & 22, 2023.
 - Background Model DEM consists of O2 DEM provided on September 30, 2024 and modified by Matrix on November 8, 2024.
 - Safe Boating Advisory water boundary from modified draft Bow and Elbow River Flood Hazard Study (Golder 2020). Modeling was altered by Matrix to incorporate the DEM developed for this project.
 - Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.

The Digital Elevation Model (DEM) was developed with input from The City of Calgary, O2, Applied Ecohydraulics, Surf Anywhere, and Matrix. It incorporates findings from physical modeling by the National Research Council, morphodynamic modeling by the University of Ottawa, and 1- and 2-dimensional numerical modeling. Detailed bathymetry/LiDAR from 2020 provided by the city was modified in HEC-RAS to represent the five nodes in a "proposed hydrotechnical conditions" DEM, which was iterated using the physical, numerical, and morphodynamic modelling. O2 then modified this hydrotechnical DEM to include landscape architecture details not possible to make with the HEC-RAS tools, such as detailed curves and transitions. The DEM represents the 3D design, balancing cut and fill volumes for excavating river sediments (from the North Channel, Louise Bar, and the Landing) and constructing new river features (the South Slopes and the Wave). The DEM represents the proposed final surface extents of the works for this project. The wave structure is included, but will be refined by Applied Ecohydraulics and Surf Anywhere in subsequent design phases.



Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

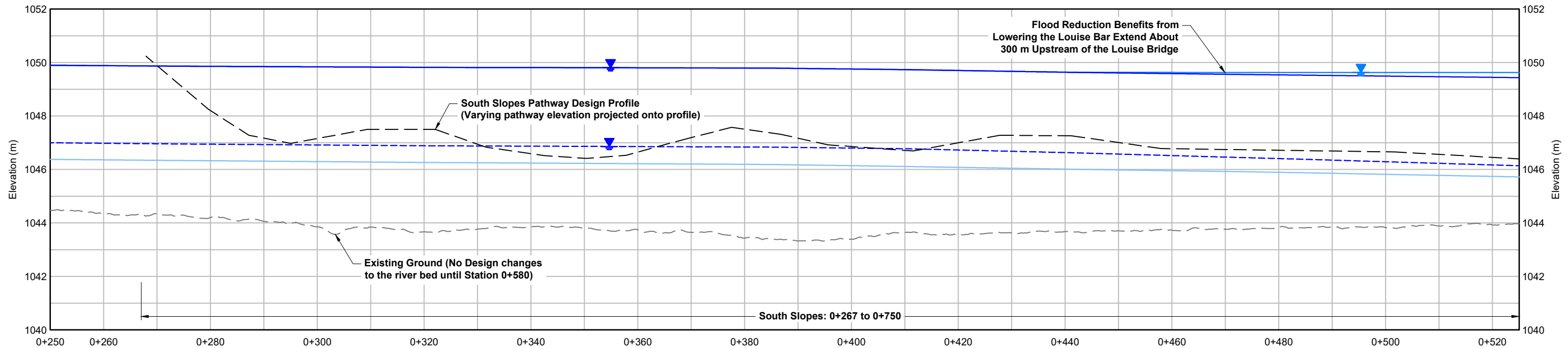


O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

Preliminary Site Plan and Digital Elevation Model

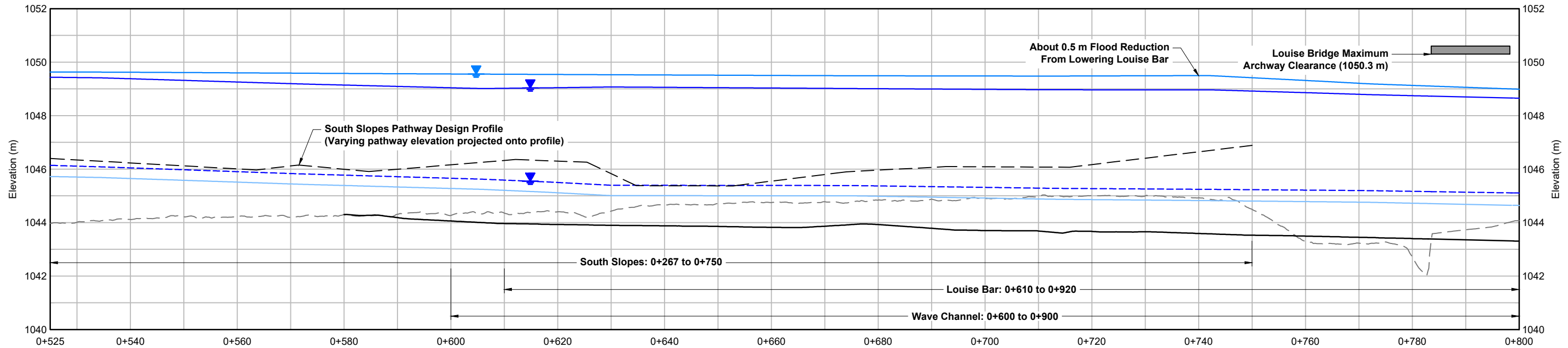
Date: May 2025 Project: 34737-522 Submitter: K. Seasons Reviewer: K. Curtis

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Note:
1. Station 0+000 to 0+250 not shown as no design alterations to the river are proposed upstream of 0+267.

5 Main Channel Alignment - Sta 0+250 to 0+525 (see Note 1)
Horizontal Scale 1:750
Vertical Scale 1:150

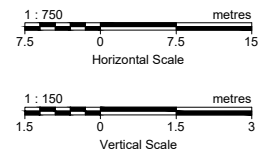


Legend

- 1:100-year Water Level (Before Louise Bar Lowering)
- 1:100-Year Water Level (2,090 m³/s; After Louise Bar Lowering)
- 1:2-Year Water Level (401 m³/s; After Louise Bar Lowering)
- Safe Boating Advisory Water Level (280 m³/s)
- Existing Ground Profile
- Design Profile

References:

- Existing ground profile created from Bathymetry data dated 2020.
- Design profile from O2 DEM provided on September 30, 2024 and modified by Matrix on November 8, 2024.
- Pre-alteration 1:100-year water level and LRT and Louise Bridge clearance elevations from modified draft Bow and Elbow River Flood Hazard Study (Golder 2020). Modeling was altered by Matrix to account for the effects of the vegetated Louise Bar. Post alteration 1:100-year water levels from the same model but using the DEM developed for this project.
- Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.



Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

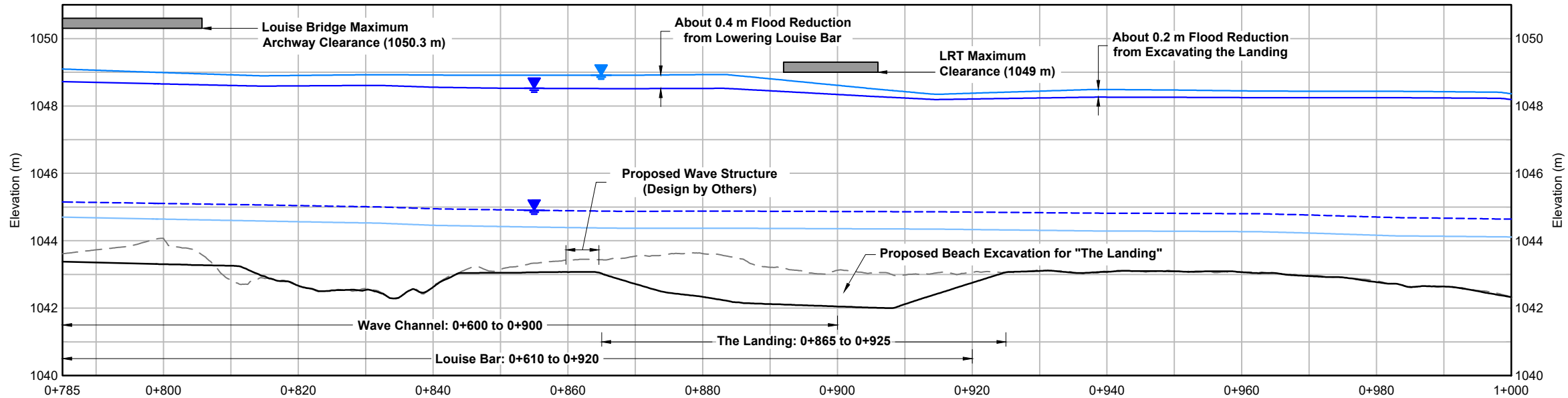


O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

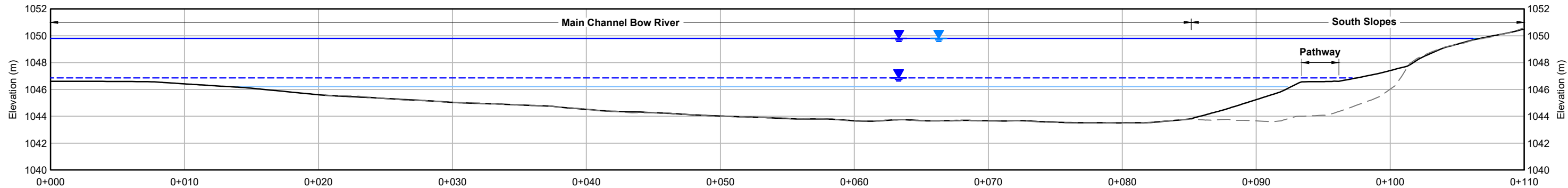
Main Channel Profiles

Date: May 2025	Project: 34737-522	Submitter: K. Seasons	Reviewer: K. Curtis
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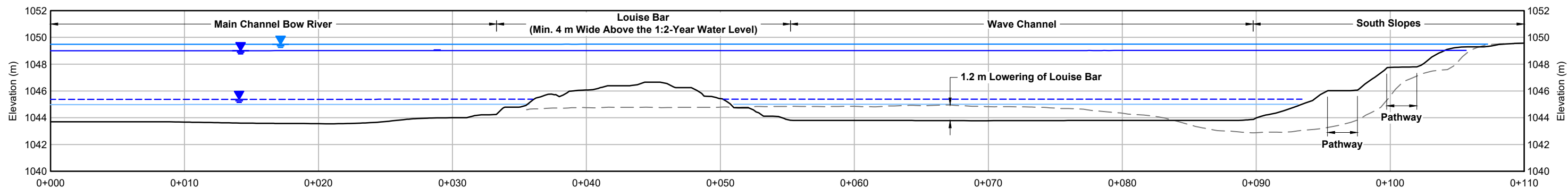
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5 Main Channel Alignment - Sta 0+785 to 0+1000
Horizontal Scale 1:750
Vertical Scale 1:150



2 Section 2 South Slopes
Scale 1:300



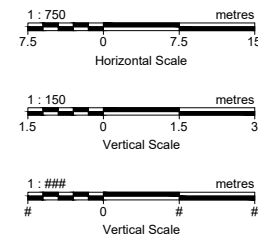
3 Section 3 Louise Bar and Wave Channel
Scale 1:300

Legend

- 1:100-year Water Level (Before Louise Bar Lowering)
- 1:100-Year Water Level (2,090 m³/s; After Louise Bar Lowering)
- 1:2-Year Water Level (401 m³/s; After Louise Bar Lowering)
- Safe Boating Advisory Water Level (280 m³/s)
- Existing Ground Profile
- Design Profile

References:

- Existing ground profile created from Bathymetry data dated 2020.
- Design profile from O2 DEM provided on September 30, 2024 and modified by Matrix on November 8, 2024.
- Pre-alteration 1:100-year water level and LRT and Louise Bridge clearance elevations from modified draft Bow and Elbow River Flood Hazard Study (Golder 2020). Modeling was altered by Matrix to account for the effects of the vegetated Louise Bar. Post alteration 1:100-year water levels from the same model but using the DEM developed for this project.
- Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.



Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

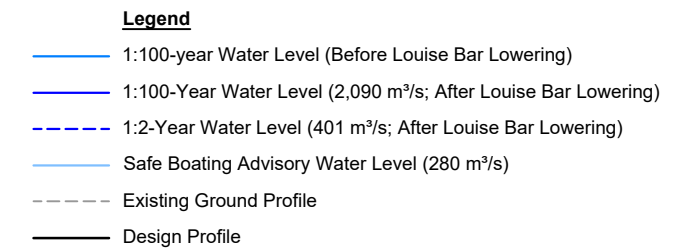
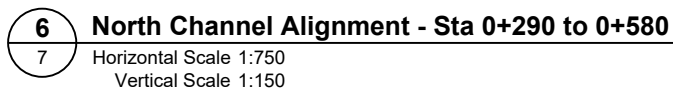
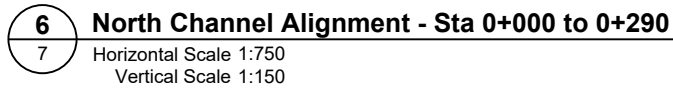


O2 Planning and Design Ltd.
Louise Bar: Bow River Flood Reduction and Recreational Wave

Main Channel Profile and South Slope / Wave Channel Sections

Date: May 2025 Project: 34737-522 Submitter: K. SEASSONS Reviewer: K. CURTIS

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Note: Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

References:

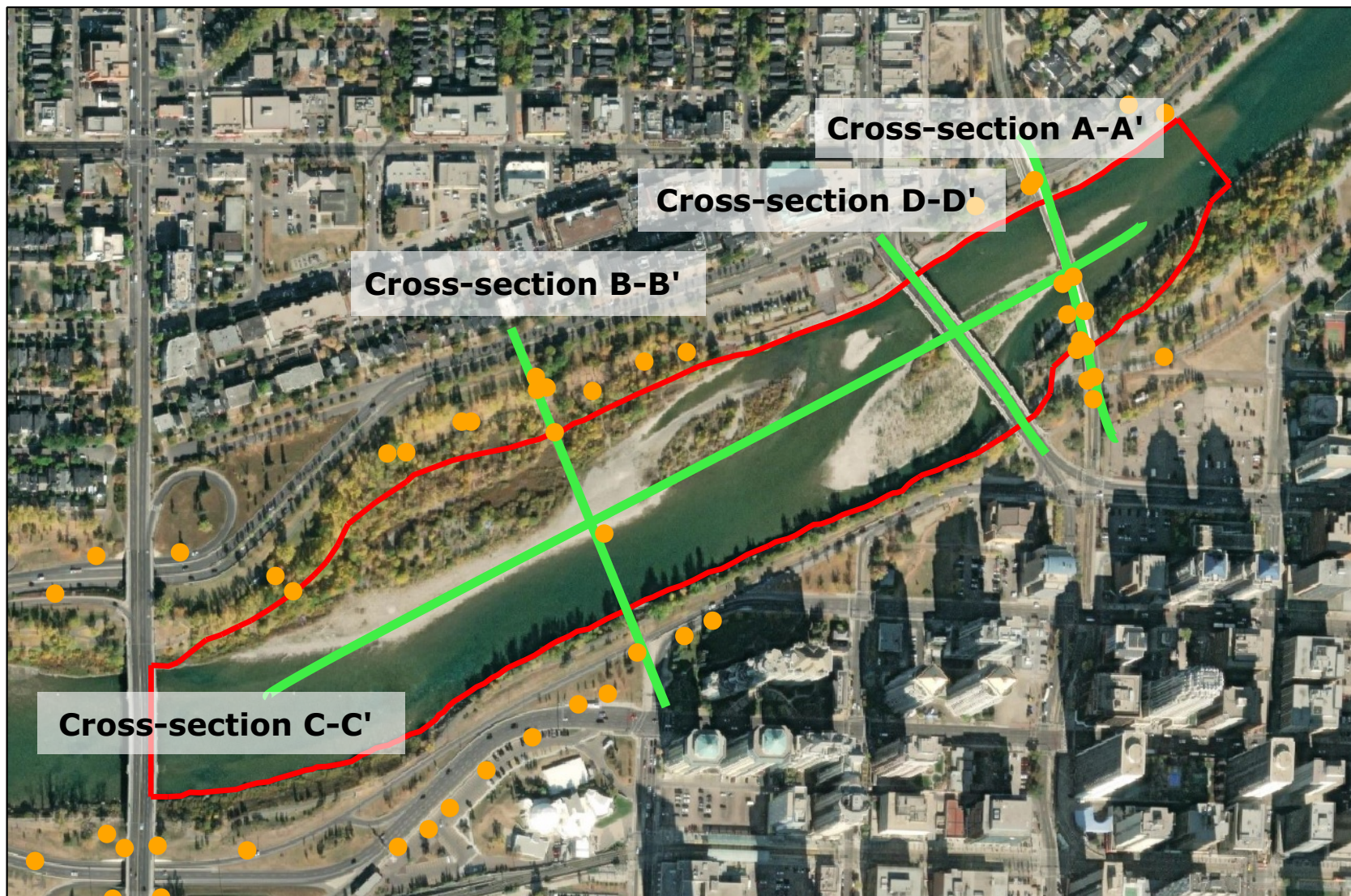
1. Existing ground profile created from Bathymetry data dated 2020.
2. Design profile from O2 DEM provided on September 30, 2024 and modified by Matrix on November 8, 2024.
3. Pre-alteration 1:100-year water level and LRT and Louise Bridge clearance elevations from modified draft Bow and Elbow River Flood Hazard Study (Golder 2020). Modeling was altered by Matrix to account for the effects of the vegetated Louise Bar. Post alteration 1:100-year water levels from the same model but using the DEM developed for this project.
4. Matrix Solutions Inc. operating as Montrose Environmental as of January 1, 2025.

North Channel Profile and Section

Date:	May 2025	Project:	34737-522	Submitter:	K. Seasons	Reviewer:	K. Curtis
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APPENDIX A

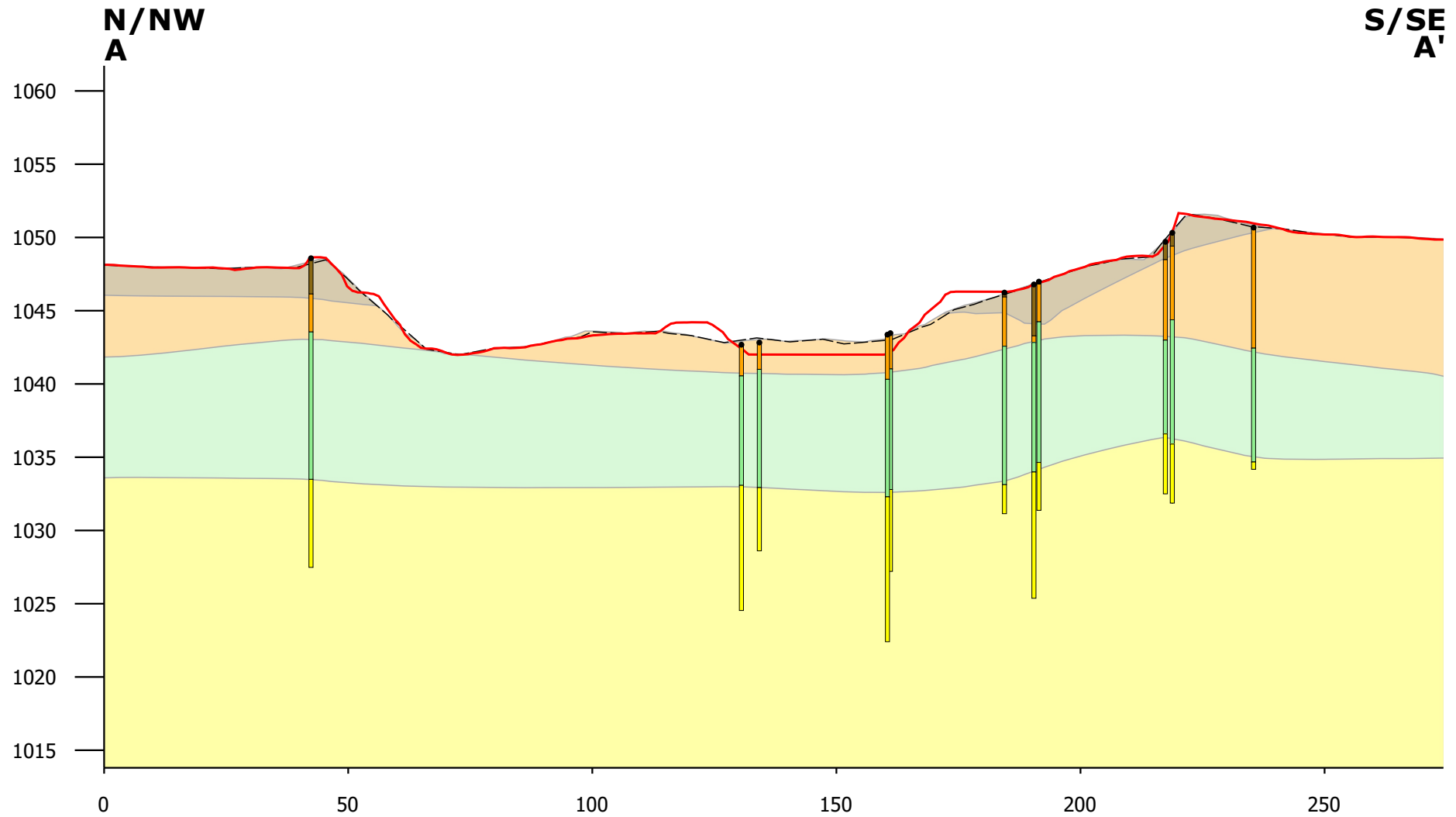
Lithology Mapping

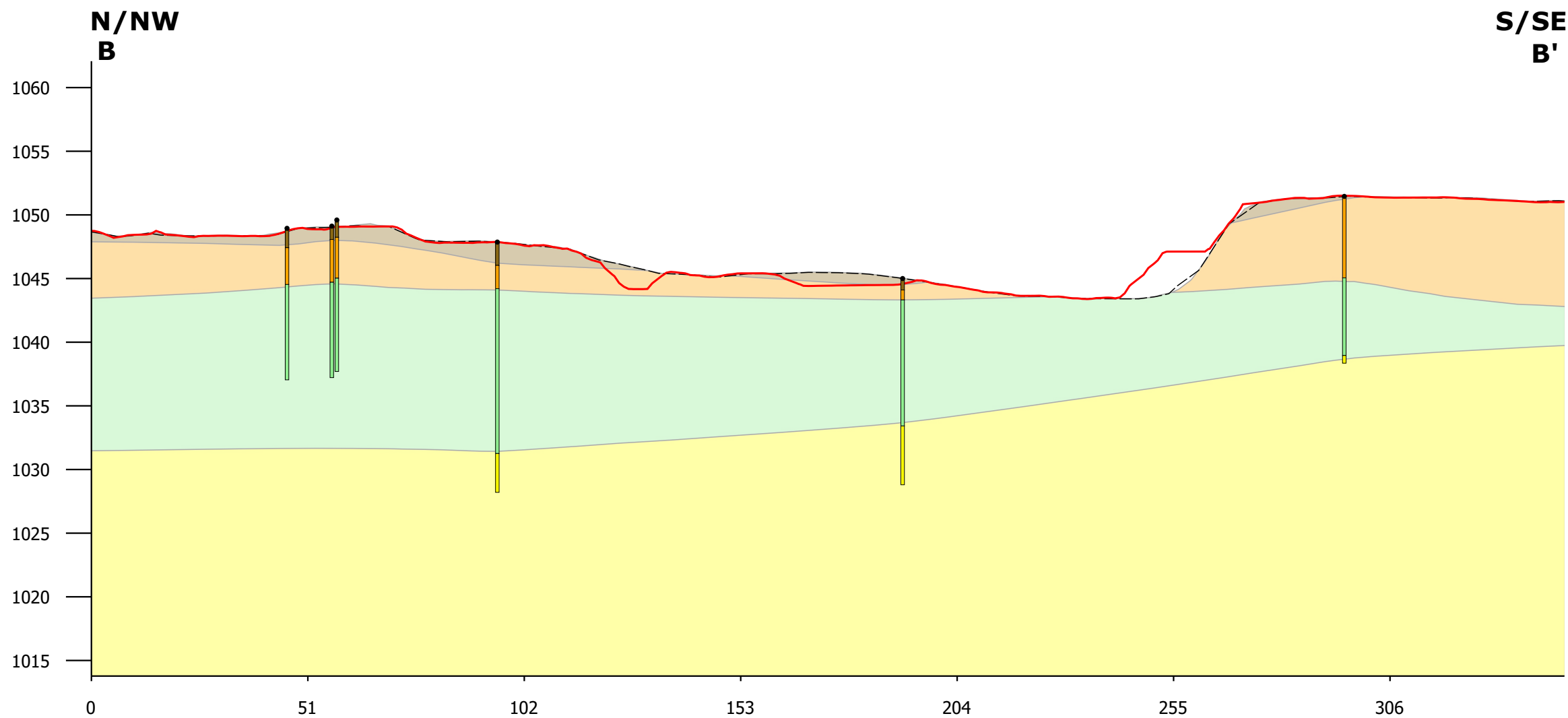


- Section Line
- Study Area
- Borehole

Scale: 1:5,200







Surfaces

- Current Topography
- Proposed DEM

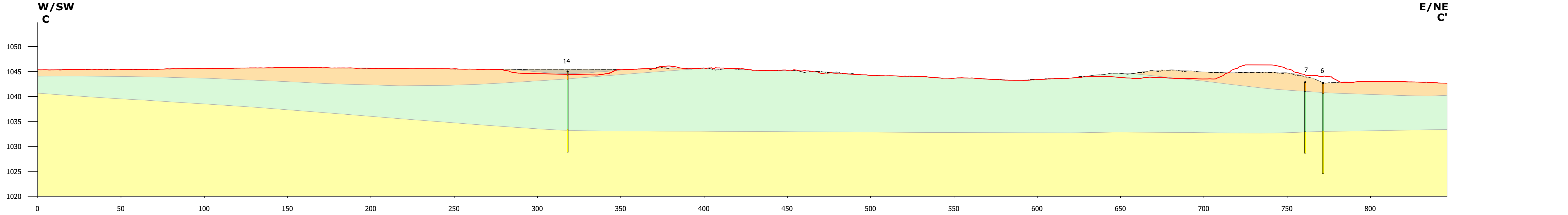
Borehole Lithology / Geologic Units

- | | |
|--|---|
| clay | sandstone |
| gravel | silt/fill |

Scale: 1:1,200

Vertical exaggeration: 3x





Surfaces

--- Current Topography
— Proposed DEM

Borehole Lithology / Geologic Units

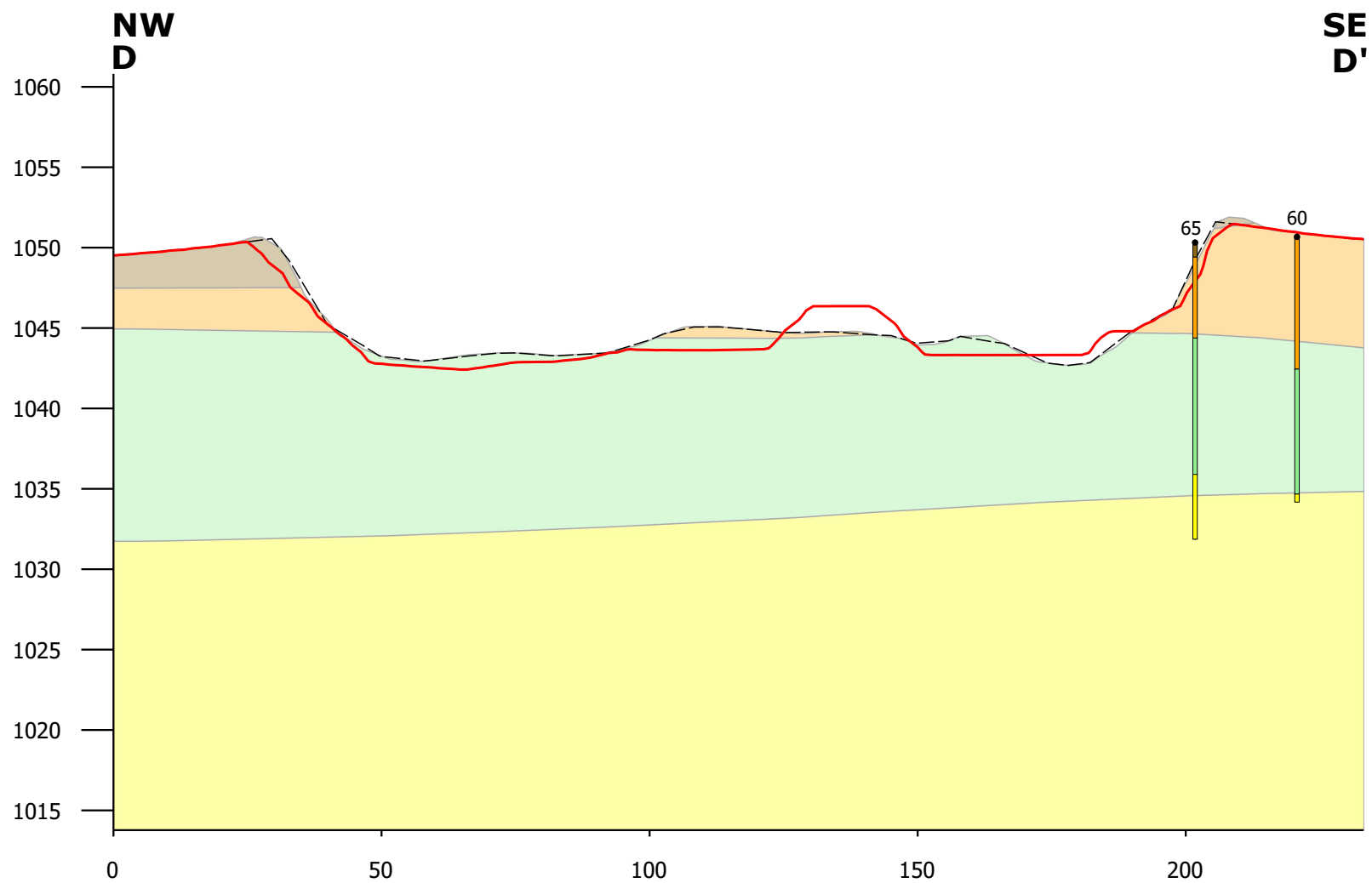
clay sandstone
gravel silt/fill

Boreholes are projected onto the cross-section line from north of the river.
Lithologic contacts dip down towards the river as shown by geologic units.
Projection distances are shown above boreholes.

Scale: 1:1,200

Vertical exaggeration: 3x

0m 50m



Boreholes are projected onto the cross-section line from the north-east.
Lithologic contacts dip up as shown by geologic units. Projection
distances are shown above boreholes.

Surfaces

----- Current Topography
— Proposed DEM

Borehole Lithology / Geologic Units

 clay	 sandstone
 gravel	 silt/fill

Scale: 1:1,200

Vertical exaggeration: 3x

0m  50m