**ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2,
DATED NOVEMBER 18, 2019**

Appendix 15-1 Suspended Sediment Modelling Approach
June 2020

APPENDIX 15-1 SUSPENDED SEDIMENT MODELLING APPROACH

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 15-1 Suspended Sediment Modelling Approach
June 2020

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Suspended Sediment Modelling Approach Report

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

June 2020

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1.0 INTRODUCTION

Alberta Transportation has proposed to construct flood mitigation infrastructure adjacent to Elbow River, approximately 15 km west of Calgary. The purpose of this infrastructure (a key feature of which is the off-stream reservoir that will temporarily retain water) is to divert water during extreme floods (i.e., flows in Elbow River become greater than 160 m^3/s and up to 760 m^3/s) to mitigate flooding downstream.

This technical memorandum summarizes the two-dimensional (2D) modelling approach used to model the effects of the Springbank Off-stream Reservoir Project (the Project) on suspended sediment processes within the model domain. This memo describes how the model was developed to evaluate the effects of the Project on suspended sediment concentration and deposition upstream and downstream of the Project during the 1:10 year, 1:100 year, and the 2013 floods. Late and early release from the off-stream reservoir were also modelled for each flood in order to assess the impacts of temporal variations of water released on suspended sediment concentration and deposition within Elbow River. The updated model was developed in response to information requirements from Alberta Environment and Parks (AEP) and Natural Resources Conservation Board (NRCB). Previous models used three separate model domains:

1. Elbow River
2. diversion structure diversion channel, reservoir and dam outlet
3. low-level outlet channel

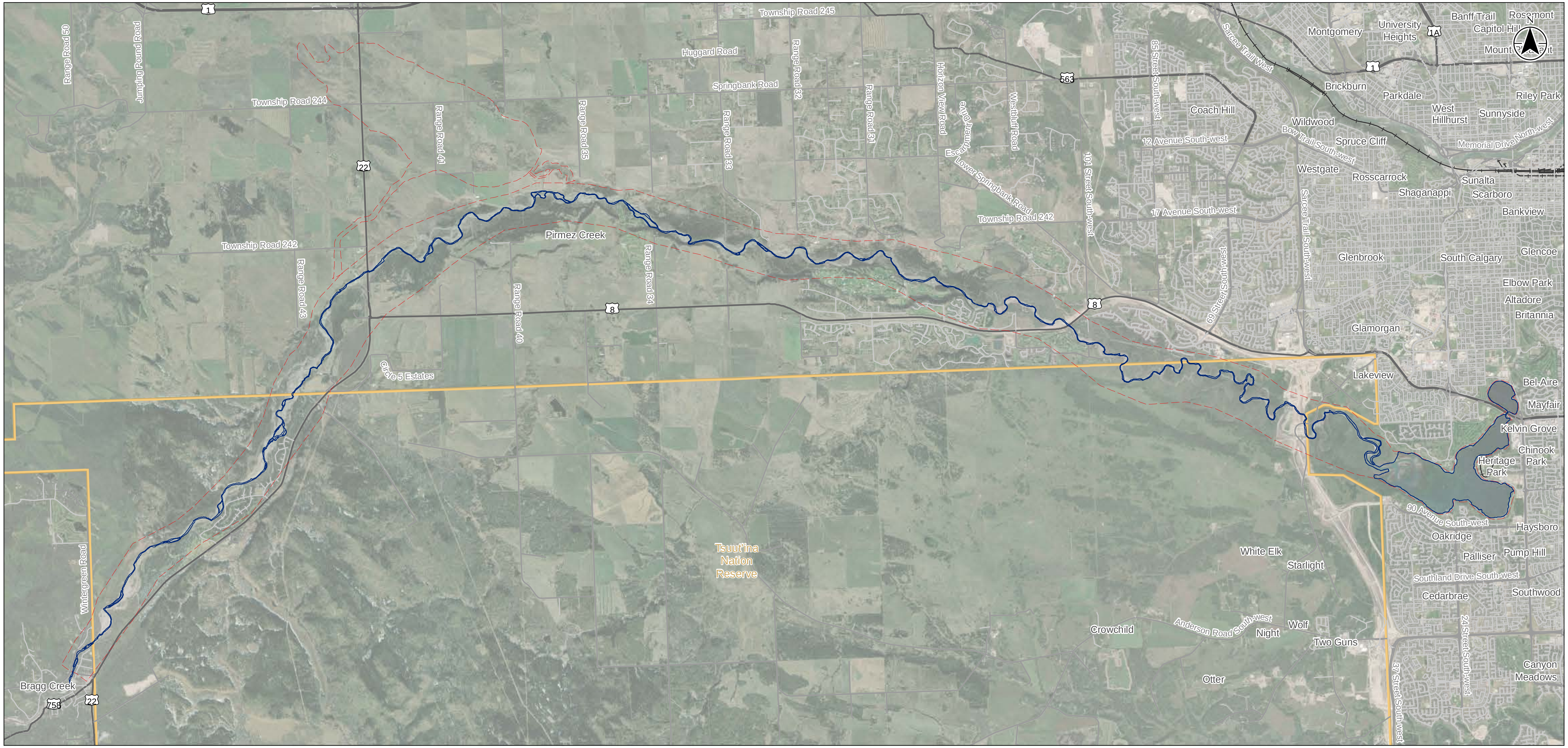
These three model domains are as described in the EIA, Volume 4, Appendix J, Section 2.4.1. The Elbow River domain included the channel only, did not include the floodplain, and was developed based on light detection and ranging (LiDAR). The new model is an improvement on the previous model because it incorporates:

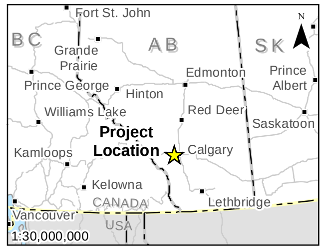
- early and late release options and low-level outlet works drawdown curve
- the floodplain
- updated channel bathymetry
- updated single model domain
- utilization of cloud computing to efficiently run the larger model in the single domain

2.0 MODELLING EXTENT

The model extent includes an approximately 40 km reach of Elbow River, from Bragg Creek to Glenmore Dam. The model extent incorporates the Elbow River channel, the Elbow River floodplain inundated during the 2013 flood, the proposed spillway gates, diversion channel, floodplain berm and the low-level outlet works (LLOW) and the unnamed creek channel and Glenmore Reservoir. Figure 2-1 presents the model extent.

Modelling Extent
June 2020





- Highway
- Road
- Local Street
- Railway
- Tsuut'ina Nation Reserve
- Low Flow Channel
- TSS Modelling Extent

Notes
1. Coordinate System: NAD 1983 UTM Zone 11N
2. Data Sources: Natural Resources Canada

0 0.5 1 1.5 2 2.5 3 km
1:90,000 (at original document size of 11x17)

Project Location
Calgary,
Alberta

Project Number 110773396
Prepared by LTRUDELL on 20200505
Requested by LBURGE on 20200505

Client/Project/Report
Alberta Transportation
Springback Off-Stream Reservoir Project
Sediment Deposition Modelling

Figure No.
2-1

Title
The Project TSS Modelling Extent

3.0 MODELLING APPROACH

3.1 MODEL DESCRIPTION

A 2D hydrodynamic and sediment transport model was utilized to evaluate the effects of the Project on total suspended solids (TSS) during floods The MIKE 21 Flow Model Flexible Mesh (FM) and MIKE 21 Mud Transport Module (MT) were coupled to model hydrodynamics and sediment transport within the model domain. The MIKE 21 FM is a powerful commercial 2D finite volume model that solves the 2D incompressible Reynolds averaged Navier-Stokes equations under the Bossinesq and hydrostatic pressure assumptions. The model consists of continuity, momentum, and density equations and considers a turbulent closure scheme. The MIKE 21 MT module is an add-on module to MIKE 21 FM, which was used to assess suspended sediment transport, erosion, and deposition within the model domain, both with and without the Project. MIKE 21 MT solves 2D governing equations of cohesive sediment equations. The MIKE 21 MT module can include multiple fractions of suspended sediment, including non-cohesive sediment.

3.2 MODELLING SCENARIOS

The purpose of the modelling is to evaluate the effects of the Project on the distribution of TSS and geomorphological changes during 1:10 year, 1:100 year, the 2013 design floods. The model was run with and without the Project. Two release options from the reservoir were investigated:

- Early release refers to the release of water from the off-stream reservoir after the flood peak and when flow in Elbow River is less than 160 m^3/s.
- Late release refers to the release of water from the off-stream reservoir when flow in Elbow River is less than 20 m^3/s.

The low-level outlet gate at the reservoir was assumed to be fully opened during early and late release. To evaluate the effects of release operations of the low-level outlet gate, the 2013 flood for early and late release included additional model runs with the gate being 50% and 75% open. In total, 13 modelling runs were executed. Table 3-1 summarizes the modelling runs.

Table 3-1 Modelling Runs

Run Number	Modelling Scenario	Flood	Release Scenario	Low-Level Outlet Gate Opening
1	Without the Project	1:10 year	N/A	N/A
2	Without the Project	1:100 year	N/A	N/A
3	Without the Project	2013	N/A	N/A
4	With the Project	1:10 year	Early Release	100%
5	With the Project	1:100 year	Early Release	100%
6	With the Project	2013	Early Release	100%
7	With the Project	1:10 year	Late Release	100%
8	With the Project	1:100 year	Late Release	100%
9	With the Project	2013	Late Release	100%
10	With the Project	2013	Early Release	50%
11	With the Project	2013	Early Release	75%
12	With the Project	2013	Late Release	50%
13	With the Project	2013	Late Release	75%

3.3 MODEL SETUP

MIKE 21 FM and MT model set up and assumptions are discussed in the following sections.

3.3.1 MIKE 21 FM

Model Domain

Two model domains were created using the MIKE Zero mesh generator: a model domain without the Project and a model domain with the Project. The model domains include an approximately 40 km long reach of Elbow River, extending from Bragg Creek to Glenmore Reservoir. The model domain includes the extent of the 2013 floodplain. For model domain with the Project, the following are included: diversion inlet and outlet, and reservoir. A combination of unstructured mesh and rectangular mesh was used to create the model domain. The unstructured mesh was used within the channel, floodplain, the reservoir, and Glenmore Reservoir and the rectangular mesh was used within the diversion inlet and outlet to ensure an accurate bathymetry for these features. The model domain, without and with the Project, has 45,967 and 56,723 computational elements, respectively. Figures 3-1 to 3-4 shows model domain without and with the Project (in Alberta reference meridian 114 W coordinate system).

The following two open boundaries were included in the model domains:

- Upstream boundary condition is the flow measured at the Elbow River at the Bragg Creek Water Survey of Canada (WSC) Station (05BJ004).
- Downstream boundary condition is the water level in Glenmore Reservoir.

For the model domain with the Project, the service spillway gates, diversion inlet gates, LLOW, and floodplain berm were included in MIKE 21. This approach allows modelling of a dynamic flood condition by creating more realistic backwater effects due to operation of the floodplain berm and the service spillway gates in Elbow River. Moreover, modelling the inlet and outlet diversion structures allow for the calculation of TSS in the model with fewer assumptions, including the definition of sediment rating curves at the inlet and outlet of the reservoir which are not known. Dike and gate structures were used in the MIKE21 FM to model the hydraulic structures. Inclusion in the model domain of the floodplain areas inundated during the 2013 flood improved modelling of flow conditions, especially for the 1:100 year and 2013 floods, as well as suspended sediment depositional processes.

Once the computational mesh was created, available bathymetric data was used to interpolate bathymetric data points in the MIKE mesh generator and create the bathymetry file required for the model. Attachment A provides a summary of the approach used to process the available bathymetric data. Mesh files are the primary input parameter of the MIKE 21 FM model.

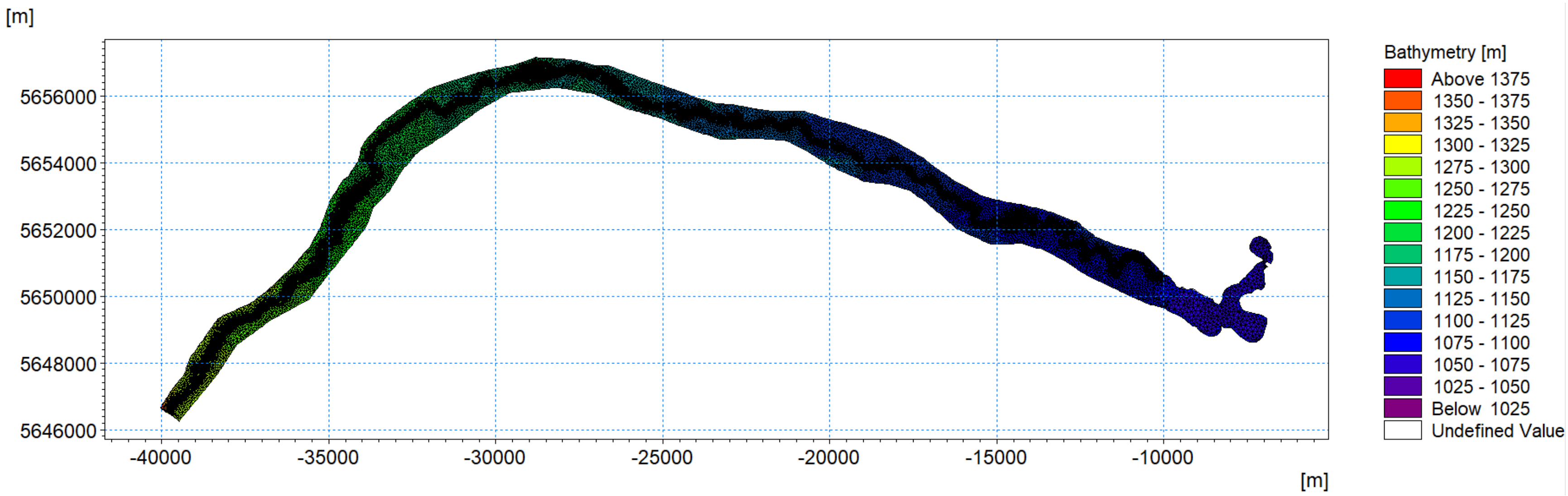


Figure 3-1 Model Domain Without the Project Showing the Location of the Computational Elements (with Computational Mesh)

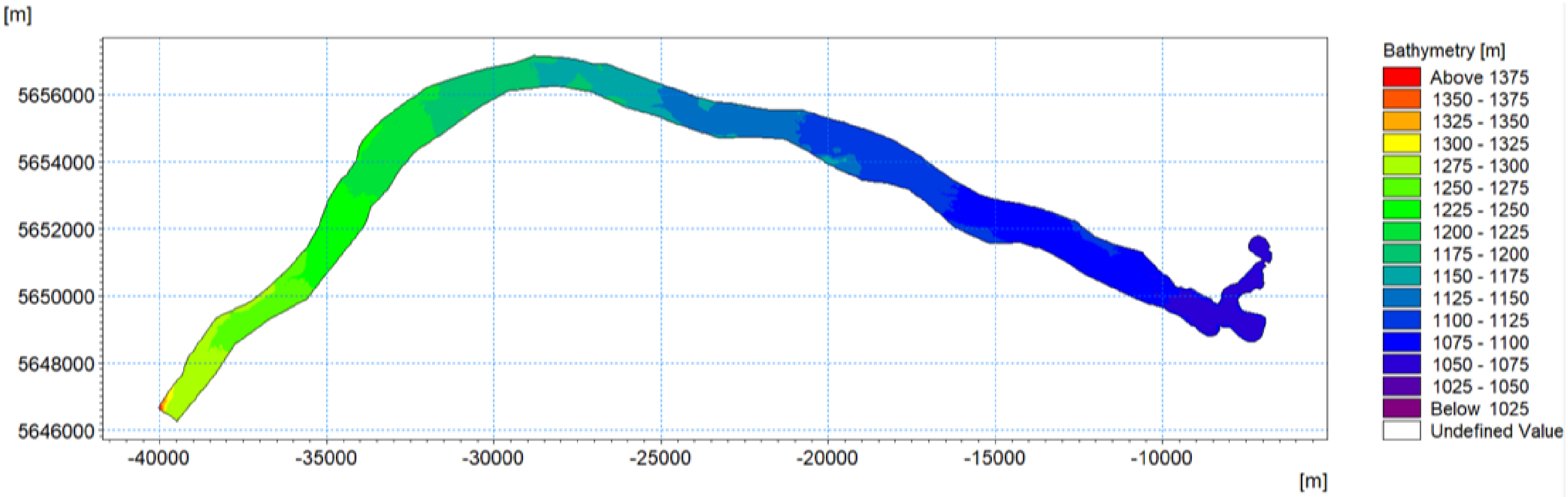


Figure 3-2 Model Domain Without the Project Showing the Location of the Computational Elements (without Computational Mesh)

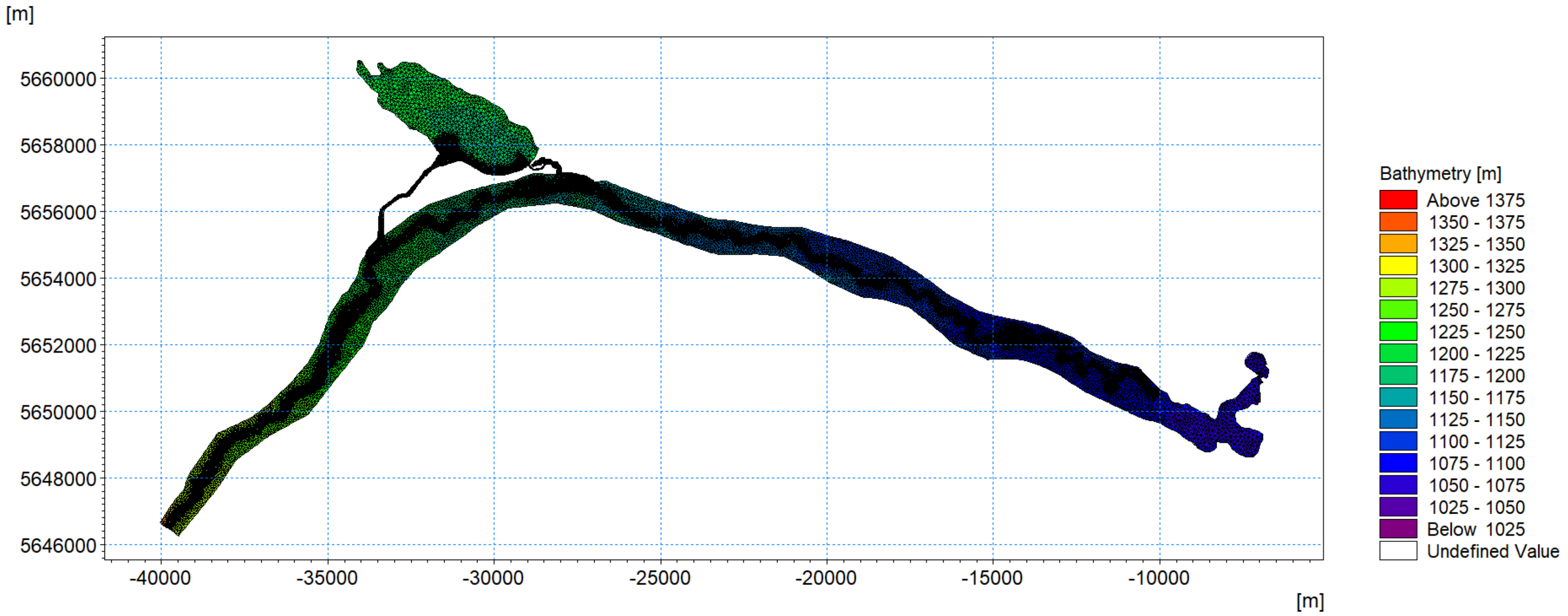


Figure 3-3 **Model Domain with the Project, Location of the Computational Elements (with Computational Mesh)**

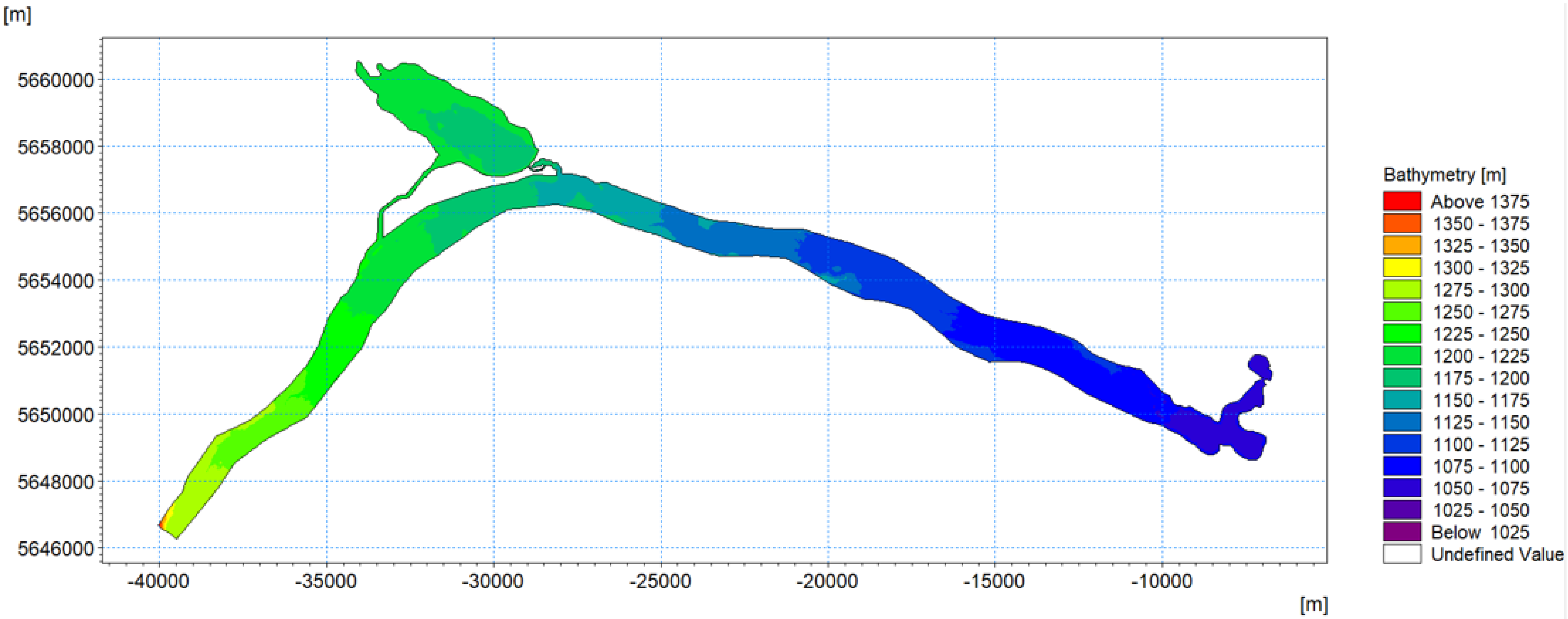


Figure 3-4 Model Domain with Project, Location of the Computational Elements (without Computational Mesh)

Bed Resistance

Bed resistance (M) is another important input parameter to the MIKE 21 FM. MIKE 21 FM uses a reciprocal form of Manning roughness coefficient (n) to represent roughness (M = 1/n). Bed resistance mainly affects hydrodynamic conditions within the river and floodplain. Spatially variable M values were used within the river, floodplain, diversion structures, and reservoirs. Figure 3-5 presents the final M values used in the MIKE 21 FM models. These values were verified during a model validation (see Section 3.4).

Horizontal Eddy Viscosity

Eddy viscosity is used to calculate Reynolds stress components in the shallow water equations. The turbulence model (Smagorinsky 1963) was selected in the MIKE 21 FM to calculate horizontal eddy viscosity at each time step. The required input parameters in MIKE 21 FM is the coefficient of Smagorinsky (C_s), the default value of 0.28 was used in the model (DHI 2019). A sensitivity analysis was conducted to evaluate the sensitivity of the model results to this default value (see Section 3.4).

Hydraulic Structures, Boundary Conditions, and Initial Conditions

The MIKE21 FM upstream and downstream boundary conditions were the hourly flow in the Elbow River and daily water level in Glenmore Reservoir. May 2008 and June 2013 hourly observed flows at WSC Station 05BJ004 were used as the upstream boundary condition for the MIKE 21 FM model to model the 1:10 year and the 2013 flood. The 1:100 year hourly flow hydrograph was obtained from a previously developed HEC-HMS model used in the EIA. Figure 3-6 presents upstream flow boundary condition of the MIKE 21 FM for the 1:10 year, 1:100 year, and design floods.

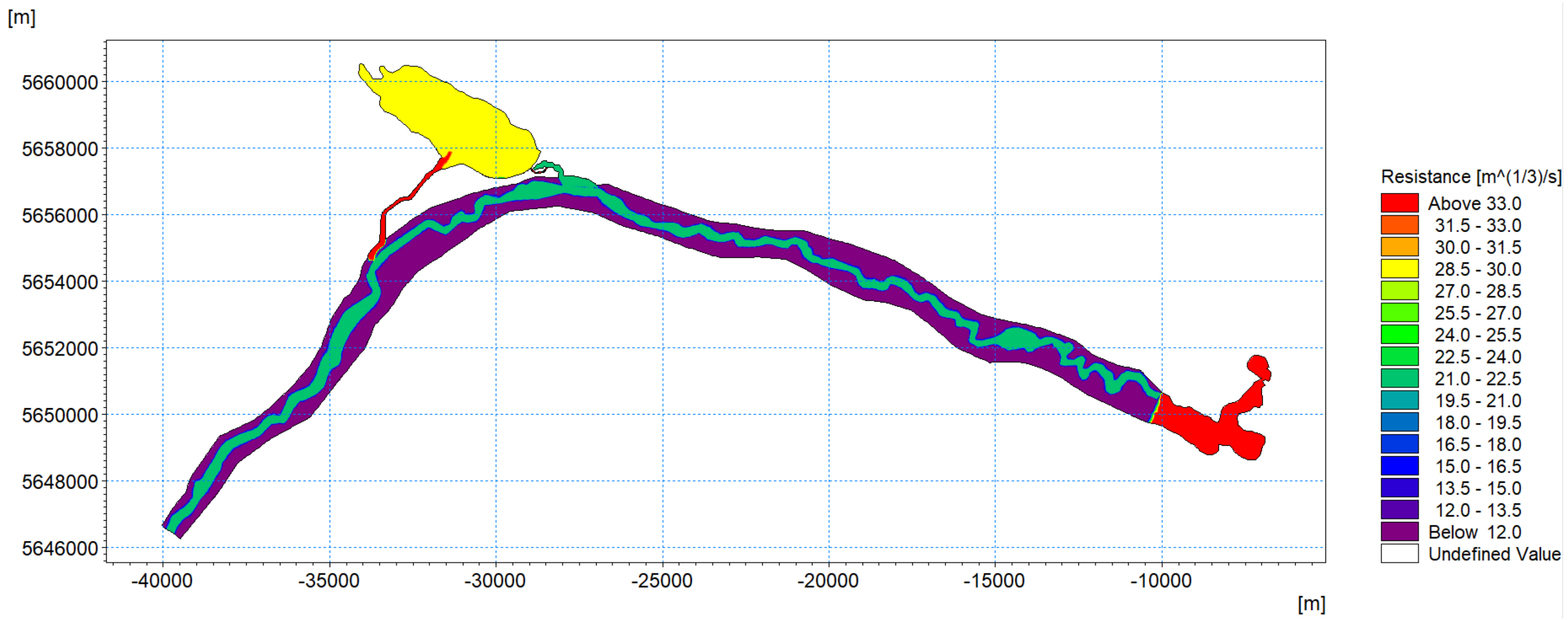


Figure 3-5 Bed Roughness Coefficient Within the Model Domain

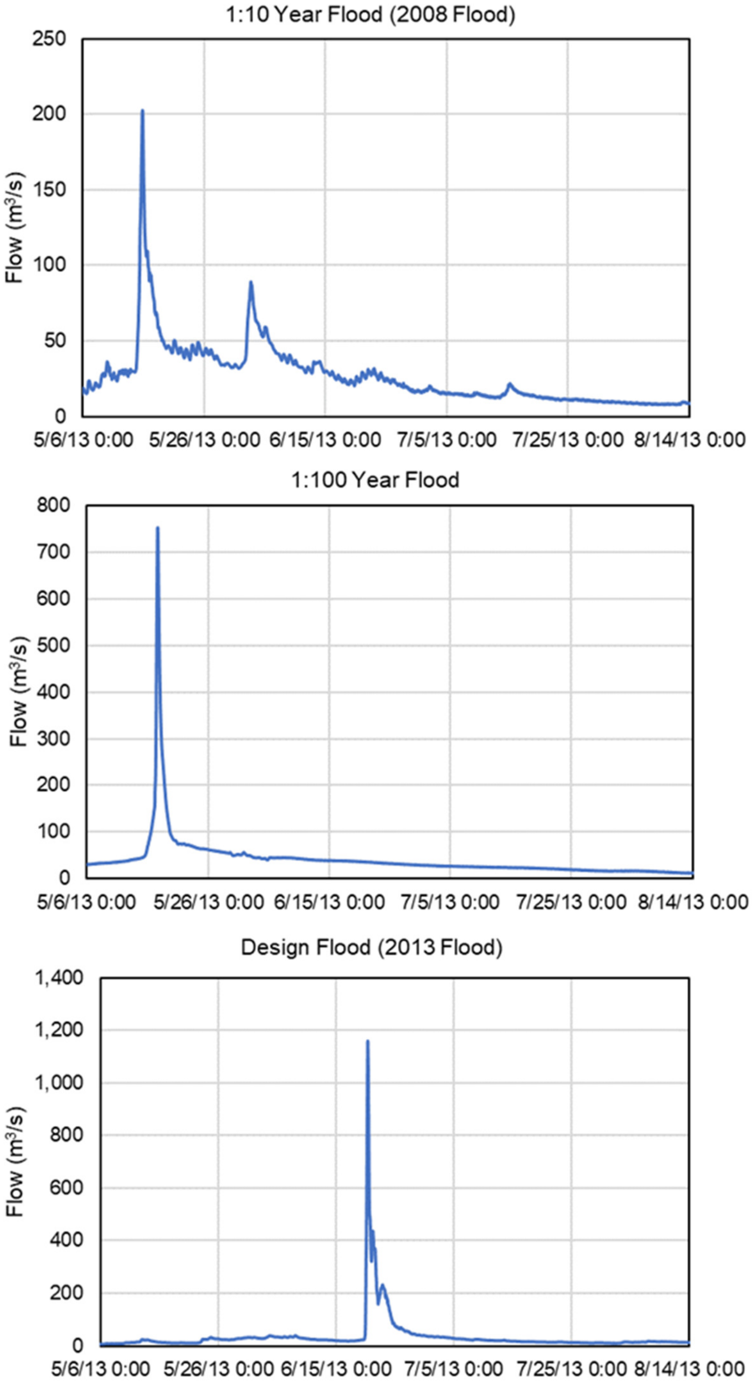


Figure 3-6 MIKE 21 FM Model Flow Boundary Condition

The downstream model boundary condition was daily water level in Glenmore Reservoir. For model runs without the Project, daily water level data was obtained from WSC station 05BJ008 for the 1:10 year (2008 flood) and the design flood (2013 flood). The downstream boundary of the model domain is located at the Glenmore Reservoir outlet. Historical records of water level at this location are available at WSC Station 05BJ008 for the period of 1976 to 2018.

Figure 3-7 presents a histogram of mean monthly, and maximum and minimum daily water levels in Glenmore Reservoir for the period of 1976 to 2018. The maximum water level of 1077.43 m was observed on June 21, 2013 and the minimum water level of 1071.41 m was observed on March 26, 1982. The average daily water level was 1074.83 m for this period.

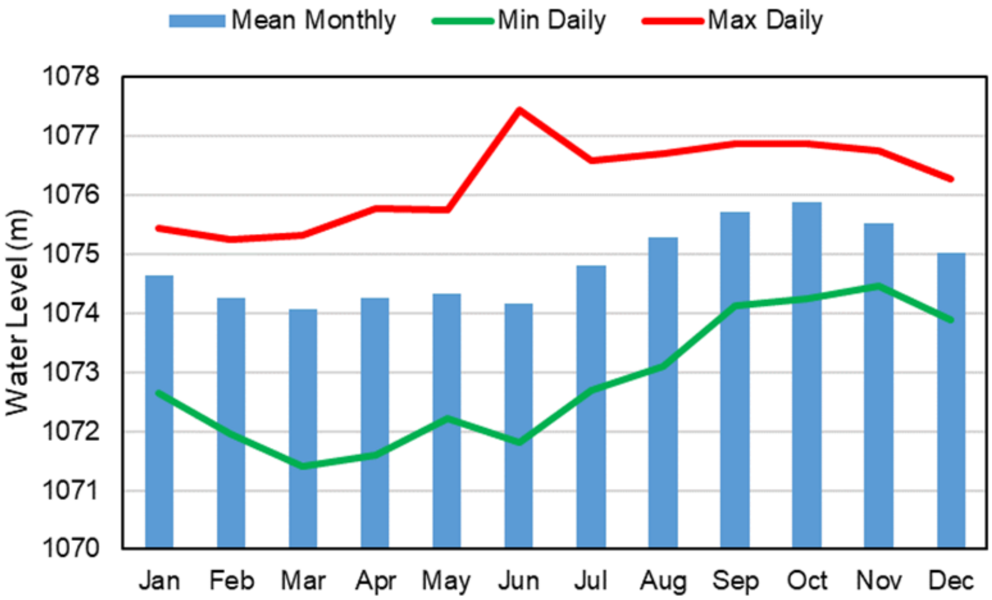


Figure 3-7 **Mean Monthly, and Maximum and Minimum Daily Water Level in Glenmore Reservoir at WSC Station 05BJ008 for the Period of 1976 to 2018**

For model runs, with the Project, and 1:100 year flood, water level in Glenmore Reservoir was calculated using the following reservoir routing equation:

$$\frac{\Delta S}{\Delta t} = I - O$$

where $\frac{\Delta S}{\Delta t}$ is the change in storage in the reservoir, *I* is the inflow to the reservoir, and *O* is the outflow from the reservoir. An hourly hydrograph of the flow downstream of the Project and provided storage-area and Glenmore Reservoir rating curve by the City of Calgary was used to route the reservoir and calculate water level in Glenmore Reservoir for model runs with the Project and the 1:100 year flood.

To evaluate the effects of the Project on hydrodynamics and sediment transport, the Elbow River gates, floodplain berm, diversion inlet gates, and low-level outlet gate were modelled in the MIKE 21 FM. Geometry and location of the hydraulic structures were defined based on the preliminary design drawings. Two gates with a "subset of water column" geometry and a top elevation of 1215 m were modelled at the location of the Elbow River gates. A dike structure was used to model the Elbow River floodplain berm. In addition, dike structures were used to model the diversion inlet and LLOW. Application of dike structures in MIKE 21 allows the user to assign a specific overtopping discharge time series to the structure. Based on the 2019 design criteria flow hydrographs into the diversion inlet and from the outlet diversion were calculated and assigned to the associated hydraulic structures. Figure 3-8 to Figure 3-10 present hydrographs of the inlet diversion and LLOW for the three floods and two releases.

Initial conditions for water surface elevation (WSE) varied spatially within the model domain. Results from initial short runs for a few days were used to create the initial water surface in the model domain. This initial model runs allow the model to start running with a realistic water level distribution within the domain.

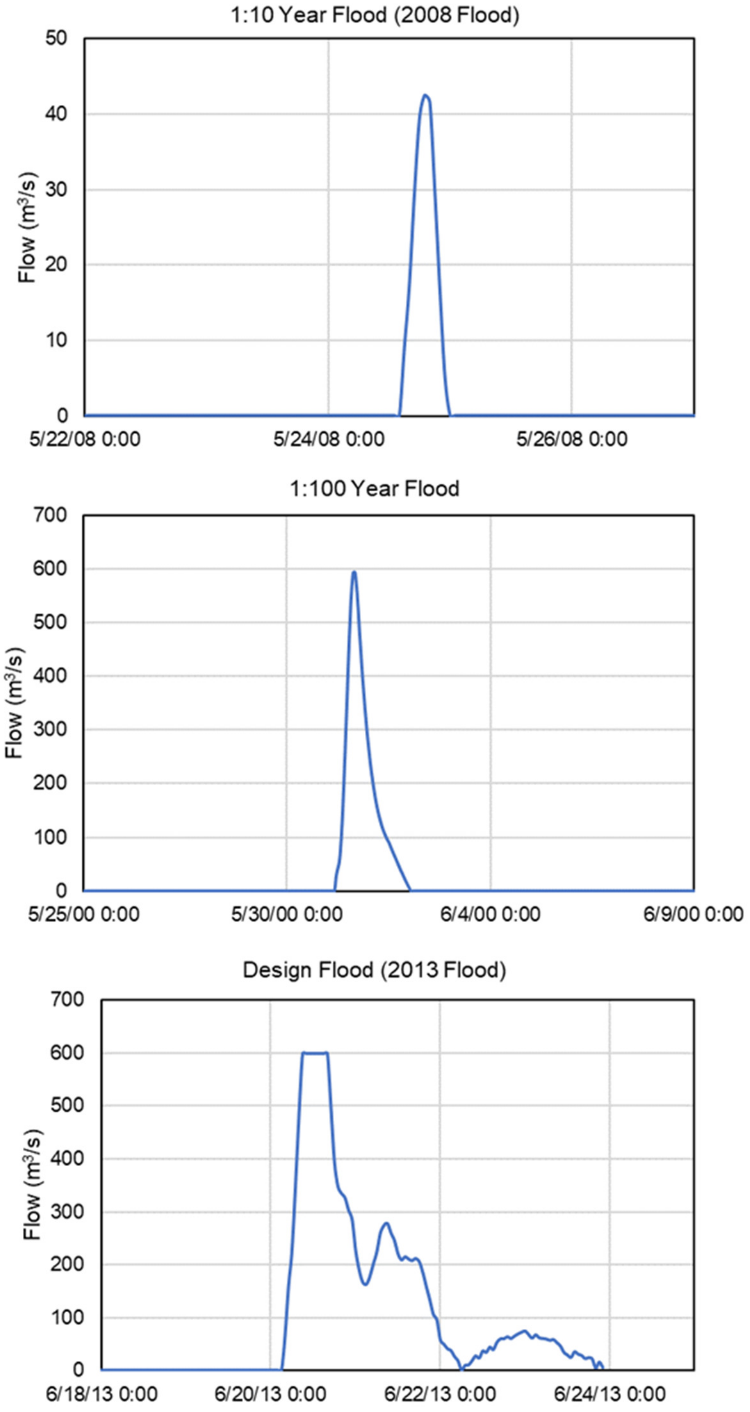
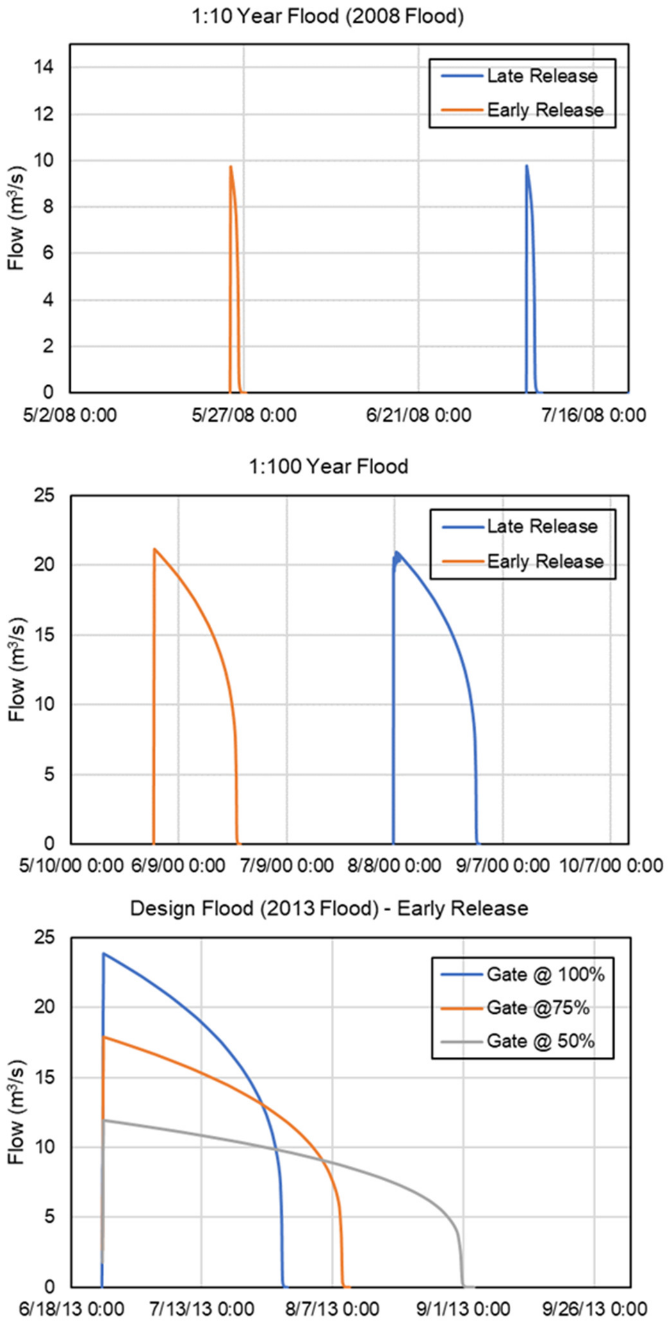


Figure 3-8 Inlet Diversion Hydrographs for the Three Floods



1:10 Year Flood (2008 Flood)

1:100 Year Flood

Design Flood (2013 Flood) - Early Release

Figure 3-9 Early and Late Release Low-Level Outlet Hydrographs for the Three Floods

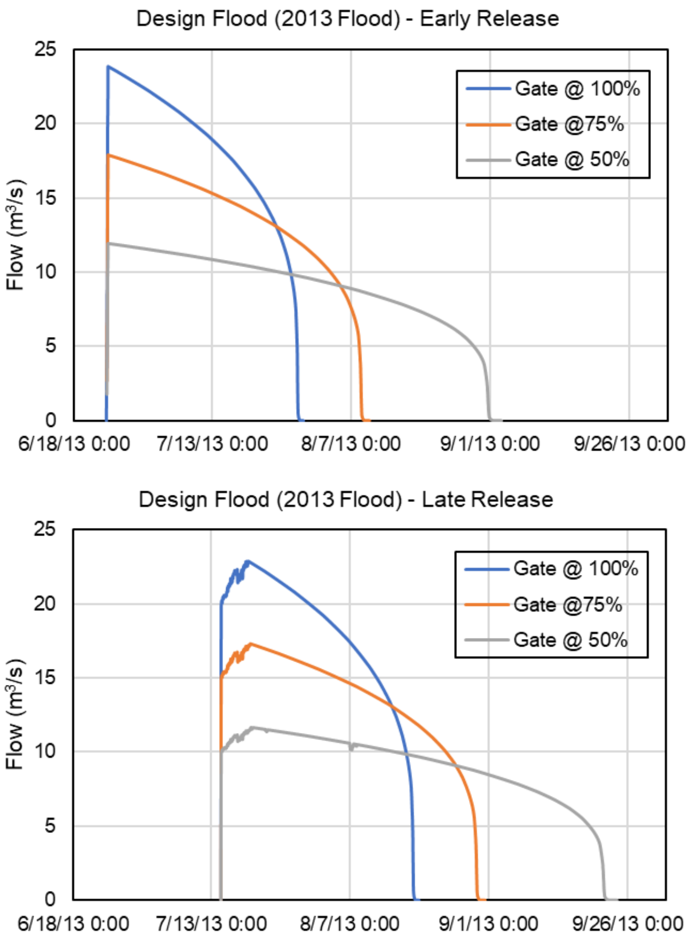


Figure 3-10 Low-Level Outlet Design Flow Hydrographs for Early and Late Release

3.3.2 MIKE 21 MT

The key input parameters to the MIKE 21 MT module were the model boundary conditions, bed erosion parameters, and water column parameters. A rating curve was developed using available the historical record of TSS in Elbow River at WSC station 05BJ004. Figure 3-11 presents developed TSS rating curve at this location. The upstream boundary condition of the MIKE 21 MT model was hourly TSS in Elbow River at Bragg Creek, calculated using the developed TSS rating curve and hourly flow hydrographs used at the downstream boundary of the MIKE 21 FM model. Suspended sediment in Elbow River near Bragg Creek were characterized using a study by Hudson (1983). According to Hudson (1983) suspended sediment consists of 18% clay, 47% silt, and 35% sand fractions with median grain size of 0.002 mm, 0.0205 mm, and 0.1625 mm, respectively. This information was used to develop a sediment boundary condition at the upstream boundary of the model domain. Figure 3-12 shows TSS boundary conditions in Elbow River for the three floods calculated using the TSS rating curve. A Neumann boundary condition was used at the downstream boundary condition in Glenmore Reservoir which uses adjacent computational element values to calculate TSS at the downstream boundary. Water column parameters were settling velocities and deposition characteristics of the suspended sediment. Stokes Law was used to calculate settling velocity of the suspended sediment fractions based on median grain size obtained from Hudson (1983). Bed parameters, including bed critical shear stress and erosion rate, were used in MIKE 21 FM.

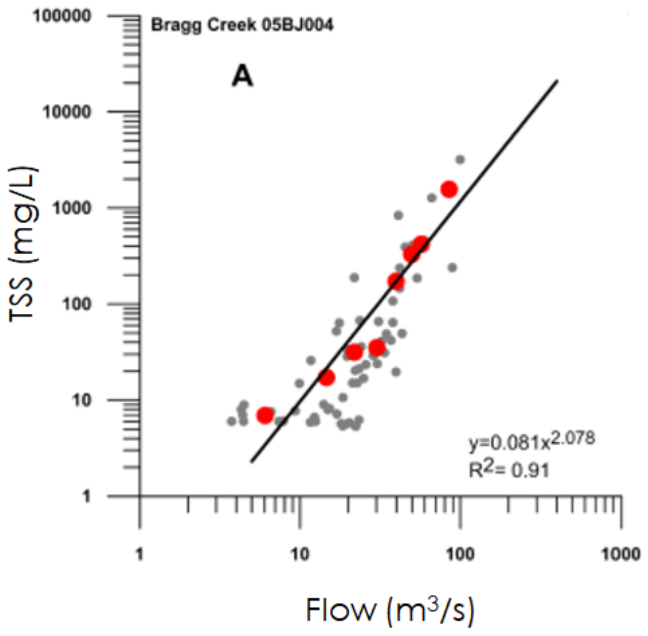


Figure 3-11 Suspended Sediment Versus Flow in Elbow River at Bragg Creek (EIA, Appendix J, Figure 3-12)

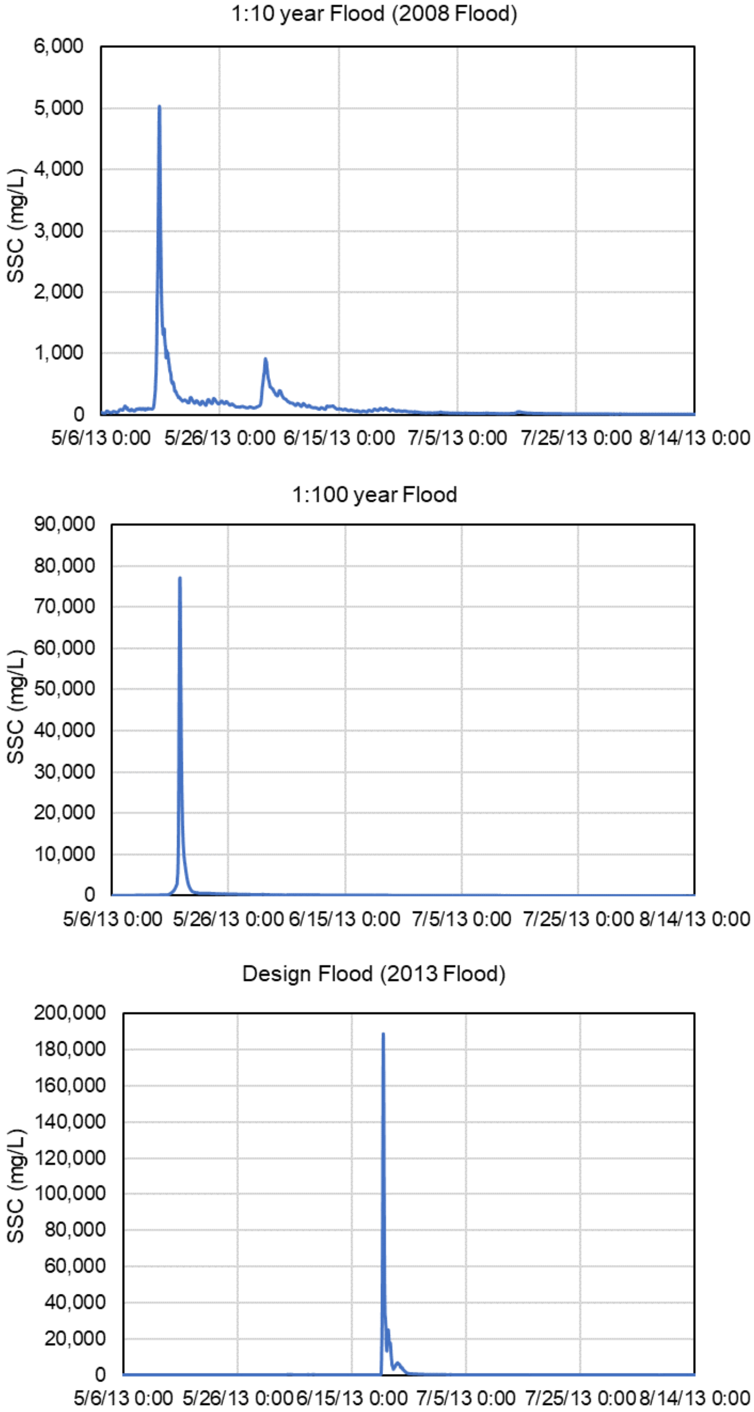


Figure 3-12 **MIKE 21 MT Model TSS Boundary Condition**

3.4 MODEL CALIBRATION, VALIDATION, AND SENSITIVITY ANALYSIS

An unpublished one-dimensional (1D) HEC-RAS hydraulic model, developed as part of the Bow and Elbow River flood hazard program was provided by AEP. Detailed calibration and validation were conducted on the HEC-RAS model to determine the Manning coefficients (n) for the model, which are used to represent bed roughness for high flow events within the floodplain and main channel of Elbow River. For consistency, the new MIKE 21 FM model used the same Manning coefficients as used in the HEC-RAS model. The MIKE 21 FM was validated using the surveyed high-water marks (HWM) as the flood hazard program. The HWMs were surveyed in July 2013 by the AEP to record the HWM due to the 2013 flood. The HWM were surveyed at four locations within the model domain after the 2013 flood. Surveyed HWMs were compared against the modelled peak water levels at the same locations. Table 3-2 and Figure 3-13 summarize the model validation results. As shown in the table and figure there is a good agreement between surveyed and modelled HWMs due to the 2013 flood with a difference less than 1% between the modelled and surveyed HWMs. In addition, Figure 3-13 shows that the fitted trendline to modelled versus surveyed HWM data points has a slope of 1 and coefficient of determination (R^2) of 0.9997, which indicates that the MIKE 21 FM model can produce accurate water levels within the model domain.

Table 3-2 Results of MIKE 21 FM Model Validation to Surveyed 2013 HWM

No.	Coordinates	Surveyed HWM	Modelled HWM	Difference (m)	Difference (%)
1	-11564.844 m E, 5651019.964 m N	1082.50	1082.87	0.37	0.03%
2	-11572.738 m E, 5650943.000 m N	1082.45	1082.85	0.40	0.04%
3	-14324.467 m E, 5652592.561 m N	1092.34	1092.75	0.41	0.04%
4	-16839.274 m E, 5653450.087 m N	1105.83	1105.88	0.05	0.00%

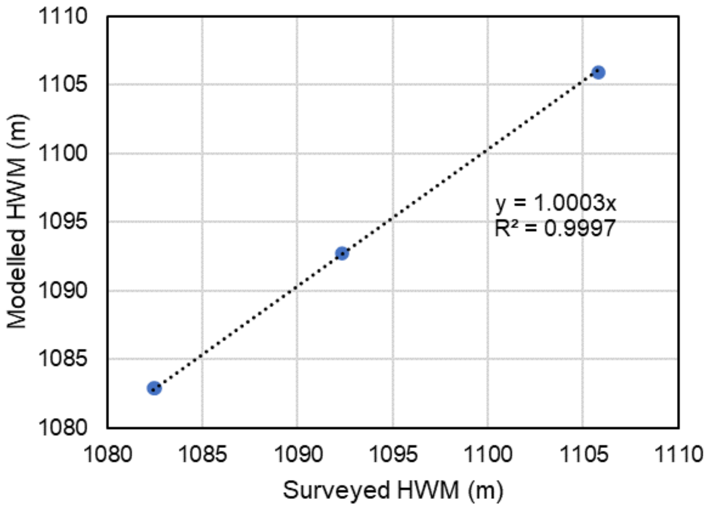


Figure 3-13 2013 Modelled versus Surveyed HWMs

The two main parameters affecting results of the MIKE 21 FM hydrodynamic model are bed roughness and horizontal eddy viscosity. A sensitivity analysis was conducted to evaluate the sensitivity of the model results to bed roughness and horizontal eddy viscosity. The horizontal eddy viscosity affects the turbulence characteristics of the flow in the MIKE 21 FM. The Smagorinsky formulation was used to define the horizontal eddy viscosity as a function of current velocity in the model. The recommended default value of 0.28 (DHI 2019) was used in the model. While previously verified bed roughness coefficients and recommended Smagroinsky coefficients were used in the model, the sensitivity of the model to these two main input parameters was tested.

Main channel *n* and C_s were adjusted ±10% in the model to evaluate the sensitivity of the model to these parameters. The 2013, early release modelling (see Section 3.2) was selected as the baseline scenario to perform the sensitivity analysis. To assess model sensitivity, hourly velocity and water surface elevation time series were extracted at an arbitrary location in Elbow River downstream of Bragg Creek (-38846.642 m E, 5647943.380 m N).

Table 3-3 presents a summary of the sensitivity of the modelled WSE at that location. The WSE is the elevation of the water surface that is predicted by the model. As shown in the table, WSE is more sensitive to bed roughness than the horizontal eddy viscosity. The 10% changes in Cs did not affect the maximum (Max) and average (Avg) WSEs and only changed the minimum (Min) WSE by 1 cm. Increasing and reducing *n* by 10% changed Max WSE by + 7 cm and - 5 cm, respectively; however, Avg WSE only changed ± 1 cm. Figure 3-14 Modelled Water Surface Elevation Time Series modelled scenarios. Overall, changes in WSE were less than 1% and are insignificant.

Table 3-3 Sensitivity of Water Surface Elevation

Modelling Scenario	Max WSE (m)	Avg WSE (m)	Min WSE (m)
Baseline ($n_{channel}$=0.045; C_s=0.28)	1,282.050	1,279.730	1,280.050
$n_{baseline}$ + 10% ($n_{channel}$ =0.05; C_s=0.28)	1,282.120 (+ 0.07 m)	1,279.740 (+0.01 m)	1,280.070 (+0.02 m)
$n_{baseline}$ - 10% ($n_{channel}$ =0.04; C_s=0.28)	1,282.000 (-0.05 m)	1,279.720 (-0.01 m)	1,280.033 (-0.017 m)
$C_{s(baseline)}$ + 10% ($n_{channel}$ =0.045; C_s=0.31)	1,282.050	1,279.730	1,280.051 (+0.001)
$C_{s(baseline)}$ - 10% ($n_{channel}$ =0.045; C_s=0.25)	1,282.050	1,279.730	1,280.049 (-0.001)

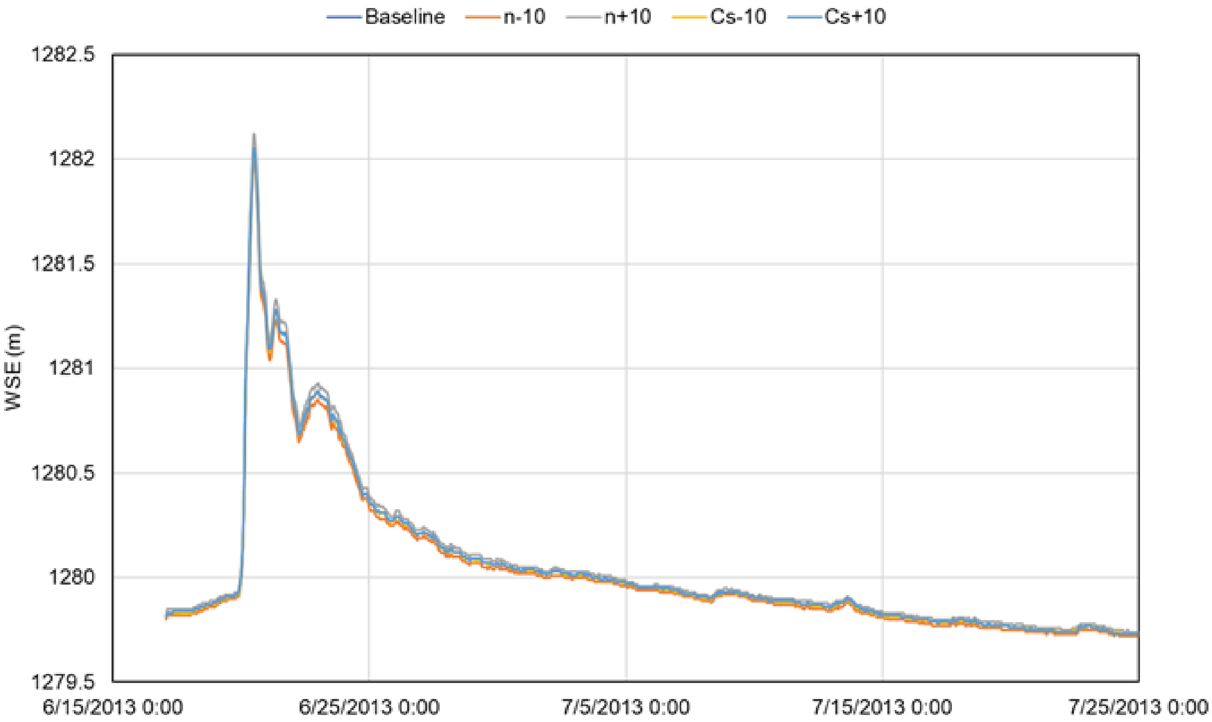


Figure 3-14 Modelled Water Surface Elevation Time Series

Table 3-4 presents a summary of the sensitivity analysis of the modelled velocity at this location. As shown in the table, like WSE, current velocity is more sensitive to bed roughness compared to the horizontal eddy viscosity. The 10% changes in C_s had an insignificant effect on the velocity (less than1%). Whereas, increasing and reducing *n* 10% changed the maximum current velocity by -0.173 m/s and 0.154 m/s, respectively. Also, average velocity changed -0.062 m/s and +0.065 m/s by increasing and reducing roughness coefficient by 10%, respectively. Figure 3-15 presents velocity time series for the modelled scenarios. Overall, velocity is sensitive to change in bed roughness coefficient. A 10% change in *n* resulted in 5% change in the maximum velocity and 9% in the average velocity.

Table 3-4 Sensitivity Analysis of Current Velocity

Modelling Scenario	Max Velocity (m/s)	Avg Velocity (m/s)	Min velocity (m/s)
Baseline ($n_{channel}$=0.045; C_s=0.28)	2.951	0.739	1.158
$n_{baseline}$ + 10% ($n_{channel}$=0.05; C_s=0.28)	2.778 (-0.173)	0.677 (-0.062)	1.066 (-0.092)
$n_{baseline}$ - 10% ($n_{channel}$=0.04; C_s=0.28)	3.105 (+0.154)	0.804 (+0.065)	1.248 (+0.090)
$C_{s(baseline)}$ + 10% ($n_{channel}$=0.045; C_s=0.31)	2.942 (-0.009)	0.737 (-0.002)	1.156 (-0.002)
$C_{s(baseline)}$ - 10% ($n_{channel}$=0.045; C_s=0.25)	2.960 (+0.009)	0.741 (+0.001)	1.159 (+0.002)

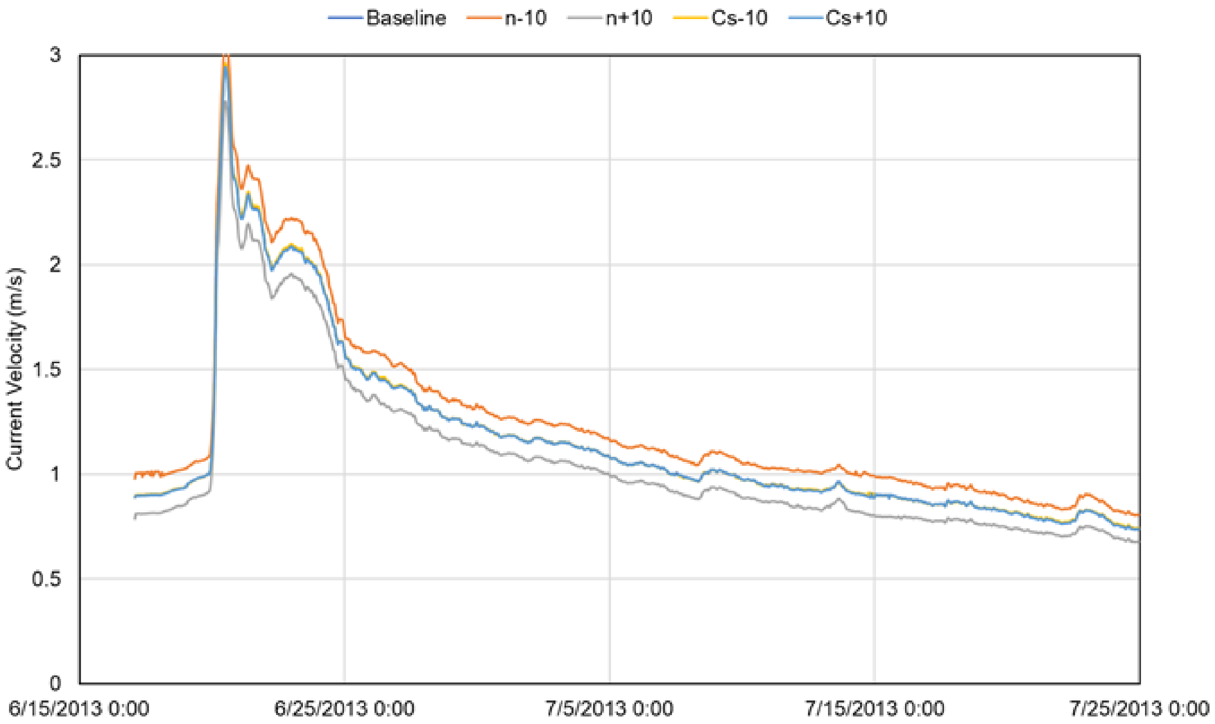


Figure 3-15 Modelled Current Velocity Time Series

4.0 SUMMARY

A 2D hydrodynamic and sediment transport model was developed using MIKE 21 FM and MT models to evaluate the effects of Project on suspended sediment concentration and deposition within Elbow River and potential impacts on Glenmore Reservoir. In total 13 scenarios, including 1:10 year, 1:100 year, and 2013 flood were modelled.

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
SUSPENDED SEDIMENT MODELLING APPROACH REPORT

Summary
June 2020

5.0 REFERENCES

DHI (Danish Hydraulic Institute). 2019. MIKE 21 Flow Model FM: Hydrodynamic Module, User Guide.

Hudson, H.R. 1983. Hydrology and sediment transport in the Elbow River basin, SW Alberta. Unpublished PhD Thesis, The University of Alberta. 344 pp.

Smagorinsky, J. 1963. General circulation experiments with the primitive equations. Monthly Weather Review, 91(3): 99-164.

Attachment A BATHYMETRY SURFACE CREATION

A bathymetry surface was created for Elbow River extending from the headworks of Glenmore Reservoir upstream to the town of Bragg Creek. The bathymetry surface was used as an input into a two-dimensional (2D) hydraulic and sediment model in MIKE 21C. Data used to construct the bathymetry surface comprised:

- Surveyed cross sections collected by Alberta Environment and Parks (AEP) between October 2015 to August 2016.
  - Only survey points matching the description stream bottom and water level were used. Stream bottom is defined as a survey point below the water line and water level as a survey point where water meets the bank.
- Bathymetry contour data from Klohn Crippen Berger (KCB) captured post-flood 2013 conditions.
  - Contour data was provided as polylines at 0.5 m vertical interval.

The extent of the bathymetry surface that was created can be seen in Figure A-1.

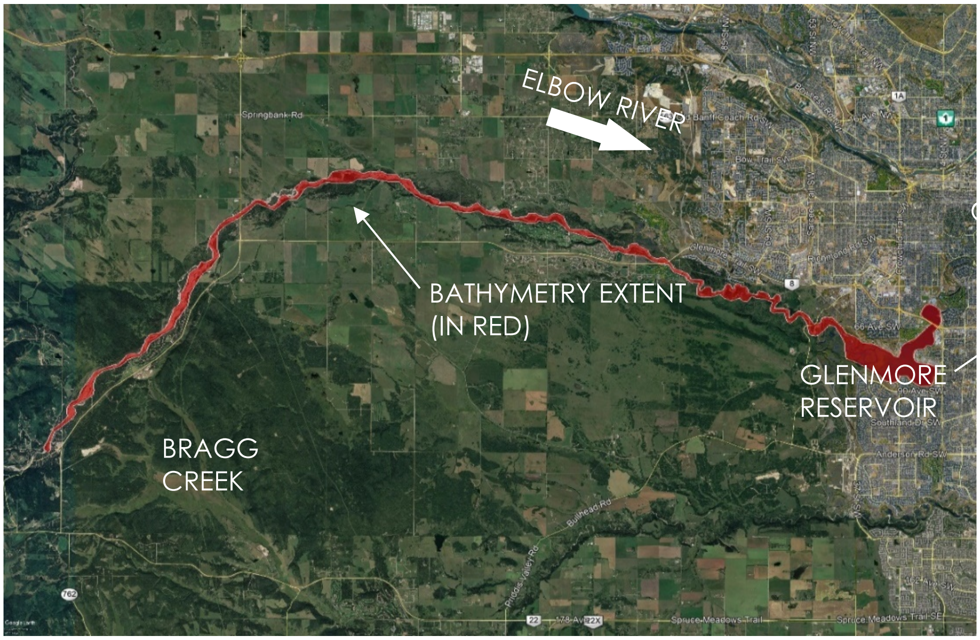


Figure A-1 Extent of Bathymetry Surface

The continuous bathymetry surface was created using Autodesk Civil 3D 2019 (Civil 3D). The process used in the creation of the bathymetry surface is outlined here:

1. AEP's survey points were imported into Civil 3D as coordinate geometry (COGO) points.
2. Water level points surveyed along the left bank, right bank and islands of Elbow River were linked together with a three-dimensional (3D) polyline, establishing a rough outline of the watercourse. Due to the limited water level points, 2016 aerial imaging and light detection and ranging (LiDAR) were used in determining the location of additional vertexes to better establish water's edge. The additional vertexes maintained the surveyed grades.
3. The thalweg of the watercourse was developed by drawing a continuous 3D polyline connecting the deepest stream bottom points throughout the study area. Due to the limited stream bottom points, the 2016 aerial and LiDAR were used to determine the location of additional vertexes along the thalweg.
4. Civil 3D Surface Creation Tool generated surfaces from data inputs such as COGO points and 3D polylines. The bathymetry surface was generated using the COGO points and 3D polylines produced in steps 1 to 3. The generated bathymetry surface required minor modifications such as:
    a. surface triangles created outside the water level 3D polyline were deleted
    b. surface triangles within the water level 3D polyline were swapped to ensure a continual downstream slope of Elbow River
5. Compared to AEP's survey points, KCB's bathymetry contour data provided more in-depth detail of Glenmore Reservoir's bathymetry. The bathymetry contour data provided by KCB was added to the bathymetry surface.

In order to produce an adequate MIKE 21C model that predicts impacts of the Project on Elbow River, the bathymetry surface was incorporated into the 2016 LiDAR image. The bathymetry surface was exported from Civil 3D as a geotiff, a format compatible with ArcGIS, at a grid spacing of 0.5 m. The exported geotiff was then used to incorporate the bathymetry surface into the 2016 LiDAR image.

APPENDIX 21-1 FISH PASSAGE SCENARIOS

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 21-1 Fish Passage Scenarios
June 2020

21-1.1 INTRODUCTION

This appendix provides fish passage result tables for each fish species group for five confidence intervals (95%, 75%, 50%, 25% and 5% pass). The tables also indicate the maximum modelled velocity along the respective step or pool and its associated swim path length. These values compare the velocity to swim distance information available in the fish swim performance database (Katapodis and Gervais 2016). The passage rating is the result of these comparisons and is presented in each table as:

- N/N = no passage step/no passage pool. Fish Passage not achieved.
- N/Y - Y/N = no passage at either step or pool. Fish can pass one but not the other step/pool length. Fish passage not achieved.
- Y/Y = passage achieved (both step and pool).
- n/a = naturally low flows that correspond to overwintering periods where fish movement is limited (i.e., BSP-4).

Instances where "-" is denoted in the velocity categories represent a swim path that does not trigger a 'step' velocity; fish only encounter pool habitat (i.e., relatively slow velocity) throughout the swim path.

Green highlights in the tables show conditions where passage is achieved, and red highlights in the tables show where passage is not achieved.

21-1.2 FISH PASSAGE SCENARIO – EEL GROUP

Table 21-1.2-1 Calculated Fish Swimming Capabilities for Existing and Expected Conditions, Eel Species Group (i.e., Burbot in the Elbow River) at 95% Confidence Interval

	Biologically Significant Periods (BSP) for Expected Conditions								Biologically Significant Periods (BSP) for Existing Conditions							
	BSP 1 (April 2 to June 15)		BSP 2 (June 16 to Sept 25)		BSP 3 (Sept 26 to Dec 1)		BSP 4 (Dec 2 to April 1)		BSP 1 (April 2 to June 15)		BSP 2 (June 16 to Sept 25)		BSP 3 (Sept 26 to Dec 1)		BSP 4 (Dec 2 to April 1)	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	- / N	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / N	- / N	- / N	- / N	- / N	- / N	n/a	- / N	- / N	- / N	- / N	- / N	n/a	N / N	n/a	- / N

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.2-2 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Eel Species Group (i.e., Burbot in Elbow River) at 75% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	- / N	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / N	- / N	- / N	- / N	- / N	- / N	n/a	- / N	- / N	- / N	- / N	- / N	n/a	N / N	n/a	- / N

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.2-3 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Eel Species Group (i.e., Burbot in the Elbow River) at 50% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	- / N	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / N	- / N	- / N	- / N	- / N	n/a	N / N	n/a	- / N

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.2-4 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Eel Species Group (i.e., Burbot in Elbow River) at 25% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	- / N	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	N / N	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.2-5 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Eel Species Group (i.e., Burbot in Elbow River) at 5% Confidence Interval

	BSP for Expected Conditions								BSP for Existing Conditions							
	BSP 1		BSP 2		BSP 3		BSP 4		BSP 1		BSP 2		BSP 3		BSP 4	
Flow Condition	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max
Discharge (m³/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	Y / Y	N / -	Y/ Y	- / N	Y / Y	- / N	n/a	Y / Y	Y / N	N / -	Y / N	Y / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y
NOTE: Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)																

21-1.3 FISH PASSAGE SCENARIOS – SALMON AND WALLEYE GROUP

Table 21-1.3-1 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Salmon and Walleye Species Group (i.e., Brown Trout in Elbow River) at 95% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	N / -	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / N	- / N	- / Y	- / N	- / Y	- / Y	n/a	- / N	- / N	- / N	- / N	- / N	n/a	- / N	n/a	- / N

NOTE:

Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.3-2 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Salmon and Walleye Species Group (i.e., Brown Trout in Elbow River) at 75% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	N / -	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.3-3 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Salmon and Walleye Species Group (i.e., Brown trout in Elbow River) at 50% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	Y / Y	N / -	Y / Y	N / -	Y / Y	- / Y	n/a	Y / Y	Y / Y	N / -	Y / Y	Y / N	- / N	N / Y	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.3-4 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Salmon and Walleye Species Group (i.e., Brown Trout in the Elbow River) at 25% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / Y	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	Y / Y	Y / -	Y / Y	Y / -	Y / Y	- / Y	n/a	Y / Y	Y / Y	Y / -	Y / Y	Y / Y	- / Y	Y / Y	n/a	- / Y
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.3-5 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Salmon and Walleye Species Group (i.e., Brown Trout in Elbow River) at 5% Confidence Interval

Flow Condition	BSP for Expected Conditions								BSP for Existing Conditions							
	BSP 1		BSP 2		BSP 3		BSP 4		BSP 1		BSP 2		BSP 3		BSP 4	
	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max	3Q10min	3Q10max
Discharge (m³/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / Y	N / -	- / N	- / Y	- / Y	N / Y	- / Y	- / Y	- / Y	N / -	- / N	N / -	- / N	- / N	- / Y	N / Y
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	Y / Y	Y / -	Y / Y	Y / -	Y / Y	- / Y	n/a	Y / Y	Y / Y	Y / -	Y / Y	Y / Y	- / Y	Y / Y	n/a	- / Y
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

21-1.4 FISH PASSAGE SCENARIOS – PIKE GROUP

Table 21-1.4-1 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Pike Species Group at 95% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	-/ N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	N / -	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / N	- / N	- / N	- / N	- / N	- / N	n/a	- / N	- / N	- / N	- / N	- / N	n/a	- / N	n/a	- / N

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.4-2 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Pike Species Group at 75% Confidence Interval

Flow Condition	**BSP for Expected Conditions**								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
	3Q10min	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	- / N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	N / -	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / N	- / N	- / N	- / N	- / Y	- / N	n/a	- / N	- / N	- / N	- / N	- / N	n/a	- / N	n/a	- / N

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.4-3 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Pike Species Group at 50% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	-/ N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / N	N / -	N / N	N / -	N / N	- / N	n/a	N / N	N / N	N / -	N / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / N	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.4-4 Fish Swimming Performance Scenarios for Existing and Expected Conditions, Pike Species Group at 25% Confidence Interval

	BSP for Expected Conditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m^3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	-/ N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	N / Y	N / -	N / Y	N / -	Y / Y	- / N	n/a	Y / Y	Y / N	N / -	Y / N	N / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

Table 21-1.4-5 Fish Swimming Performance Scenarios for Existing and Proposed Conditions, Pike Species Group at 5% Confidence Interval

	BSP for ExpectedConditions								**BSP for Existing Conditions**							
	BSP 1		**BSP 2**		**BSP 3**		**BSP 4**		**BSP 1**		**BSP 2**		**BSP 3**		**BSP 4**	
Flow Condition	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**	**3Q10min**	**3Q10max**
Discharge (m3/s)	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81	2.8	75.7	3.47	69.5	2.38	15	0.8	9.81
Fish Size (mm)	25															
Max Velocity m/s (Step/Pool)	- / 0.5	1.0 / -	- / 0.8	- / 0.7	- / 0.4	1.1 / 0.8	- / 0.5	- / 0.7	- / 0.6	1.5 / -	- / 0.6	1.2 / -	- / 0.8	- / 0.7	- / 0.5	1.0 / 0.6
Swim Distance m (Step/Pool)	- / 9.0	5.8 / -	- / 3.1	- / 3.2	- / 2.4	1.0 / 1.8	- / 7	- / 2.3	- / 4.4	5.6 / -	- / 7.8	5.1 / -	- / 5.0	- / 38.9	- / 6.2	2.2 / 2.3
Fish Passage (Step/Pool)	- / N	N / -	- / N	- / N	-/ N	N / N	- / N	- / N	- / N	N / -	- / N	N / -	- / N	- / N	- / N	N / N
Fish Size (mm)	250															
Max Velocity m/s (Step/Pool)	1.4 / 1.0	1.9 / -	1.3 / 1.0	1.8 / -	1.3 / 1.0	- / 1.1	n/a	1.3 / 0.8	1.3 / 1.0	1.8 / -	1.3 / 1.0	1.8 / 1.3	- / 1.2	1.3 / 1.0	n/a	- / 1.0
Swim Distance m (Step/Pool)	6.2 / 11.1	10.9 / -	7.4 / 10.3	10.9 / -	6.9 / 10.4	- / 18.6	n/a	5.0 / 12.0	5.8 / 17.8	18.9 / -	6.3 / 18.0	4.4 / 13.3	- / 21.6	23.5 / 24.1	n/a	- / 35.0
Fish Passage (Step/Pool)	Y / Y	N / -	Y / Y	N / -	Y / Y	- / N	n/a	Y / Y	Y / Y	N / -	Y / Y	Y / N	- / N	N / N	n/a	- / N
Fish Size (mm)	1,000															
Max Velocity m/s (Step/Pool)	- / 1.6	- / 2.0	- / 1.5	- / 1.6	- / 1.4	- / 1.4	n/a	- / 1.7	- / 1.4	- / 1.9	- / 1.3	- / 1.8	n/a	- / 1.4	n/a	- / 1.3
Swim Distance m (Step/Pool)	- / 18.8	- / 11.2	- / 18.0	- / 15.7	- / 17.4	- / 22.0	n/a	- / 28.8	- / 32.3	- / 19.5	- / 28.1	- / 18.5	n/a	- / 59.1	n/a	- / 45.4
Fish Passage (Step/Pool)	- / Y	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	- / Y	- / Y	- / Y	- / Y	n/a	- / Y	n/a	- / Y

NOTE:
Calculations are based on the fish swimming performance data for velocity and distance, as presented in Katapodis and Gervais (2016)

APPENDIX 23-1 BEDLOAD MODEL - TECHNICAL REPORT

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 23-1 Bedload Model - Technical Report
June 2020

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Bedload Model Report

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

June 2020

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1.0 INTRODUCTION

In response to supplemental information requests received as part of the Environmental Impact Assessment (EIA) for the Springbank Off-stream Reservoir Project (the Project), a two-dimensional (2D) hydromorphodynamic bedload model was developed on the MIKE 21C software platform. The intent of the model is to answer questions regarding the effects of the Project on the bedform of Elbow River, especially in the context of downstream changes to fish habitat.

Three separate models spanning approximately 1 km each were developed at representative locations downstream of the Project, and each location is modelled for six separate scenarios:

- 1:10 year flood, existing conditions and with the Project
- 1:100 year flood, existing conditions and with the Project
- 2013 (Project design basis) flood, existing conditions and with the Project

This totaled 18 distinct model runs. The model results are used to assess changes in aggradation and degradation through the reach as a result of Project operations. The results of these runs were used for 18 additional model runs to evaluate habitat suitability indexes (HSI) for several fish species and life stages within the modelled reaches and the potential impacts of the Project on them.

The purpose of this report is to present the results of the modelling and analysis as well as describe the model development and input parameters. It does not include the HSI analysis or results.

1.1 BASIS

This report and the model development are based on:

- Unpublished 1-dimensional HEC-RAS models of Elbow River using data from 2016 for the Bow and Elbow River Flood Hazard Study and supplied for Alberta Transportation’s use on the Project.
- Unpublished bathymetric data of the Elbow River channel supplied by Alberta Environment and Parks (AEP) and captured in 2016 as part of the Bow and Elbow River Flood Hazard Study and supplied for Alberta Transportation’s use on the Project.
- Sediment gradation data from the Elbow River channel (EIA, Appendix J, Section 2.3.3).
- Light detection and ranging (LiDAR) data provided by AEP and captured in 2016 as part of the Bow and Elbow River Flood Hazard Study and supplied for Alberta Transportation’s use on the Project.

- Hydro and morphodynamic model (MIKE 21C) data and manuals.
- Relevant past literature and reports referenced herein.

2.0 BACKGROUND

The three reaches on Elbow River are located approximately 3 km to 17 km upstream of Glenmore Reservoir and downstream of the Project. Each reach has slightly different characteristics and fish habitat suitability; however, they were chosen as representative of the type and variety of channel form and fish habitat present through this part of Elbow River. Their locations relative to the Project are shown in Figure 2-1.

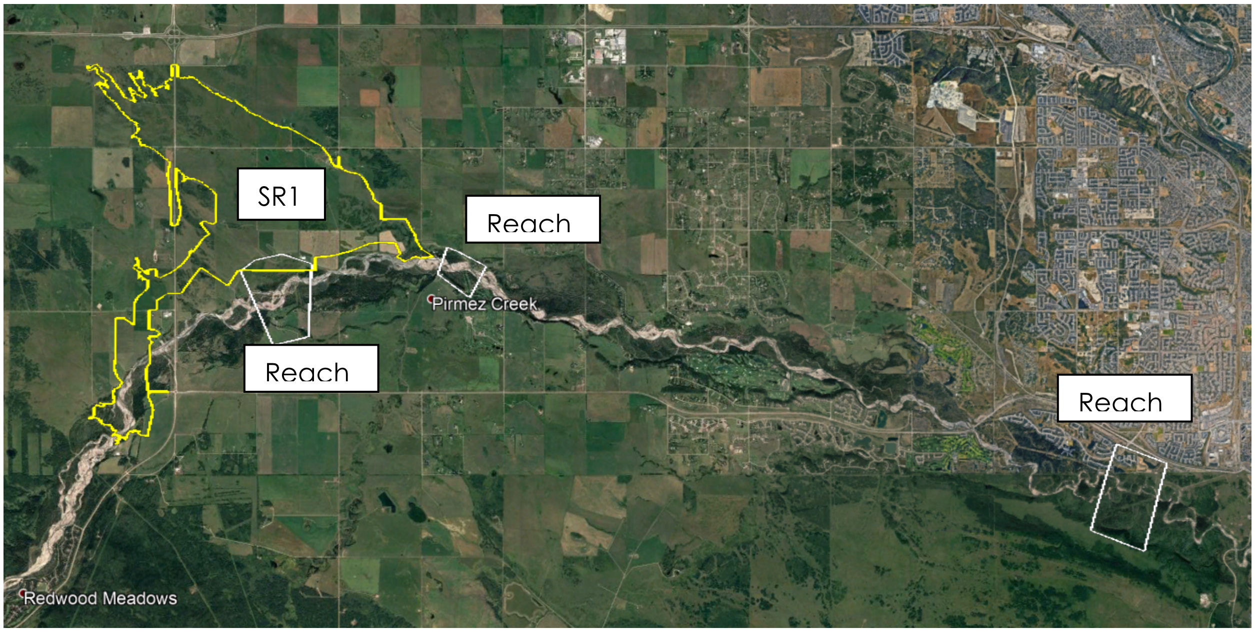


Figure 2-1 MIKE 21C Bedload Model Reach Location and Extent

Elbow River between the diversion site and Glenmore Reservoir was broken into the representative reaches in order to capture the braiding and complexity of the river that could not be captured in a model of the entire reach. Smaller reaches allowed for a smaller grid spacing to more accurately capture and model features within the mesh. Modelling the full 25 km reach would require a large mesh size which would not accurately represent the bedform and fish habitat features of interest. Conversely, having a fine mesh over the entire length would result in over ten million cells which is beyond the reasonable limits of computational power and model run time.

2.1 SITE DESCRIPTION AND GEOMORPHOLOGY

Elbow River from its origin in Elbow Lake to its confluence with the Bow River is 120 km in length and one of the steepest rivers of its size in Alberta, with an average slope of 1% (Kellerhals et al. 1972).

Elbow River can morphologically be classified as a wandering gravel-bed river. This type of river, originally defined by Neill (1973), exhibits an irregularly sinuous channel, that sometimes splits around channel islands, vegetated bars, or braids. Church (1983), observed that coarse sediments in wandering gravel-bed rivers tend to accumulate locally in unstable sedimentation zones, which were separated by narrower, stable sediment transport zones. This pattern was also observed by Desloges and Church (1987), Church and Desloges (1989), Ham (2005) and Burge (2005).

2.2 HYDROLOGY

The model was run for three separate floods: 1:10 year flood, 1:100 year flood, and design flood (2013). The inflow hydrographs for each of these floods were developed as part of the flood frequency analysis and hydrology that formed part of the preliminary design in Appendix B: Hydrology (Stantec 2017). Each flood simulation was routed through a calibrated, quasi-unsteady one-dimensional AEP HEC-RAS unpublished model to simulate the gate operations of the Project. The output hydrographs formed the basis of the second round of model runs that assessed bedload changes once the Project is in operation. Examples of the input hydrographs that formed the upstream boundary condition of the hydrodynamic modules of the MIKE 21C models are shown in Figure 2-2 to Figure 2-4.

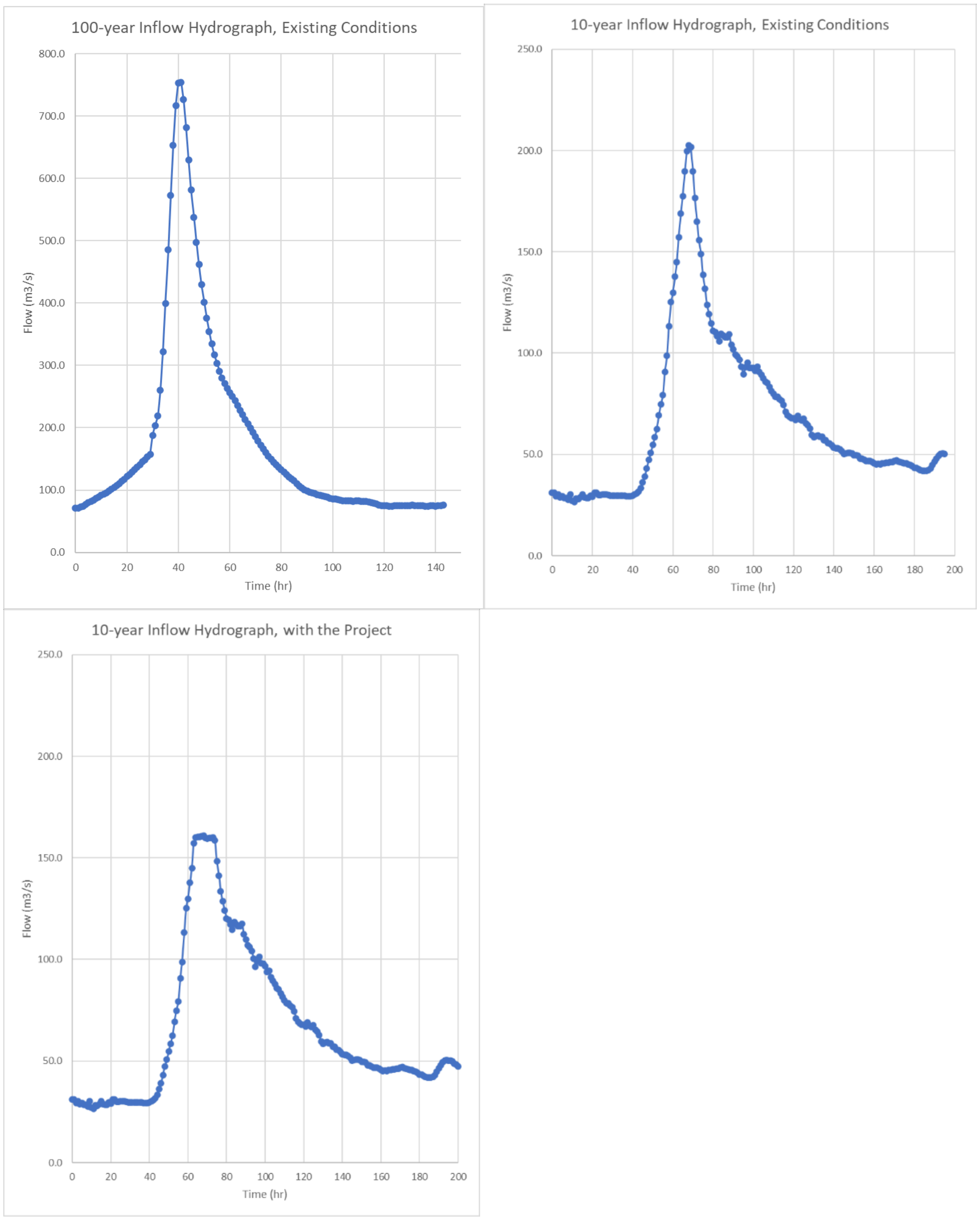


Figure 2-2 10-year Inflow Hydrograph at Reach 1, Existing Conditions and With the Project

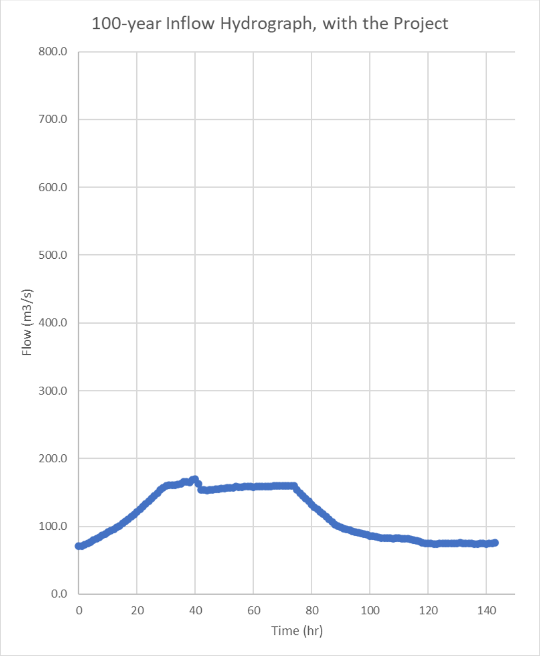


Figure 2-3 100-year Inflow Hydrograph at Reach 3, Existing Conditions and With the Project

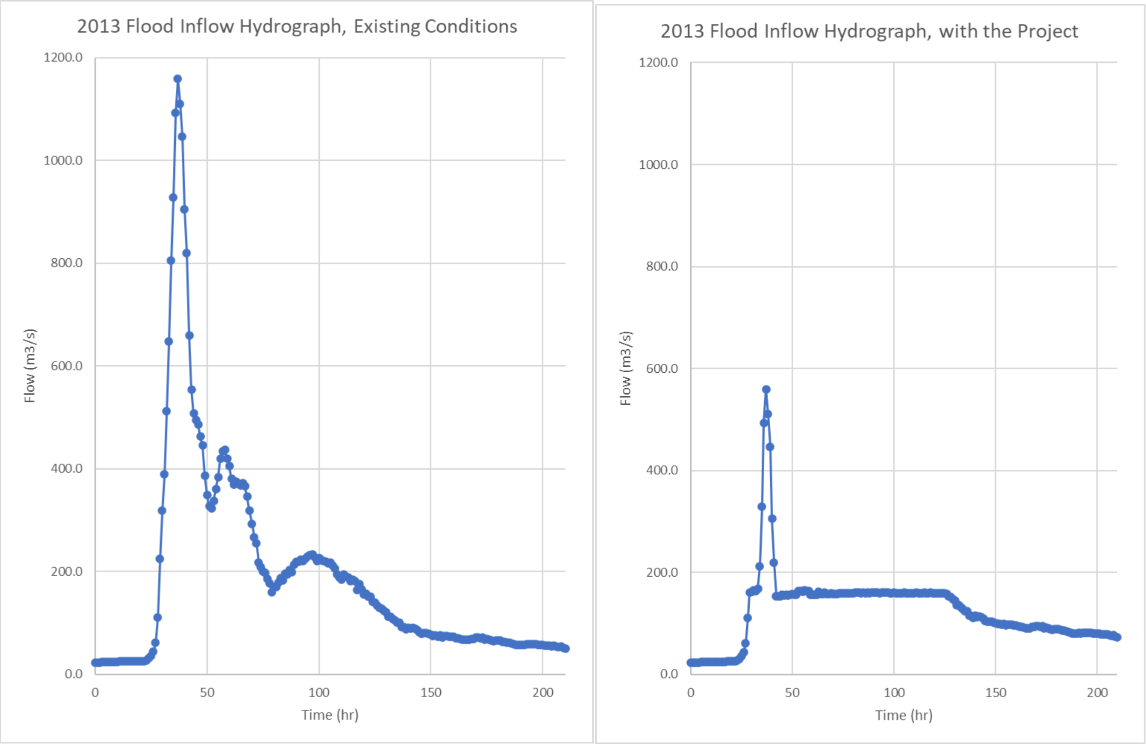


Figure 2-4 **2013 Flood Inflow Hydrograph at Reach 2, Existing Conditions and With the Project**

Project operations change the peak and shape of the hydrograph by limiting flows downstream of the diversion inlet to 160 m^3/s, while the flow duration remains the same.

2.3 BED AND BAR MATERIAL

Based on the surficial geology mapping and gradation of sediment samples, the riverbed and bank material of Elbow River consists primarily of alluvial gravels deposited through fluvial processes by the channel. The river carries most of the sediments mainly during freshet and floods when the velocities and shear stresses are high enough to transport bed material.

Bed and bar material gradation was taken from field data collected in 2016 and published values (Hudson 1983). Outliers were omitted from the average grain size distributions for modelling. One average surface and one average subsurface grain size distribution was used to characterize the channel bed material (Figure 2-5). Based on the gradation, the size of median grain size (D_{50}) in the surface layer and subsurface layer are 24.5 mm and 16.9 mm, respectively.

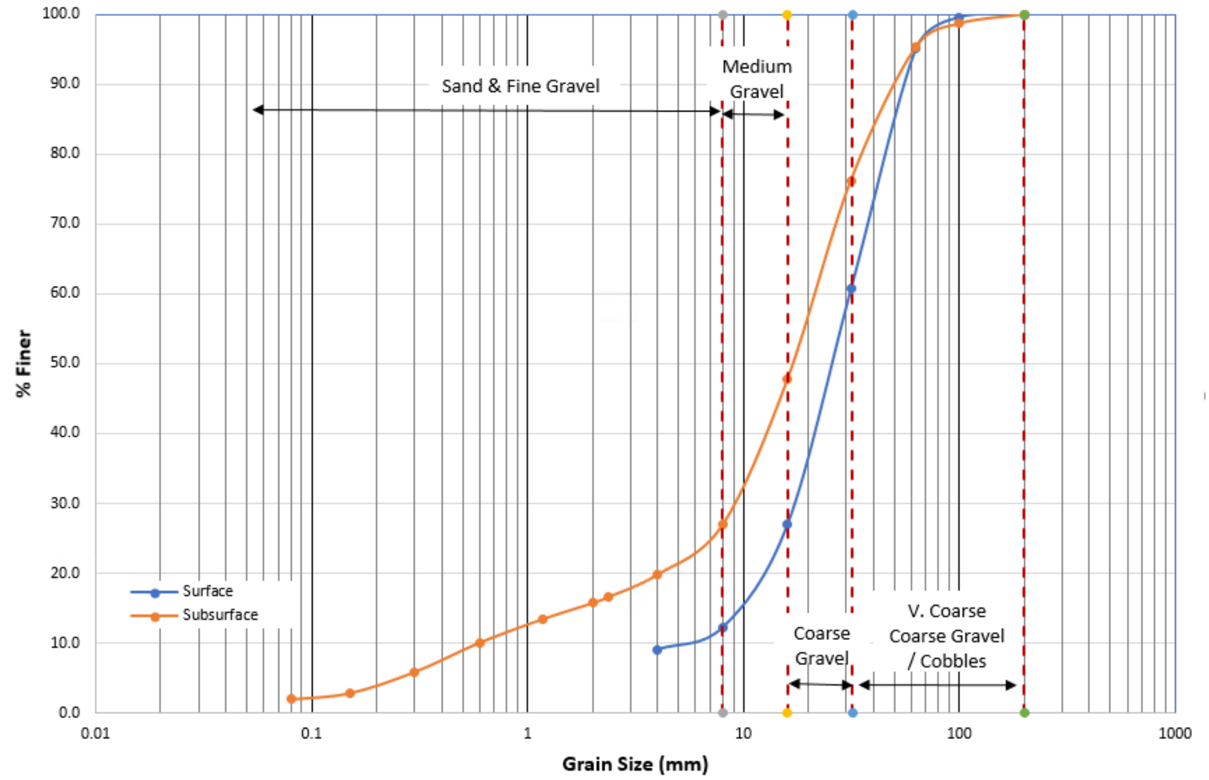


Figure 2-5 Surface and Subsurface Material Gradation

3.0 SEDIMENT TRANSPORT MODELLING

Stantec Consulting Ltd. (Stantec) prepared a morphodynamic and hydrodynamic model of the sites to estimate the future hydraulic and geomorphic conditions at the site and inform the assessment of fish habitat following the three floods. This analysis was undertaken for both existing conditions and conditions that could exist with the Project.

3.1 MODELLING SOFTWARE

MIKE 21C was used to simulate the hydrodynamic and morphodynamic responses of the river reach to the recent floods. The model was developed by Danish Hydraulic Institute (DHI). The model's main specifications are explained briefly in the following section. Detailed information is provided in the model's User Guides and Scientific Documentation (DHI 2017a,b).

3.1.1 Grid Generation

MIKE 21C uses a Curvilinear Grid Generator to discretize the calculation domain to small individual cells (grid or mesh). Hydrodynamic and hydromorphic equations are then applied in the grid cells to estimate the flow characteristics and sediment transport properties. The software generates a quadrilateral orthogonal grid by solving an elliptic system of partial differential equations using the Stone's implicit method, and the Newton-Raphson method for the boundary conditions. The grid generator also applies adaptive filters, smoothing methods and residual evaluation to produce an orthogonal grid (s, n), which is equivalent to simple potential theory where the longitudinal and normal axes can be thought of streamlines and potential lines.

3.1.2 Hydrodynamic Model Computational Methods

A simplified form of the Navier-Stokes equations, reduced to two-dimensional equations of conservation of momentum and mass (Saint Venant equations), is used in the model to calculate the flow hydraulic characteristics in a grid system. Secondary flow effects are also maintained in the depth-averaged model by applying a separate equation for helical flow component and by assuming similarity of the vertical distribution of the flow velocities. The equations are solved using an implicit finite difference technique with variables on a space staggered computational grid.

The following effects are included in the governing equations when used for a river: flow acceleration, convection and cross-momentum, pressure gradient, bed shear stress, momentum dispersion, Coriolis forces, wind forces, flow curvature and helical flow effect in a river bend.

Three main assumptions in developing the system of equations are shallow water, hydrostatic pressure, and rigid lid. Thus, the lateral exchange of momentum due to friction and the gradients of vertical velocity are neglected, and the water surface is considered as being a rigid impermeable and shear stress free plate. The error introduced by those assumptions is in order of h/R, where h is the water depth and R the radius of curvature. In summary, the model is valid for shallow, gently varying topography and mildly curved and wide river channels with small Froude numbers. Since there is no discontinuity in Elbow River flow in the reaches such as water falls or hydraulic jump, application of Saint Venant equations for the river reach is valid.

3.1.3 Sediment Transport Computational Methods

The three models described herein as the bedload models focused solely on bed load while suspended sediment was examined using a separate model set built on the MIKE 21 modelling platform (not MIKE 21C). MIKE 21 uses equations more suitable for fine grained sediment transport modelling (e.g., in the reservoir). MIKE 21C uses questions designed to simulate sediment transport in gravel bed rivers. The bedload models assumed that the bedload responds immediately to changes in local hydraulic condition, mainly through the deviation of the direction of the bed shear stress due to helical flow and the effect of a sloping riverbed. Bed slope in a river bend influences the sediment transport rate and direction by modifying the critical shear stress for initiation of motion. The model, therefore, implements a formula based on the relevant factors to estimate the portion of the sediment transport in the normal direction of a river bend.

Sediment transport for a uniform shear flow can be estimated by using one of the following sediment transport relations: Engelund and Hansen method (1967), Van Rijn method (1984), Engelund-Fredsoe and Zyserman method (1994), Meyer-Peter and Muller method (1948), Smart and Jaeggi (1983), Yang methods for sand and gravel (1984), and Wilcock-Crowe method (2003).

Since the uncertainty of sediment transport estimate is high and different methods would result in very different sediment rates, it is commonly advised that transport methods be applied only under conditions similar to those for which the method was developed. The sediment transport equation selected for Elbow River is Wilcock-Crowe (2003). That equation was developed for mixed sand and gravel bed rivers to predict transient conditions of bed armouring, scour, and aggradation. Its application in sediment transport modelling is discussed further in Section 3.2.7.

3.1.4 Advantages and Limitations

The application of streamline and normal directions as the coordinate system for solving the equations restricts the model to include the isolated areas where flow velocity is very low or close to zero. In addition, use of an orthogonal coordinate system, where the s- and n-axes are at right angles to each other in every points of a grid, makes the mathematical and numerical description of the governing equations substantially simpler, and reduces the truncation errors of the finite difference scheme and delivers a higher accuracy than in a Cartesian, rectangular coordinate system.

MIKE 21C is a combined hydrodynamic and sediment transport model that updates the geometry based on the calculated hydrodynamic flow field according to the given boundary conditions. The so-called 'morphological model' is an uncoupled model where the hydrodynamic equations are solved at a certain time step prior to solution of the sediment transport equations. Subsequently, a new bed level is computed and the hydrodynamic model proceeds with the next time step.

To ensure stability of the hydrodynamic model, two finite values for the dry and flood depths were specified as input to the model (normally between 0.2 m and 0.6 m). Those values are used as the threshold to include or exclude a cell from the flooding extents and consequently the hydraulic calculations. It is necessary to consider a small difference between dry depth and flood depth values to avoid alternating swapping, which can lead to numerical stability issues. Smaller values for the dry and flood depths can be used as long as the calculations are stable.

It was found that with the complex and braided geometry of Elbow River, the model is sensitive, in particular, to initial and boundary conditions and the calculation time step for both hydrodynamic and morphological simulations. Calculation stability issues are exacerbated when the inflow consists of a steep rising hydrograph such as that which occurred in the flood of 2013. For the simulations, the input parameters were adjusted to allow the model calculations to run smoothly and completely. Those inputs are discussed through the next sections.

3.2 MODEL DEVELOPMENT

The model was developed based on available hydraulic, geometric and geomorphic data for the purpose of estimating future conditions within the study area. The model was developed by inputting available data and then calibrating the model parameters to match observed conditions.

3.2.1 1D Hydraulic Reference Model

A one-dimensional hydraulic exercise using the unpublished HEC-RAS model was used to establish boundary conditions including inflow hydrographs, downstream water levels, and sediment inflow, attenuated at each reach location downstream of the Project.

3.2.2 2D Model Domain

The two-dimensional MIKE 21C modelling domain covers the three distinct reaches as shown in white in Figure 3-1. These locations were chosen as representative reaches with a variety of channel and bedforms, river features, and fish habitat suitability. The reaches are each approximately 1 km long and include the river and its floodplain.

Figure 3-1 Screenshot of Generated Grids at Reach 2

3.2.3 Model Grid Generation

Three grids were initially generated and then merged to cover each reach in order to cover the entire expected flood extents and maximize the cell resolution within the flooded area without creating a grid too dense to compute. Grid 1 was composed of smaller cells, approximately 5 m by 2 m, and was developed for the main-channel and floodplain where the discharge of water and sediment is concentrated. A grid with finer cells increases the detail of the bed topography captured in the model and accuracy of results of the numerical model, particularly around the edge of gravel bars and at the riverbanks. The second and third grids contained larger cells, approximately 5 m by 5 m, and covered the river valley walls and areas not anticipated to experience flood flows. Figure 3-1 shows a closeup of the curvilinear grid developed at Reach 2. Of note is the transition from a 5 m by 2 m grid spacing in the floodplain to approximately 5 m by 5 m on the valley wall and higher.

For an ideal curvilinear grid, the orthogonality measure, which is the scalar product of cell sides (*s* and *n* vectors) should be equal to zero for all cells. DHI (2017a) recommends a range between +0.05 and -0.05 for orthogonality, and an aspect ratio less than 8 for a well-designed grid. The grids were refined or regenerated if they didn't pass the orthogonality or aspect ratio check of the cells.

Once the grids were refined and orthogonal, the size of the cells were updated along the reach. The grids were merged to generate a single grid for simulations. The final grids ranged from approximately 32,000 to 79,000 cells based on the floodplain width, and each was refined and checked for orthogonality and aspect ratio. The quadrilateral curvilinear grid makes it possible to increase the efficiency of the river grid by using elongated cells in the main flow direction.

3.2.4 River Reach Geometry

The initial model geometry data was based on AEP bathymetric data (unpublished data) combined with surveyed cross sections (AEP 2015-2016) and AEP LiDAR data (unpublished data) in the overbank area to create a combined surface digital elevation model (DEM). The methods used to create the surface are described further in the memo “Bathymetry Surface Creation” (see response to Natural Resources Conservation Board [NRCB] Question 15, Appendix 15-1, Attachment A). The DEM was used to calculate the average elevation of each cell of the grid that constitute the initial geometry of the hydromorphodynamic model. When running, the model will update the geometry at each time step by using the sediment transport estimates based on the hydraulic characteristics of the flow (flow depth, velocity, bed shear stress).

3.2.5 Manning’s Roughness

The initial range of roughness coefficients (Manning’s n) used were based on the data within the supplied HEC-RAS model. The coefficients ranged from 0.03 to 0.10 within the cross-sections of the reach. During calibration, these coefficients were updated with the objective of matching the water surface profiles from available data, as described in Section 3.3. The MIKE 21C model roughness input uses Manning’s M, which is the inverse of ‘n’ values. Shapefiles were developed overlaying the different land cover types in order to create a spatially varied roughness input file for each reach.

3.2.6 Transport Formulae

Calculated bedload material transport rate using three sediment transport relationships in available literature. These relationships are all slightly different and are used for different applications.

The analysis completed in “Bedload Sediment Rating Curve Report” of Appendix C: Hydraulics (Stantec 2017) used the transport formulae proposed by Bagnold (1977), Meyer-Peter and Müller (updated by Wong and Parker 2006), and Wilcock and Crowe (2003). Figure 3-2 shows the calculated rating curves, where initiation of bedload transport was estimated to occur. The third equation, Wilcock-Crowe, is a sediment transport model which is developed for mixed sand and gravel sediments based on flume observations of five different gravel–sand mixtures. The model uses bed shear stress or shear velocity rather than critical shear stress. Therefore, it proposes some sediment transport even for a small shear stress.

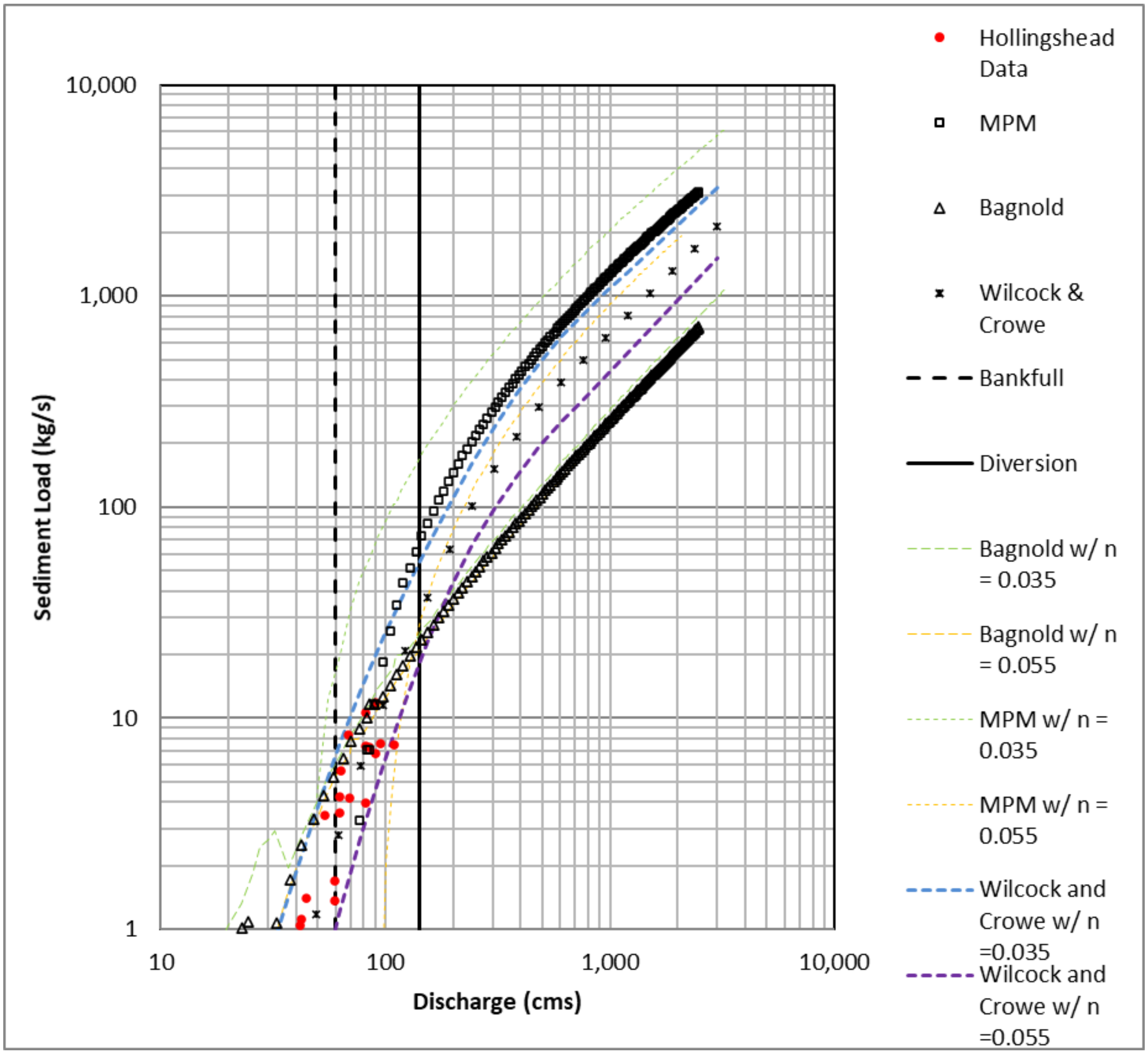


Figure 3-2 Bedload Transport Rating Curve for Elbow River (Appendix C: Hydraulics, Stantec 2017)

The grain size data within the reach showed that the surface layer is coarser than the subsurface, indicating that the bed is somewhat armoured. Therefore, the selected transport model should include the provisions for the impact of an armoured bed on the estimates of sediment transport rates.

The Wilcock and Crowe (2003) sediment transport method was recently developed for mixed sand–gravel-bed rivers. The method was developed using a set of 48 coupled observation in flume runs for flow, grain size and sediment transport with five different gravel–sand mixtures ranging from 0.5 mm to 64 mm, the same as is observed on Elbow River (Hudson 1983 and EIA, Appendix J, Section 2.3.3) The method incorporates a hiding function and a nonlinear effect of sand content on gravel transport rate. The hiding/exposure function reduces the mobility of smaller sizes and increases the mobility of coarser grains relative to the unisize case. The method was developed basically as a surface-based transport model and also includes the concepts for substrate-based transport models. The Wilcock and Crowe method has theoretically shown its capability for predicting transient conditions of bed armoring, scour, or aggradation. Since it is one of the most updated methods for sediment transport estimates and is widely implemented for gravel-bed rivers (BAGS 2009), it was selected for Elbow River modelling.

The Wilcock and Crowe method uses the bed shear stress or shear velocity for sediment transport estimates. The calculation is based on a reference shear stress rather than critical shear stress. Therefore, the method proposes some sediment transport, as shown on Figure 3-3, regardless of the shear stress values.

Other methods could be selected for sediment transport in Elbow River. In that case, a different model calibration would be needed. The reasons for selection of the Wilcock-Crowe method are summarized below:

- Sediment transport is low for low shear stresses, not zero as shown in Figure 3-4.
- The method was developed for mixed sand–gravel sediments, which is applicable to Elbow River.
- The measurement data used for the previous methods were considered for developing the Wilcock and Crowe transport method.
- The selection of the Wilcock and Crowe method as a model parameter for all simulations relates to the mobilization of sediment within the model limits. The rate of sediment influx is a separate variable and discussed in Section 3.2.8.

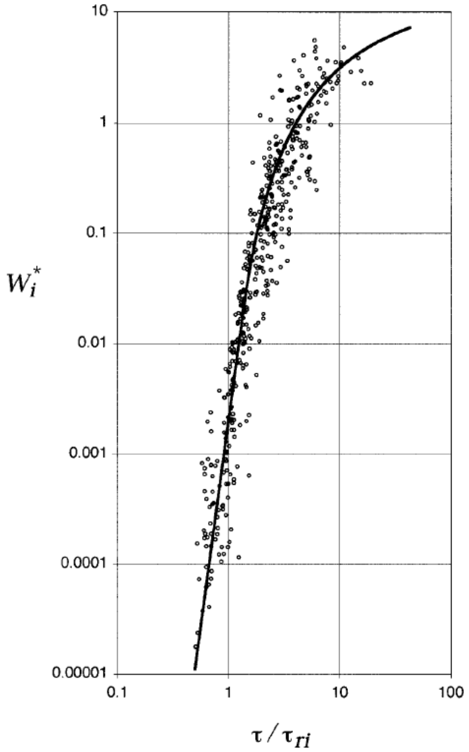


Figure 3-3 **Transport Function (W_i^*) versus Shear Stress Rate (τ/τ_{ri}) (Wilcock and Crowe 2003)**

Two layers of bed sediment were included in the model: a surface layer and a subsurface layer based on the available bed material gradation data. In the model, the surface layer is 0.1 m thick, based on field data collected in 2016 and composed of coarse gravel and cobbles. The subsurface layer in the model is 2.5 m thick, based on the size of the channel and bar characteristics and the fact that the sub-surface grain size distribution is relatively constant throughout Elbow River (Hudson 1983). The subsurface is primarily composed of a range of sand and fine gravel to coarse gravel and cobble. Based on the layer setting in the model, the total thickness of the moving bed is up to 2.6 m, and the model assumed bedrock beneath the subsurface layer.

3.2.7 Ratios and Diameters of Sediment Sizes for Riverbed Layers

The bed material gradation measured during field work in 2016 and Hudson (1983) defined two layers of material within Elbow River: surface and subsurface. The D_{50} of the measured surface material is 24.5 mm while the D_{50} of the subsurface material is 16.9 mm.

The model does not allow for the direct input of sediment distributions in terms of percent finer. Instead, the model requires the user to simplify these distributions into discrete sediment diameters and the percentages of each of those diameters in each layer. This allows for the user to model an infinite number of combinations of diameters and percentages.

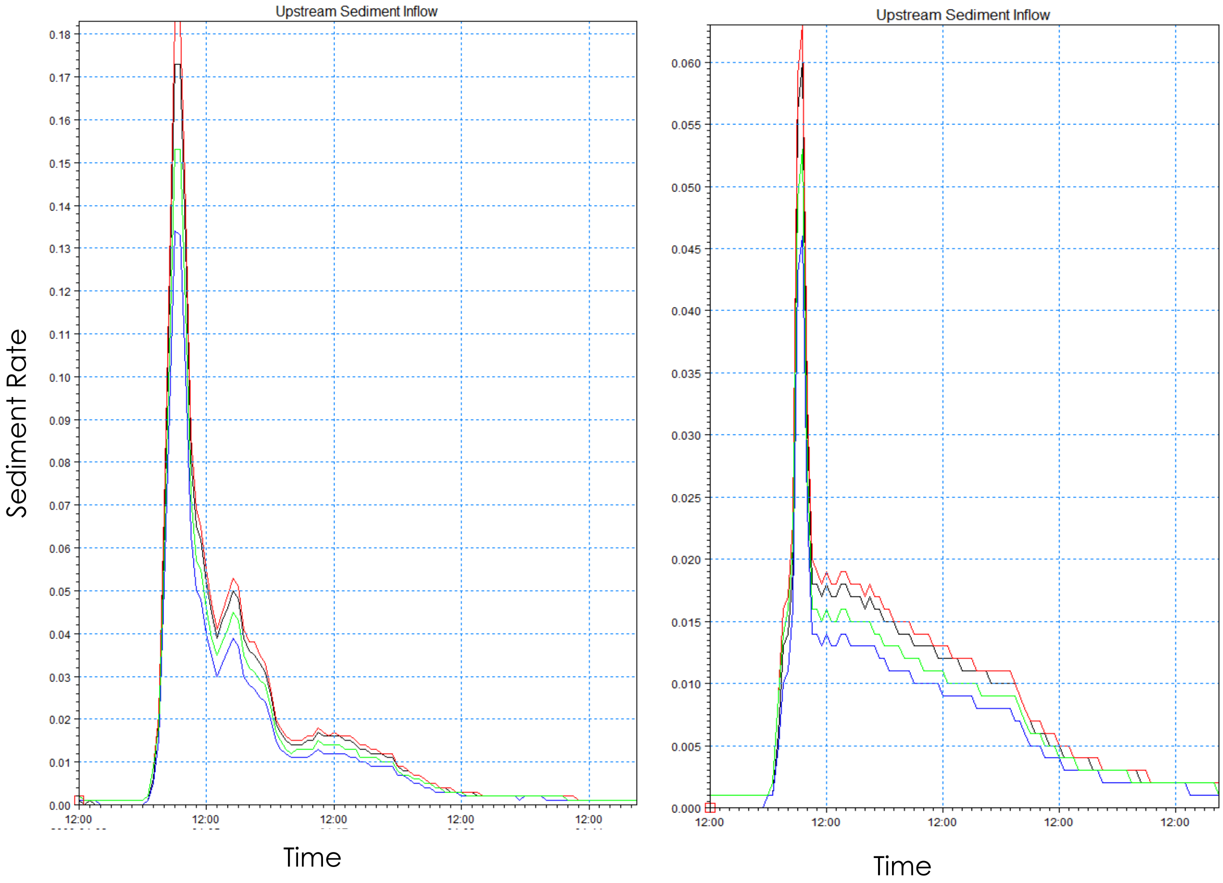
In order to simplify the modelling procedure and reduce the number of variables in the model to reduce the likelihood of instability, each layer was split into four sediment sizes: sand/fine gravel, medium gravel, coarse gravel, and very coarse gravel/cobbles. sand/fine grave is defined as 4 mm diameter particles; medium gravel as 12 mm particles; coarse gravel as 24 mm diameter particles; and very coarse gravel/cobbles as 116 mm diameter particles. The selection of the fine gravel and coarse gravel diameters is based on the measured D_{50} of each sampled layer at the site as well as available literature (Hudson 1983). Table 3-1 illustrates the initial and final sediment distributions.

Table 3-1 Composition of Sediment Material in Riverbed Layers

Classification	Grain Size	Surface Layer	Subsurface Layer
Sand/fine gravel	4 mm	12.2 %	26.9 %
Medium gravel	12 mm	14.8 %	20.8 %
Coarse gravel	24 mm	33.7 %	28.5 %
Very coarse gravel/ cobble	116 mm	39.3 %	23.8 %

3.2.8 Sediment Inflow Distribution

The upstream boundary condition for morphological module of the model was a time-based sediment inflow, broken into individual curves for each sediment size. These sediment inflows were developed through initial sediment gradation data routed through the unpublished HEC-RAS model. The results of this modelling exercise provided the boundary conditions for existing condition model runs as well as with the Project in operation.



NOTE: Red, black, green, and blue represent coarse gravel, sand/fine gravel, very coarse gravel/cobble, and medium gravel, respectively.

Figure 3-4 Sediment Inflow Curves for Reach 2, 2013 Flood (Existing Conditions and with the Project)

3.2.9 Hydraulic Boundary Conditions

3.2.9.1 Upstream Boundary Conditions

The upstream and downstream limits of the study reach had varying cross sections and valley widths. Stable locations are defined as having geometric and hydraulic symmetry in its cross section ("U-shaped"); however, this does not describe Elbow River through any of the selected reaches. Upstream boundary conditions included the hydrograph and sediment inflow, but also required a careful exercise of assigning flow boundaries and initial water levels to ensure model stability.

3.2.9.2 Downstream Boundary Conditions

Downstream boundary conditions are assigned a fluctuating level time series that was developed using discharges and the results of the initial hydrodynamic runs. A moving water level over time at the downstream boundary was necessary given the large fluctuation in flows during each of the modelled floods, but especially for the 2013 flood when discharges fluctuated by a range of over 1,200 m^3/s.

3.2.10 Model Sensitivity

The model is extremely sensitive to boundary conditions as well as a number of other input parameters. Calculation time step, grid spacing, and initial elevations are all factors were carefully adjusted to maintain stability and successfully complete model runs. This is often an iterative process of small adjustments to one or several assigned parameters to ensure a stable run completion.

3.3 MODEL CALIBRATION

The model results were calibrated to surveyed flood high water marks collected by AEP following the flood in 2013. The model was found to closely match the available water level information which confirms the equations and parameters used in the 2D model, including Manning's roughness and boundary conditions. A comparative cross section at the Highway 22 bridge is shown in Figure 3-5.

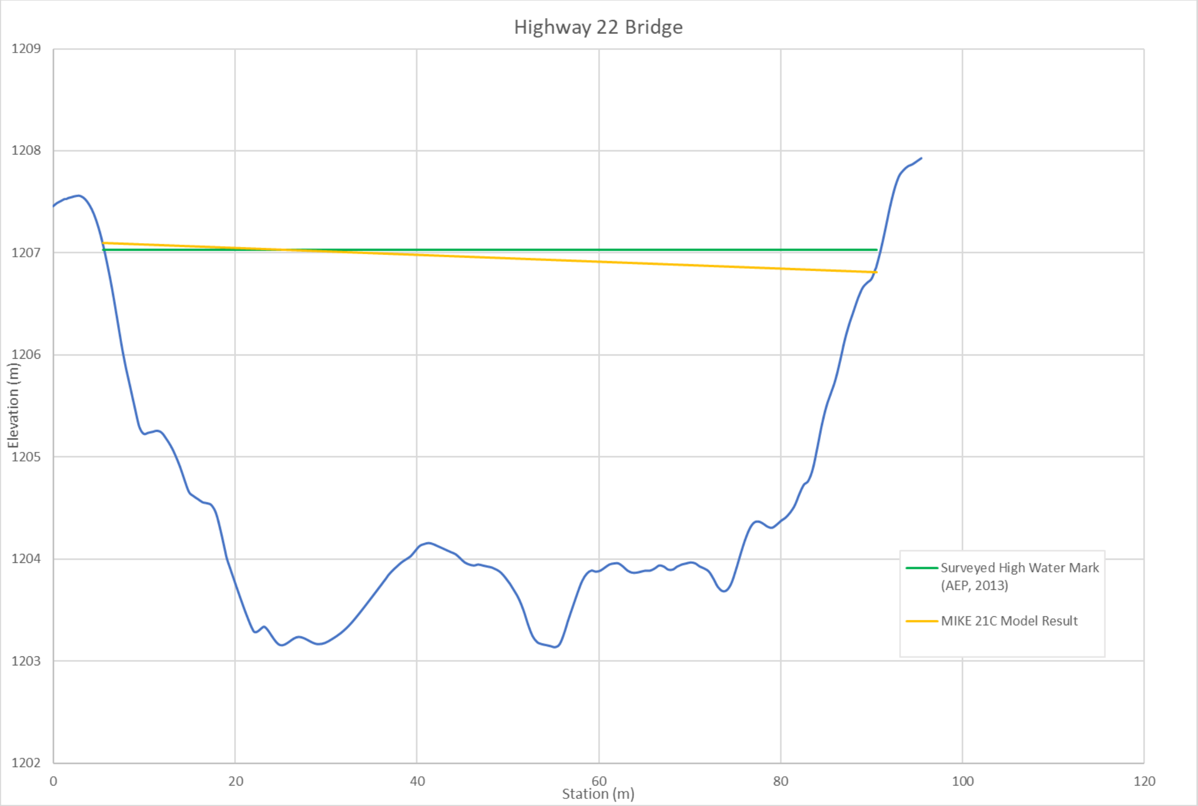


Figure 3-5 MIKE 21C Model Calibration Result

4.0 MODEL RESULTS

Models were used to estimate the hydraulic and geomorphic changes as a result of potential future floods for existing conditions and with the Project. The results allow for an assessment of the difference the Project would make to scour or aggradation in the riverbed downstream of the Project.

These results were used to assess changes to fish habitat using a habitat suitability index (HSI) analysis that quantifies the value of various river features for several fish species and life stages; but, this use or interpretation of the results is not part of this memorandum.

As required output for the HSI modelling, the post-flood bathymetry, with and without the Project, is used as the basis for an additional set of model runs where a steady flow of 7.4 m^3/s was run through to assess flow depths, velocities, and sediment size distributions.

A flow of 7.4 m^3/s is the average Elbow River flow in the fall and early winter, which is an important spawning period for bull trout and brown trout. It is comparable to the habitat work and HSI assessment already completed in the field by Stantec and described in detail in the response to NRCB Question 23, Appendix 23-2.

Tabular outputs were exported from the model as shapefiles for further data compilation using GIS software. Nine separate figures are provided (see Appendix A) that show the impacts of the Project operations on post-flood bedform, and the difference in aggradation or degradation following a 1:10 year flood, a 1:100 year flood, and a 2013 flood at all three reaches. The figures show a relative, post-flood change between existing conditions and those with the Project, and bedform changes will always occur following periods of elevated flow. The purpose of the figures is to establish the difference in river morphology that could occur following construction and operations of the Project. The change in bedform alteration following a flood is mapped as a coloured gradient to visualize the effects of Project operation, where red shows relative scour and green shows relative deposition. These effects are primarily noticeable at bends in the river, where the outside bend shows some scour while the inside bend will deposit sediment. Patterns of scour and deposition vary by reach and flood; however, the general trend shows a decrease in bedload movement because flood peaks are reduced and sediment inflows are decreased with Project operations. These changes are more pronounced in larger floods because the flow remains in channel, with the Project, while significantly more channel switching or avulsion occurs under current conditions.

For comparison, figures showing initial pre-flood bathymetry are included for each reach as well as post-flood results for each model run without the comparative overlay of with and without the Project.

4.2

5.0 CLOSING

The diversion operations of the Project cause downstream changes in bedform during and following floods due to a reduction in peak flows and decreased sediment inflow.

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
BEDLOAD MODEL REPORT

Closing
June 2020

5.2

6.0 REFERENCES

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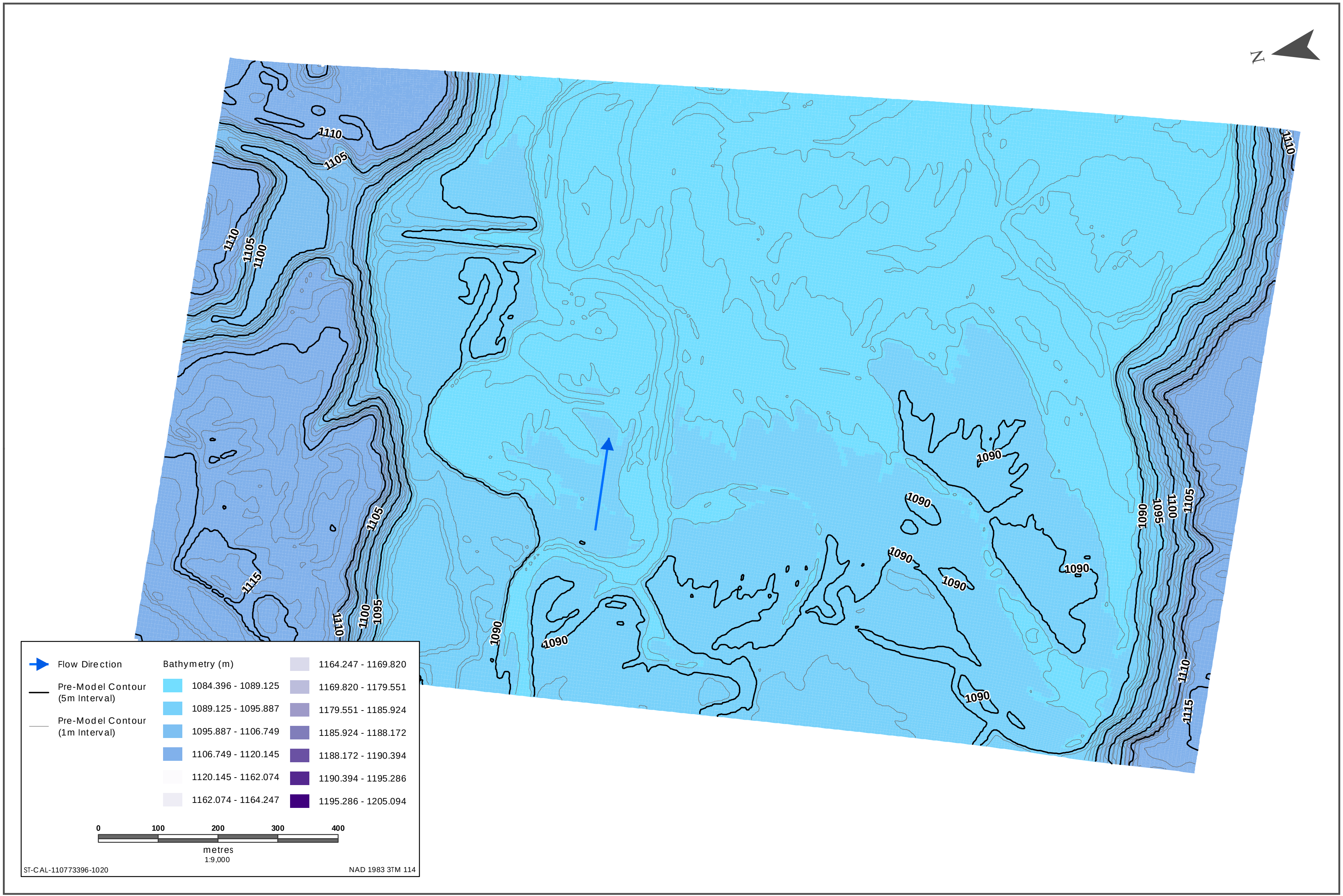
Attachment A BEDFORM CHANGE FIGURES



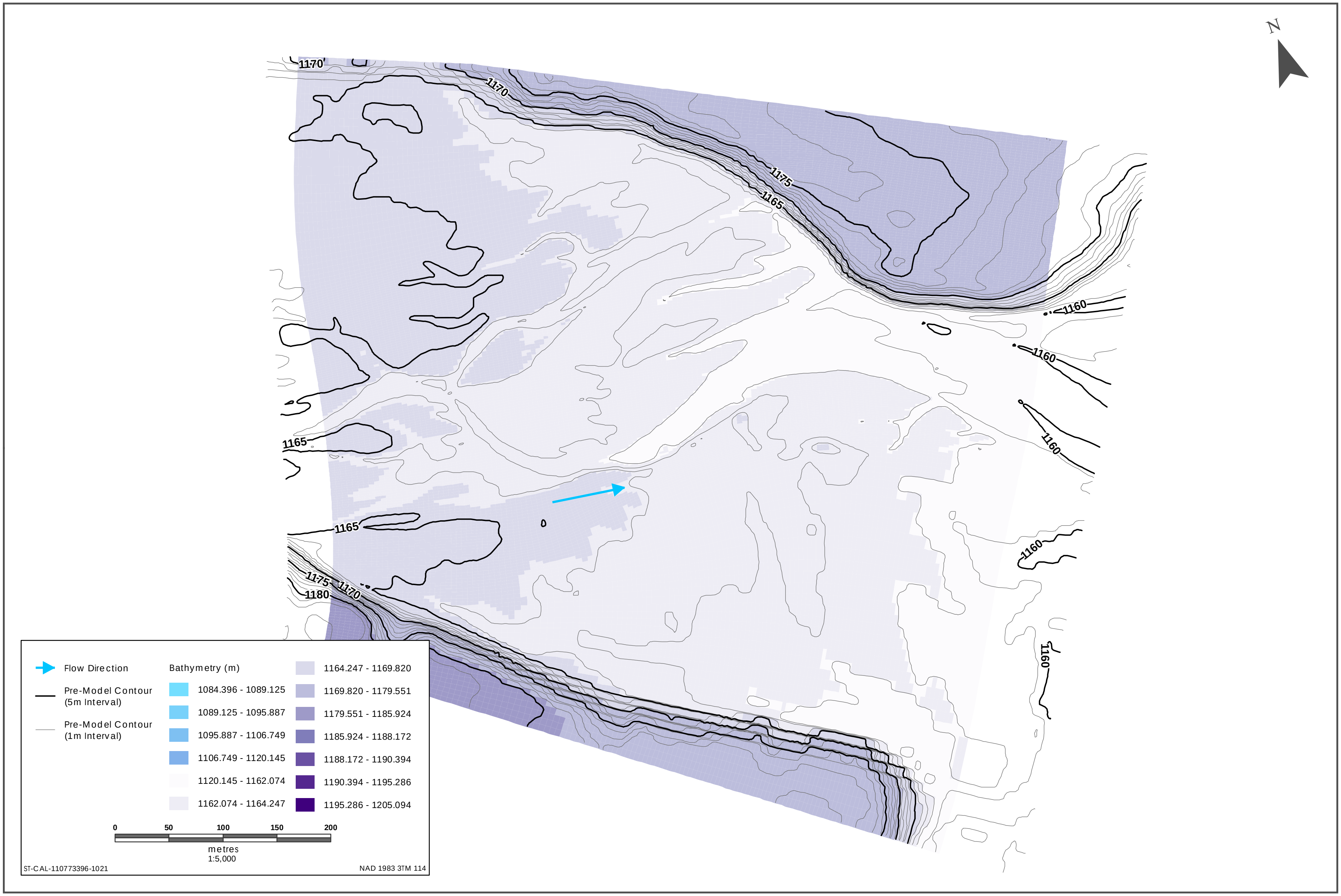
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Existing Bathymetry

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 1



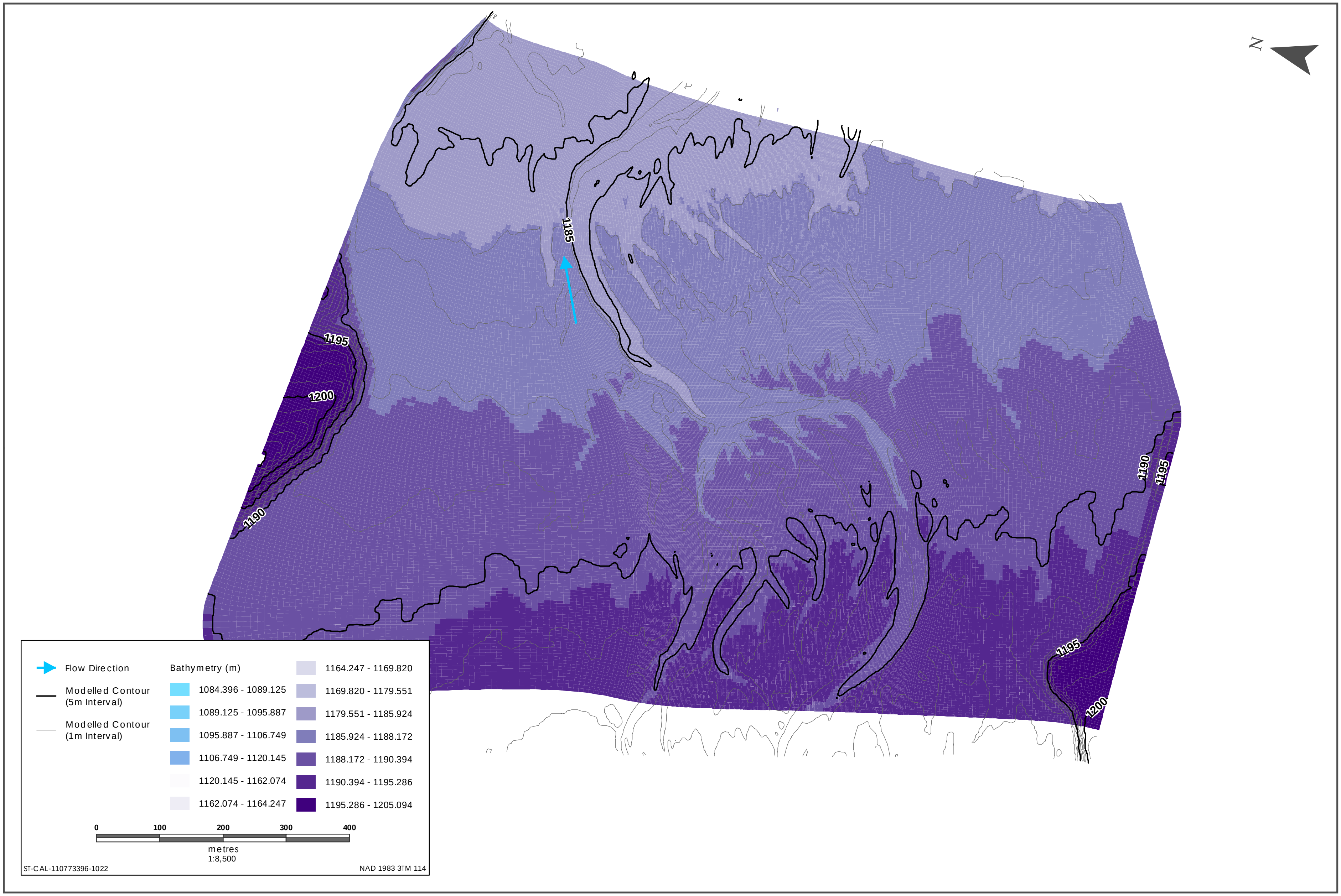
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Existing Bathymetry

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 2



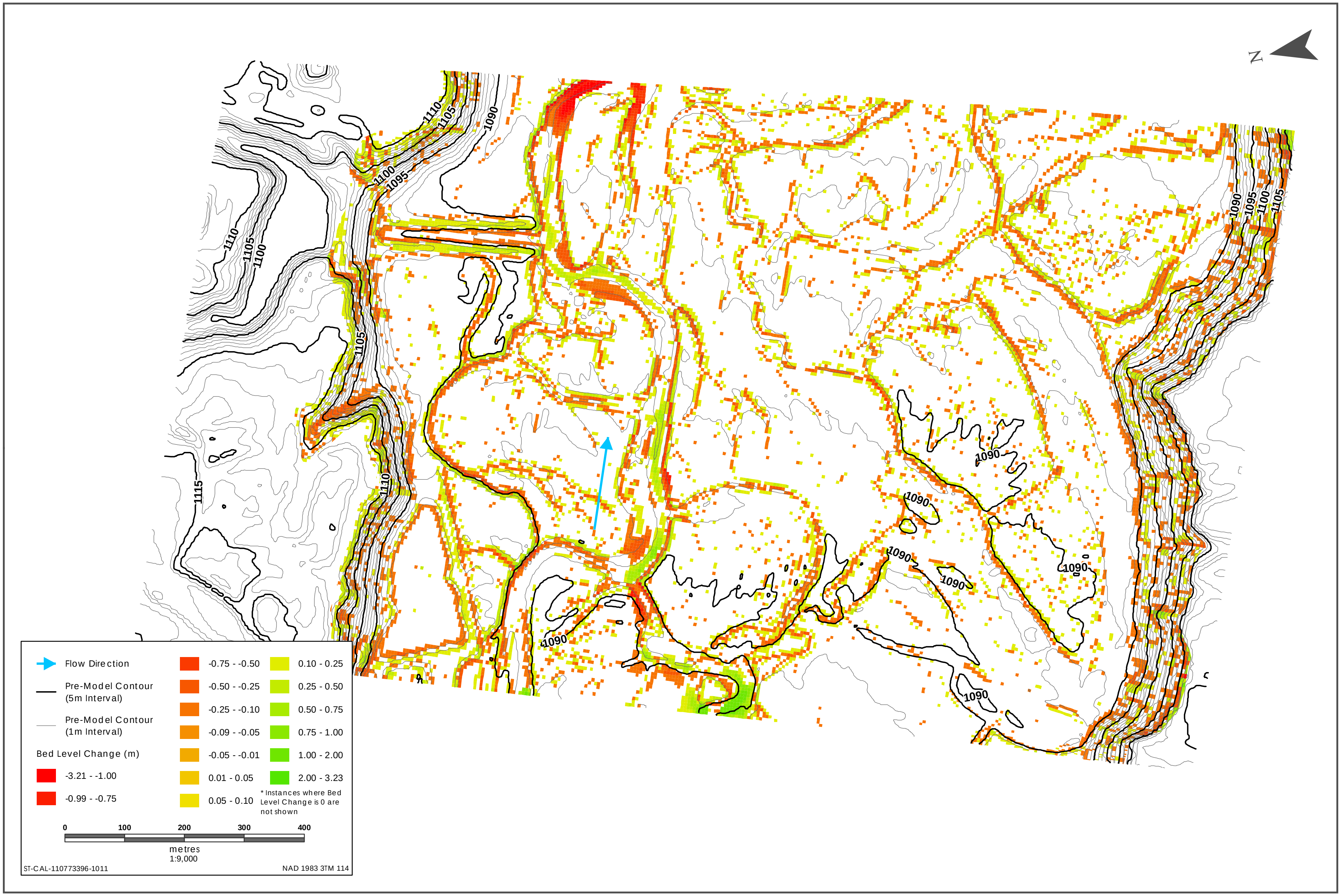
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Existing Bathymetry

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 3



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 10 Year Flood Bathymetry Change (Existing)

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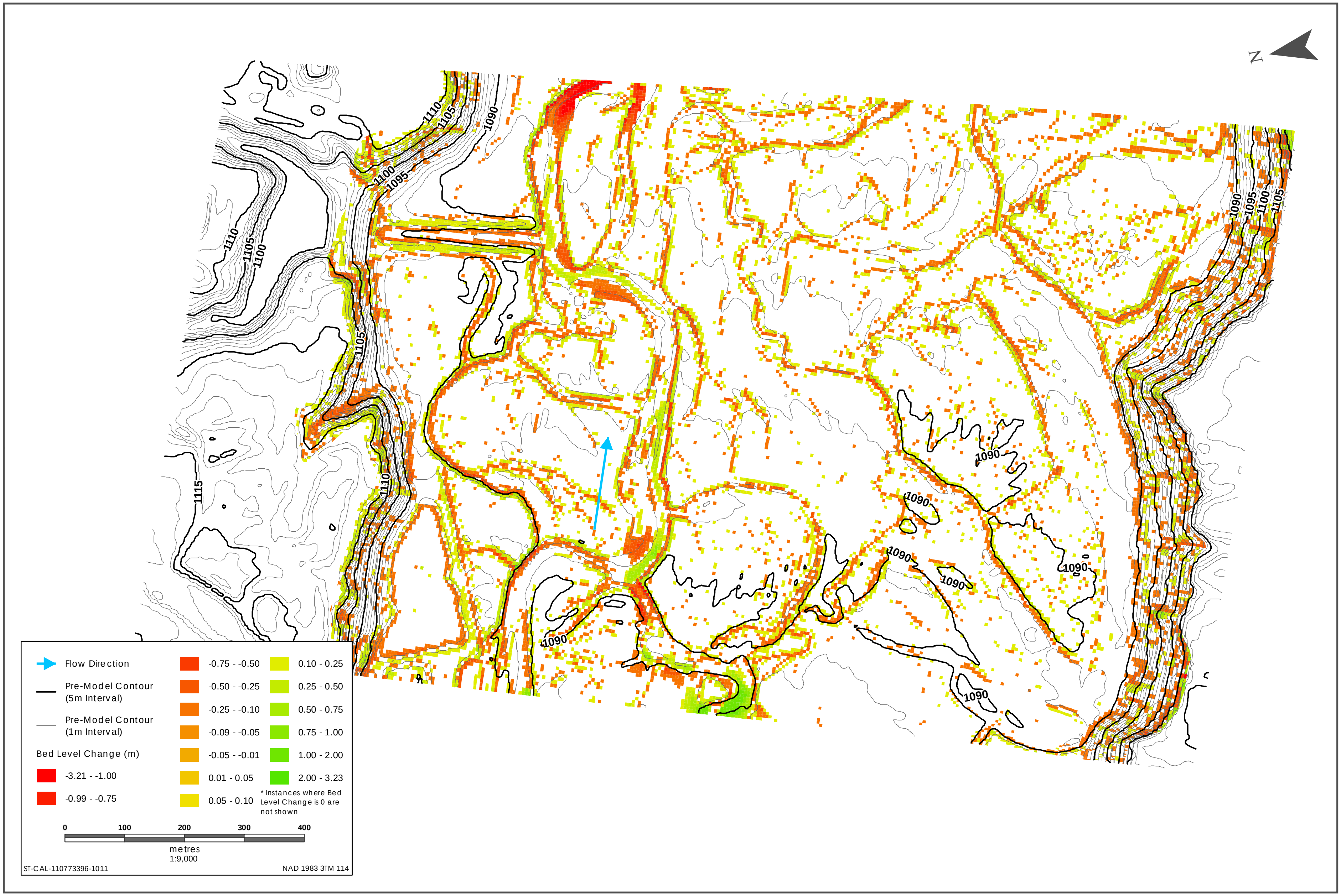
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 4



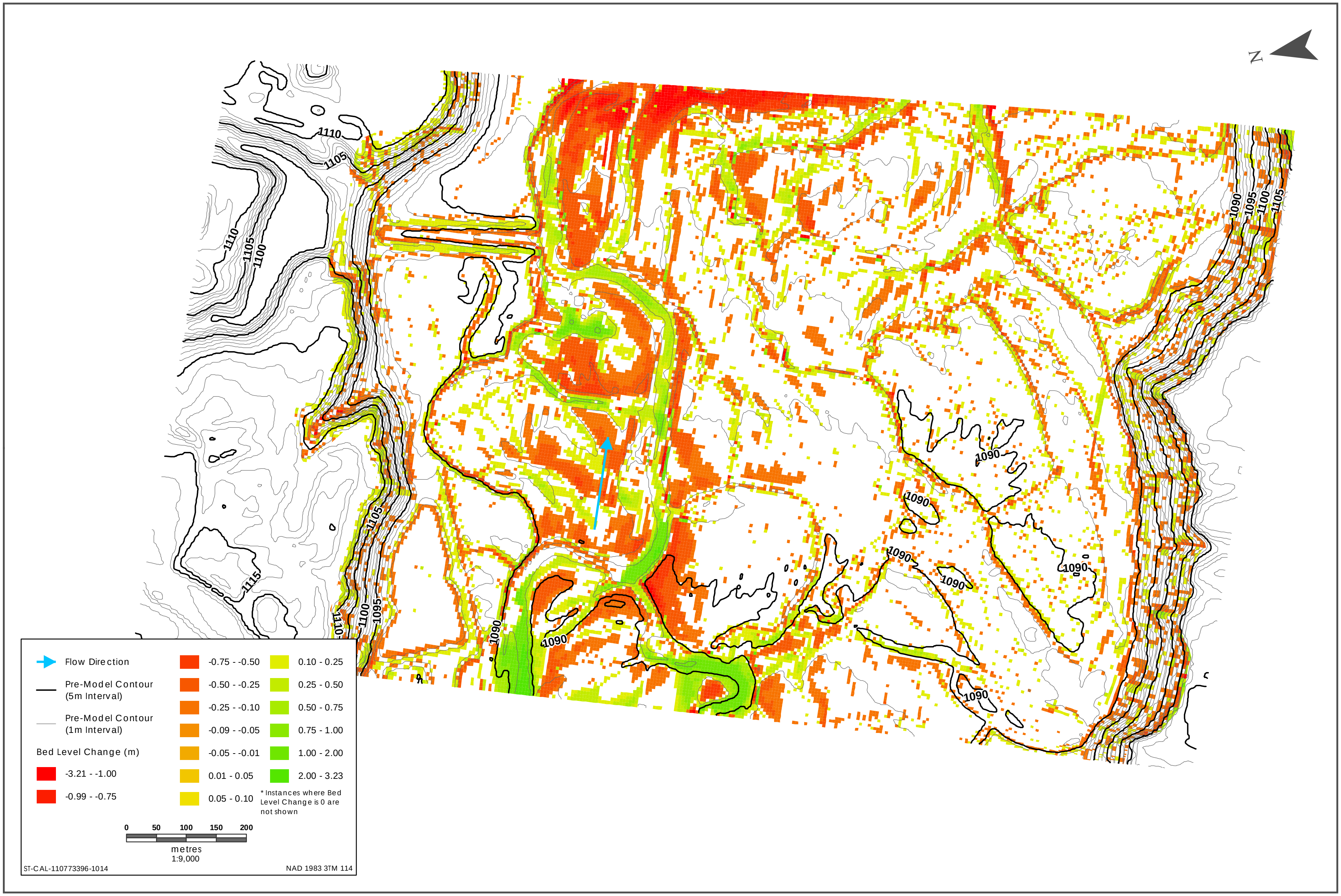
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 10 Year Flood Bathymetry Change (Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

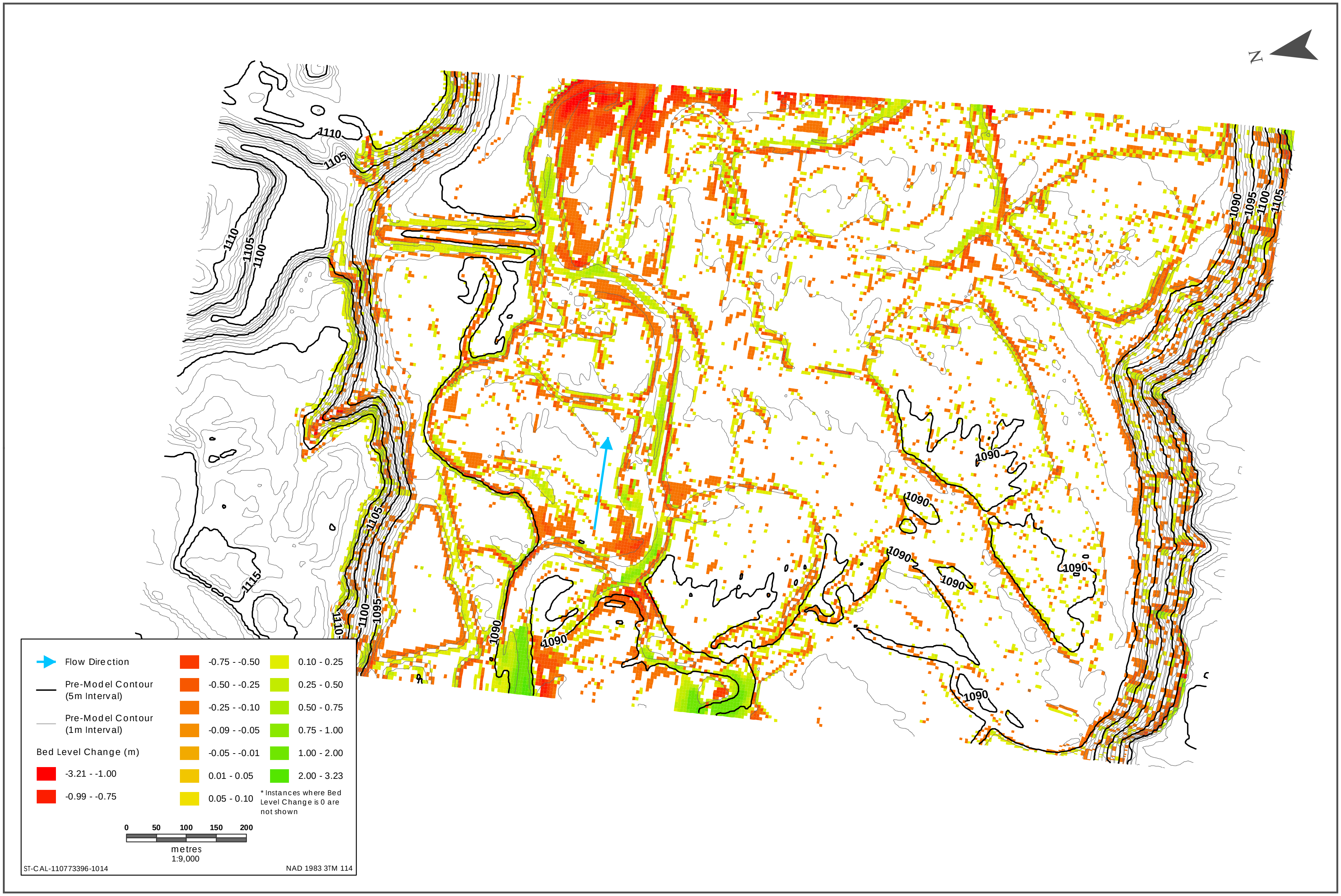
Attachment A - Figure 5



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 100 Year Flood Bathymetry Change (Existing)

Attachment A - Figure 6



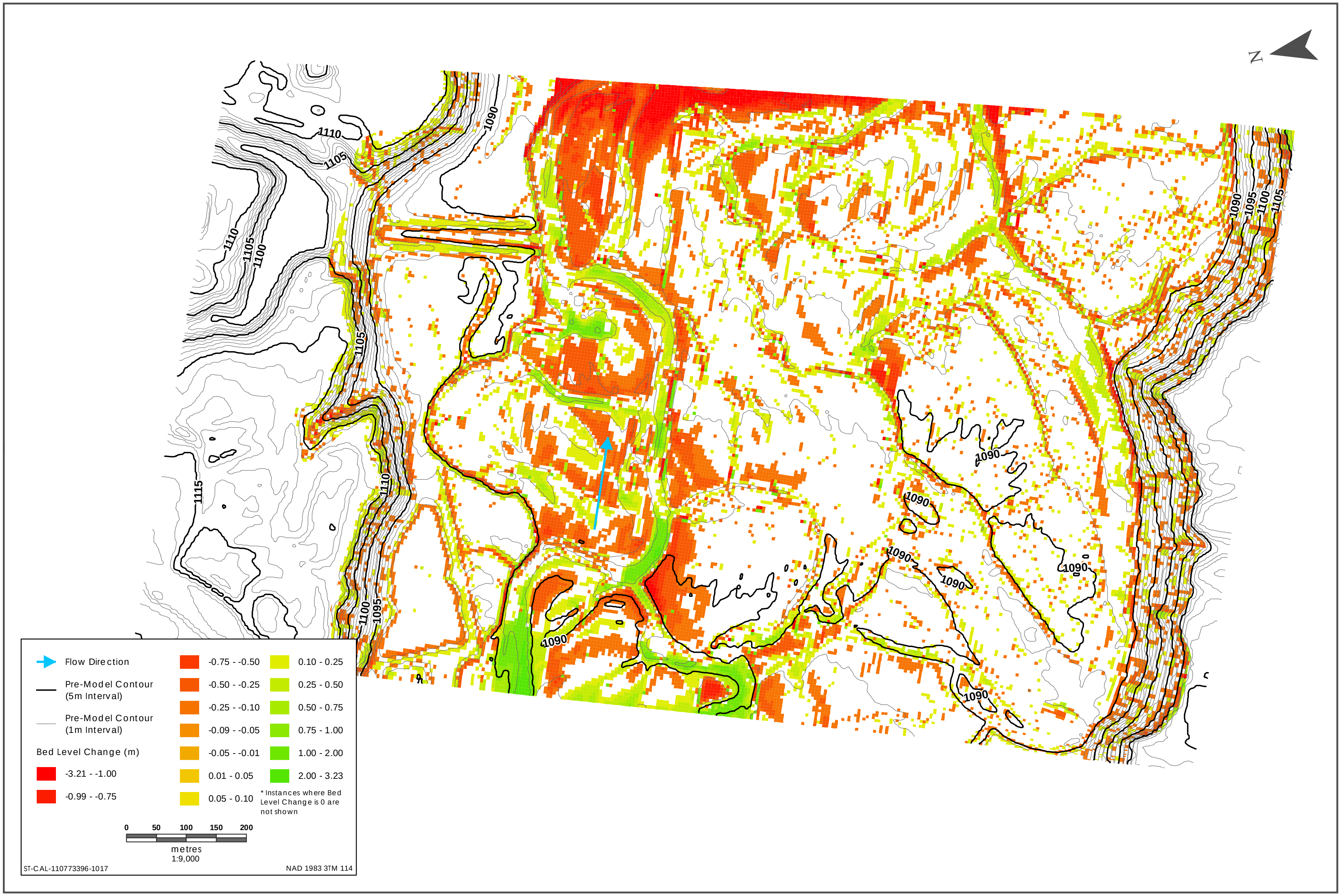
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 100 Year Flood Bathymetry Change (Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 7



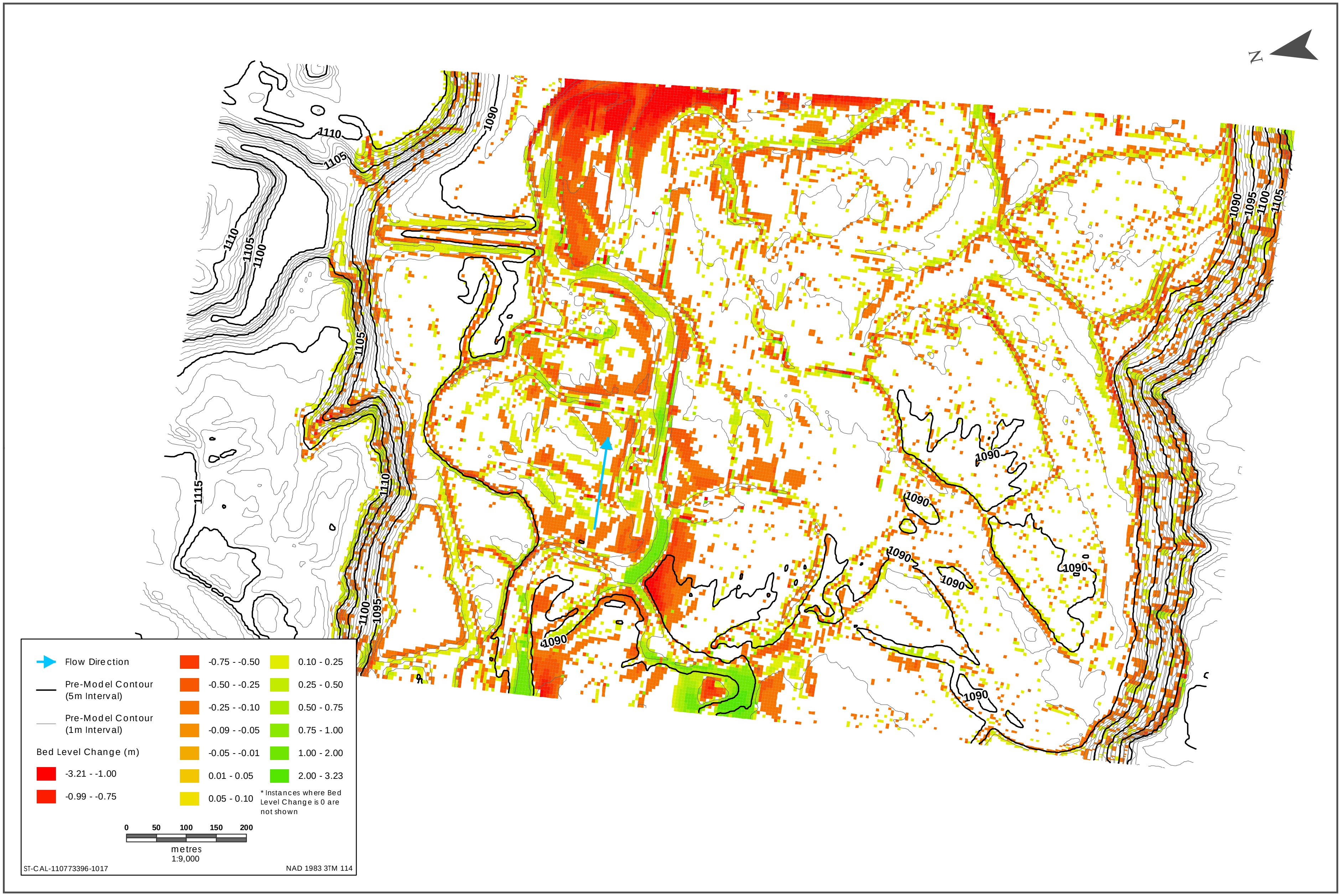
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 2013 Flood Bathymetry Change (Existing)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 8



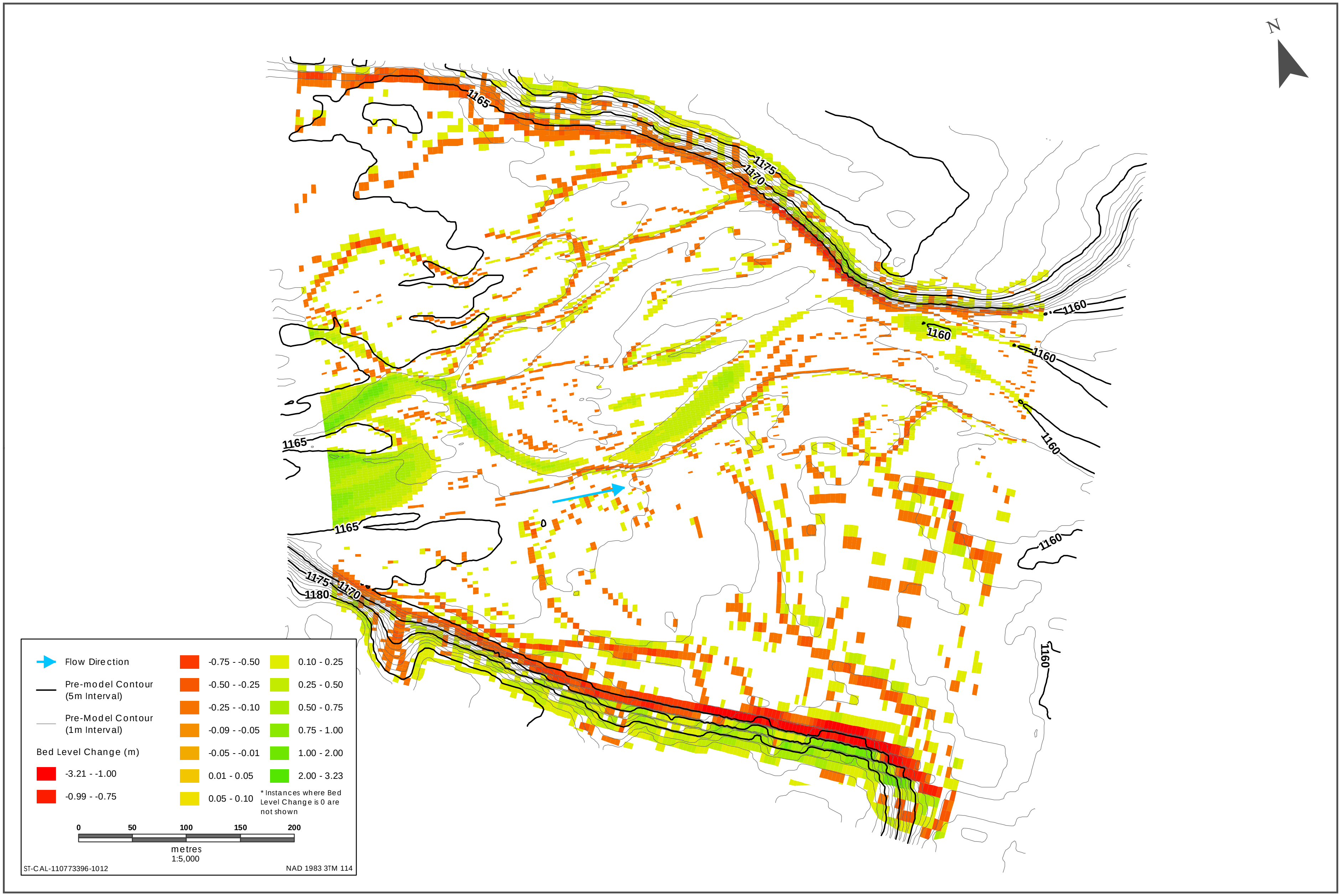
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post 2013 Flood Bathymetry Change (Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 9



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post 10 Year Flood Bathymetry Change (Existing)

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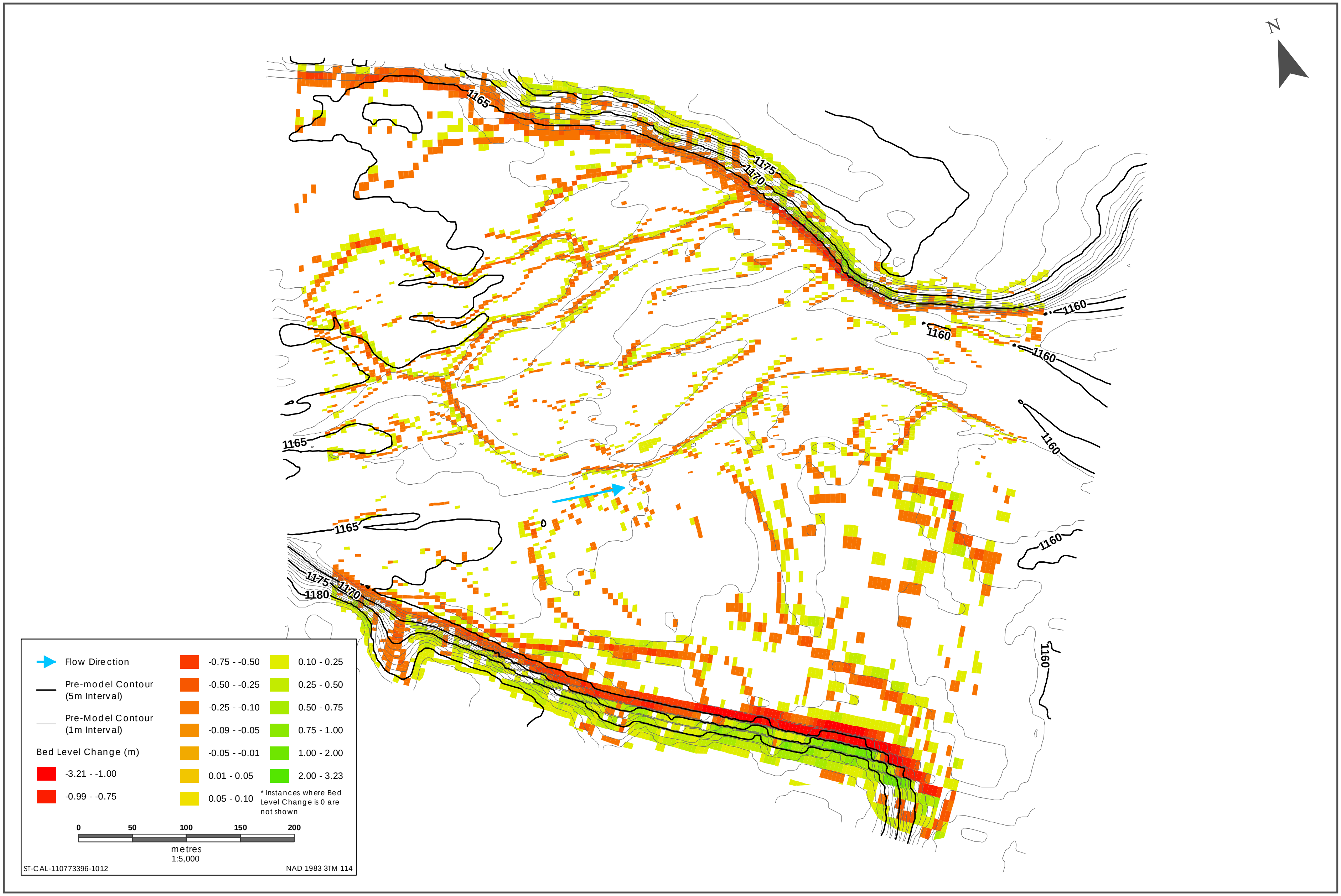
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 10

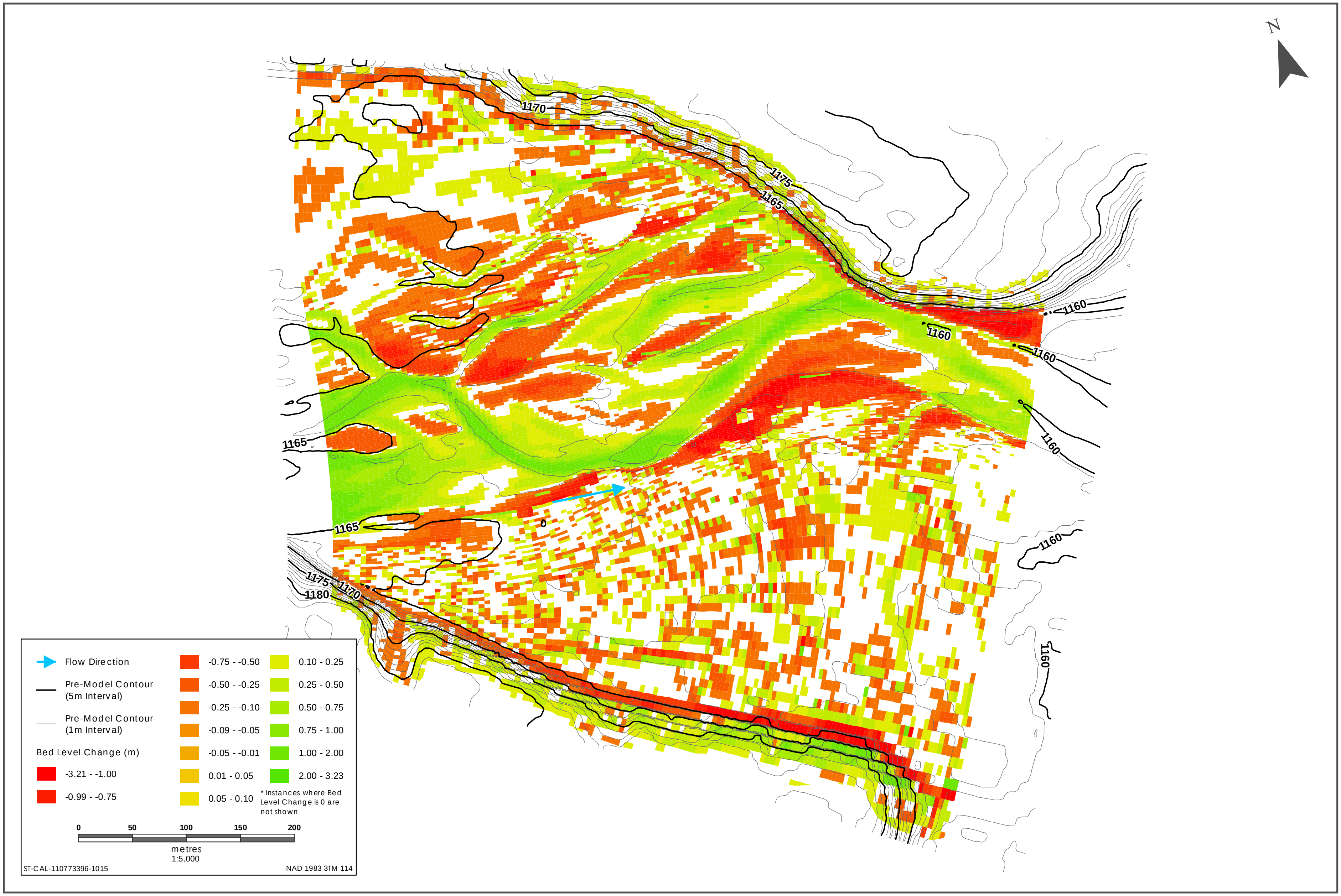


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post 10 Year Flood Bathymetry Change (Project Included)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 11



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post 100 Year Flood Bathymetry Change (Existing)

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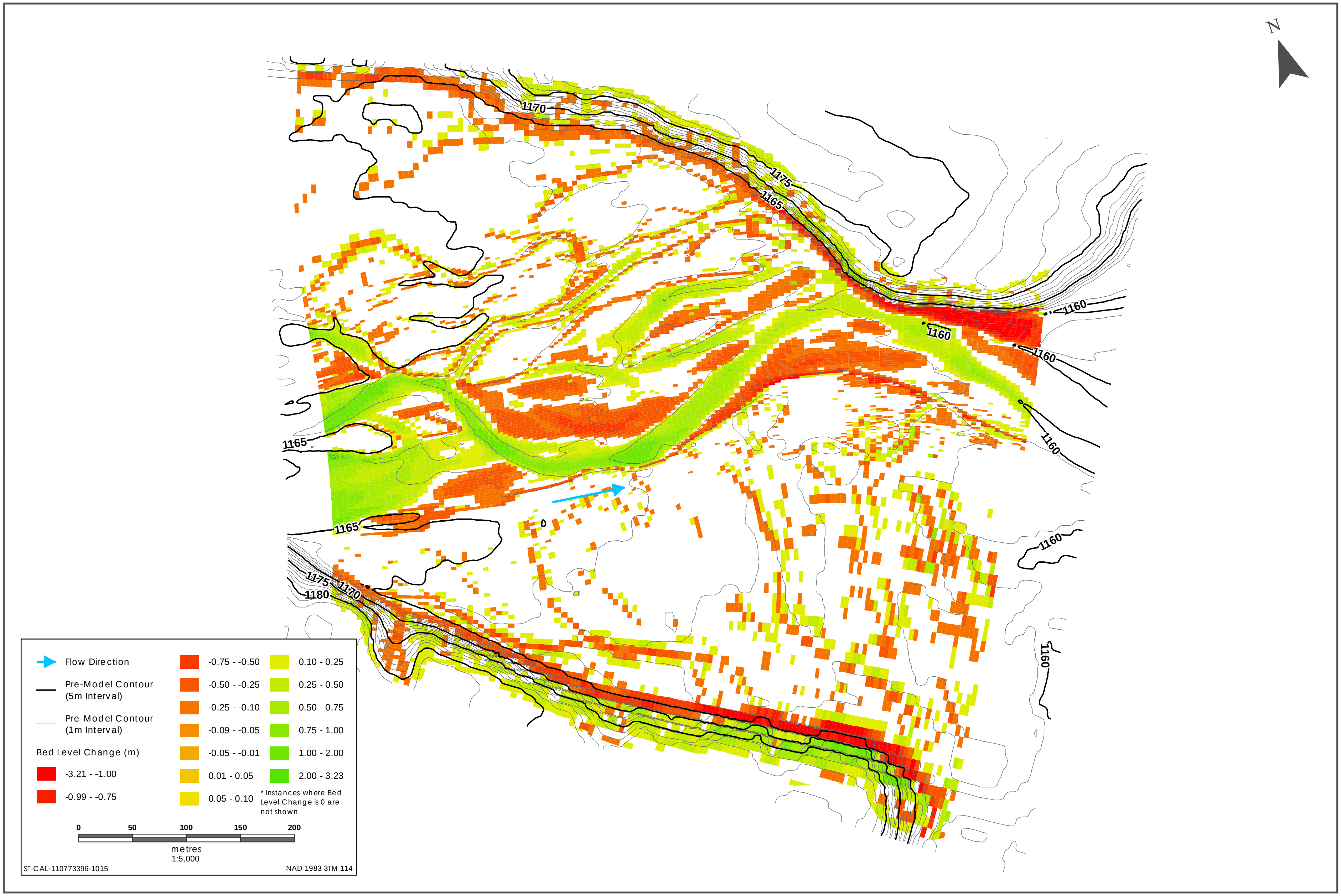
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 12

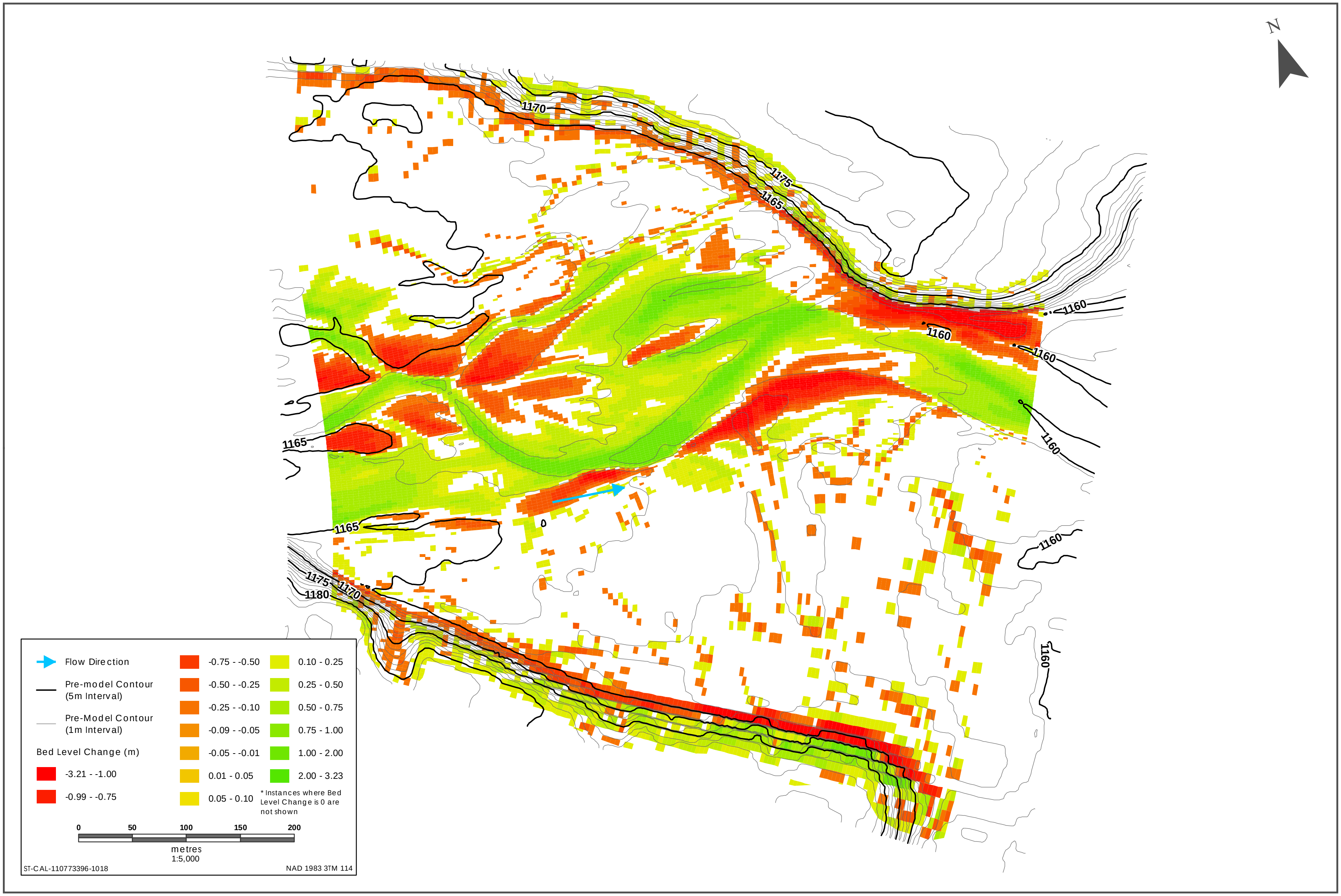


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post 100 Year Flood Bathymetry Change (Project Included)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 13



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

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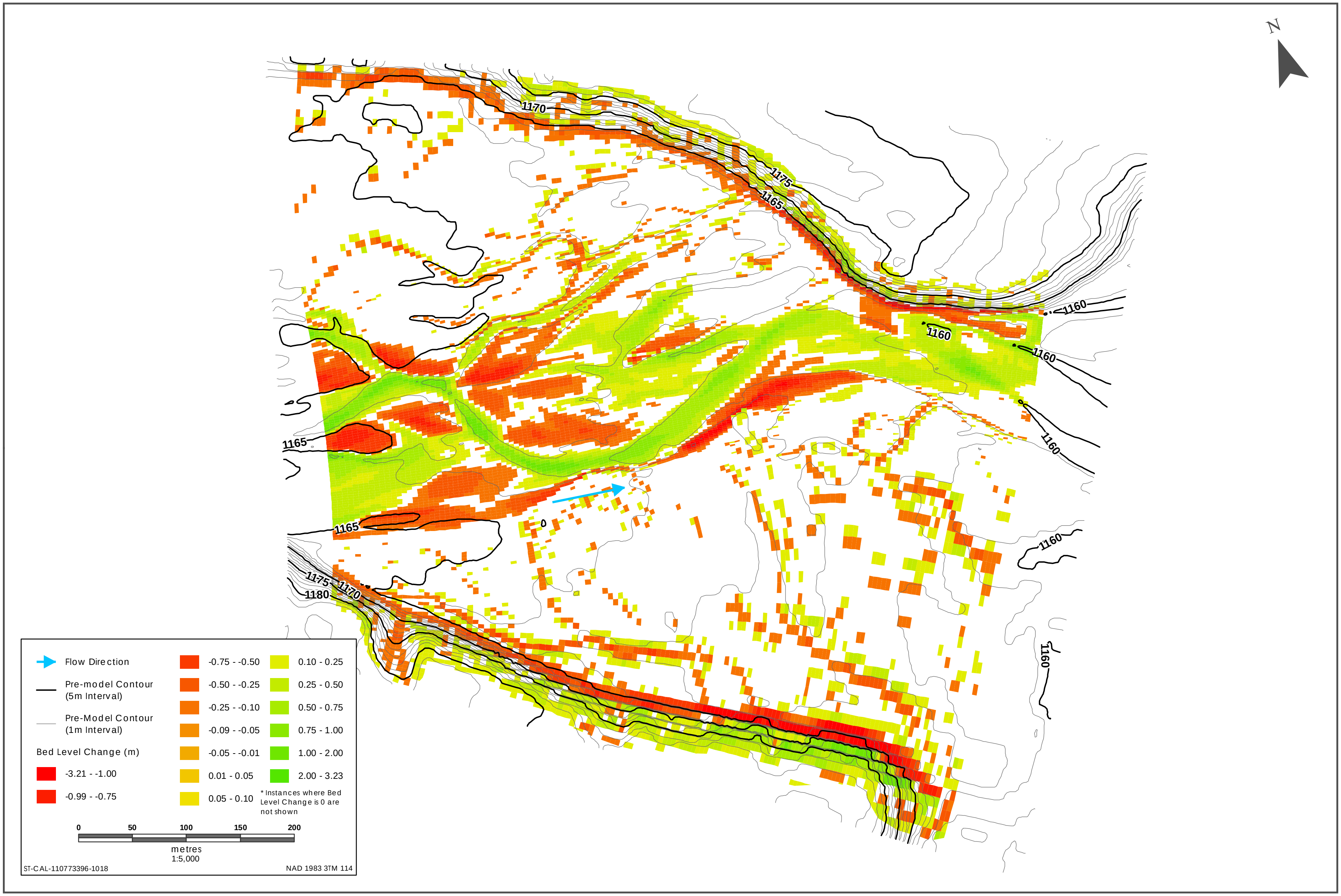
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Reach 2 Post 2013 Flood Bathymetry Change (Existing)

Attachment A - Figure 14



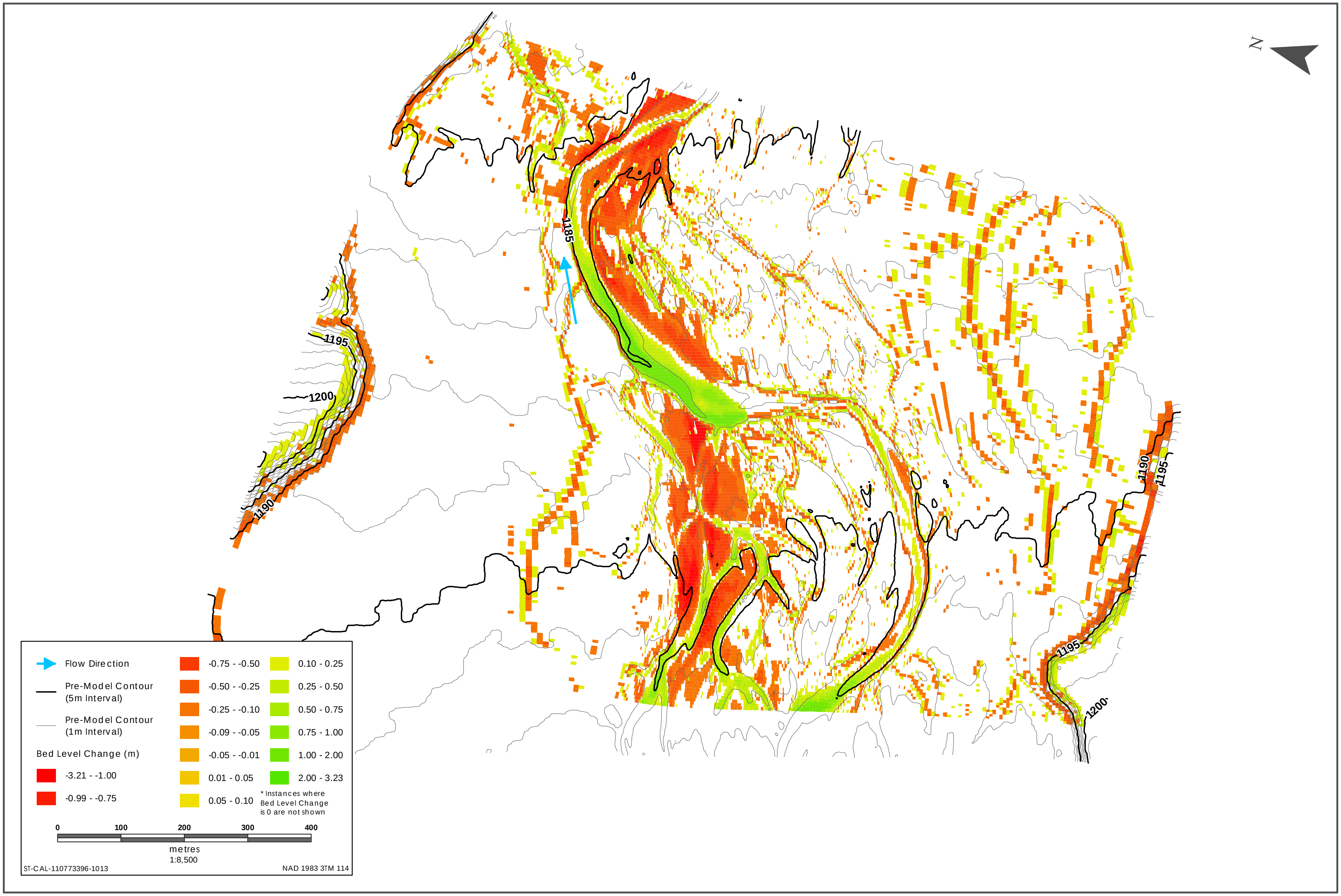
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post 2013 Flood Bathymetry Change (Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 15



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 10 Year Flood Bathymetry Change (Existing)

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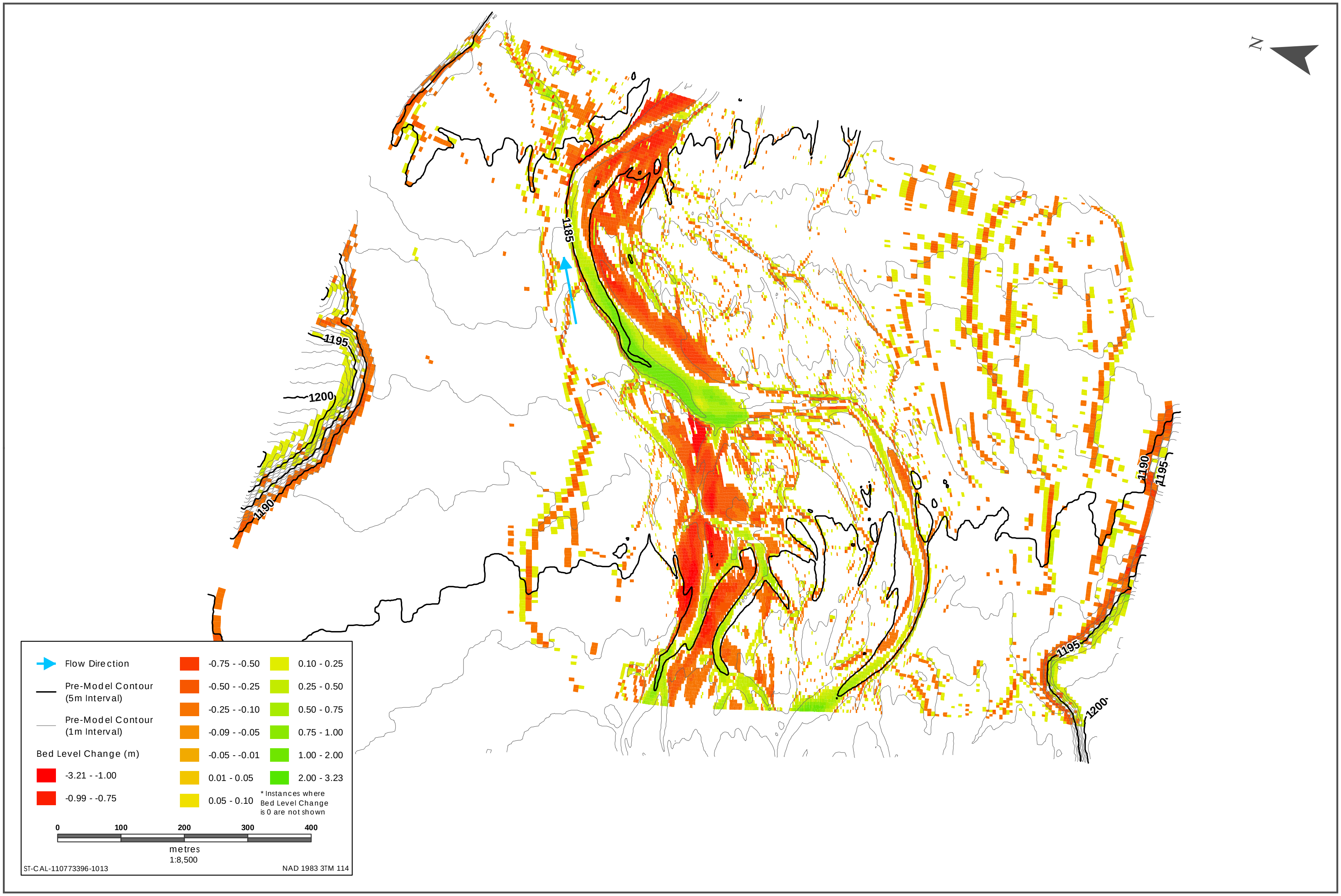
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 16

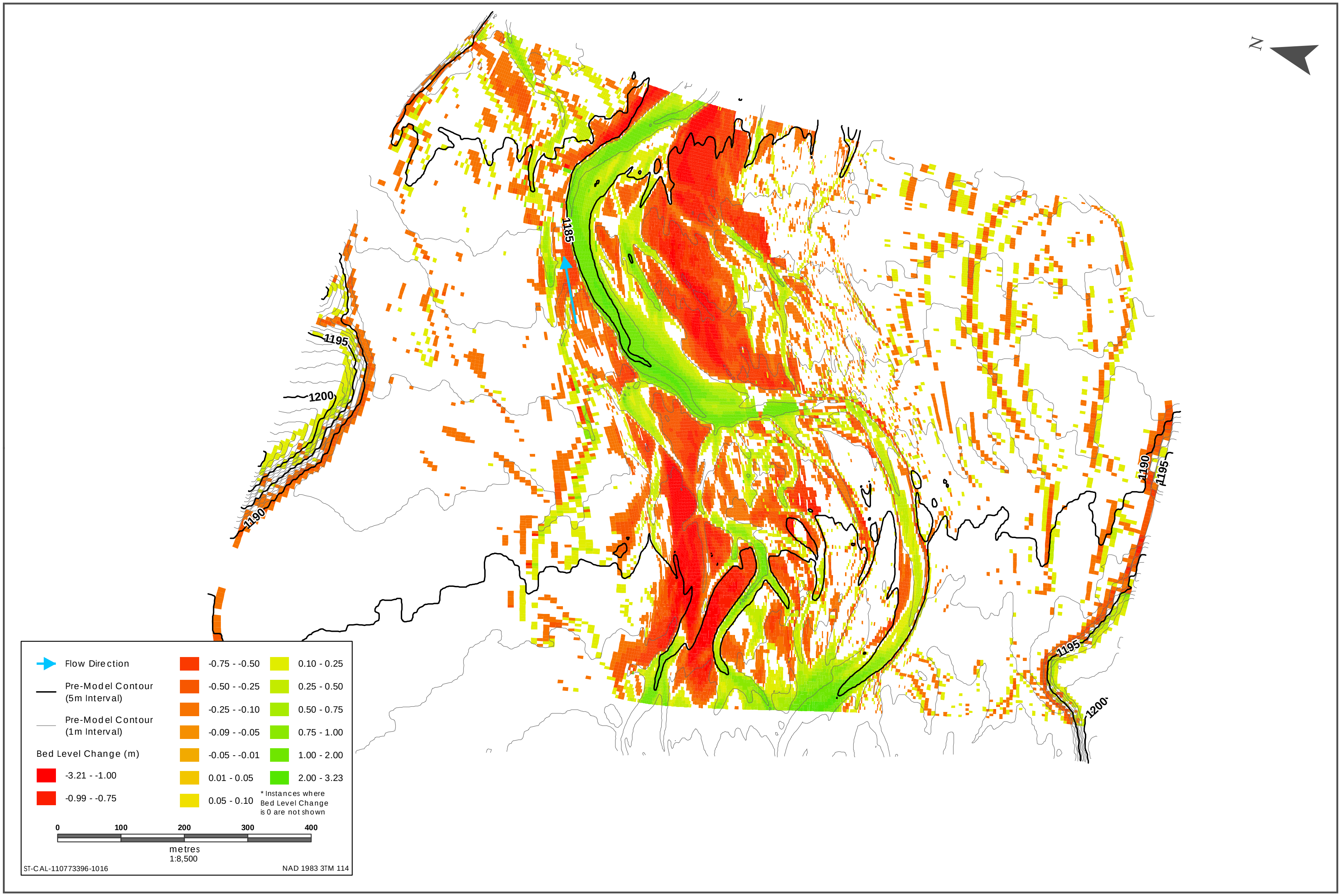


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 10 Year Flood Bathymetry Change (Project Included)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 17

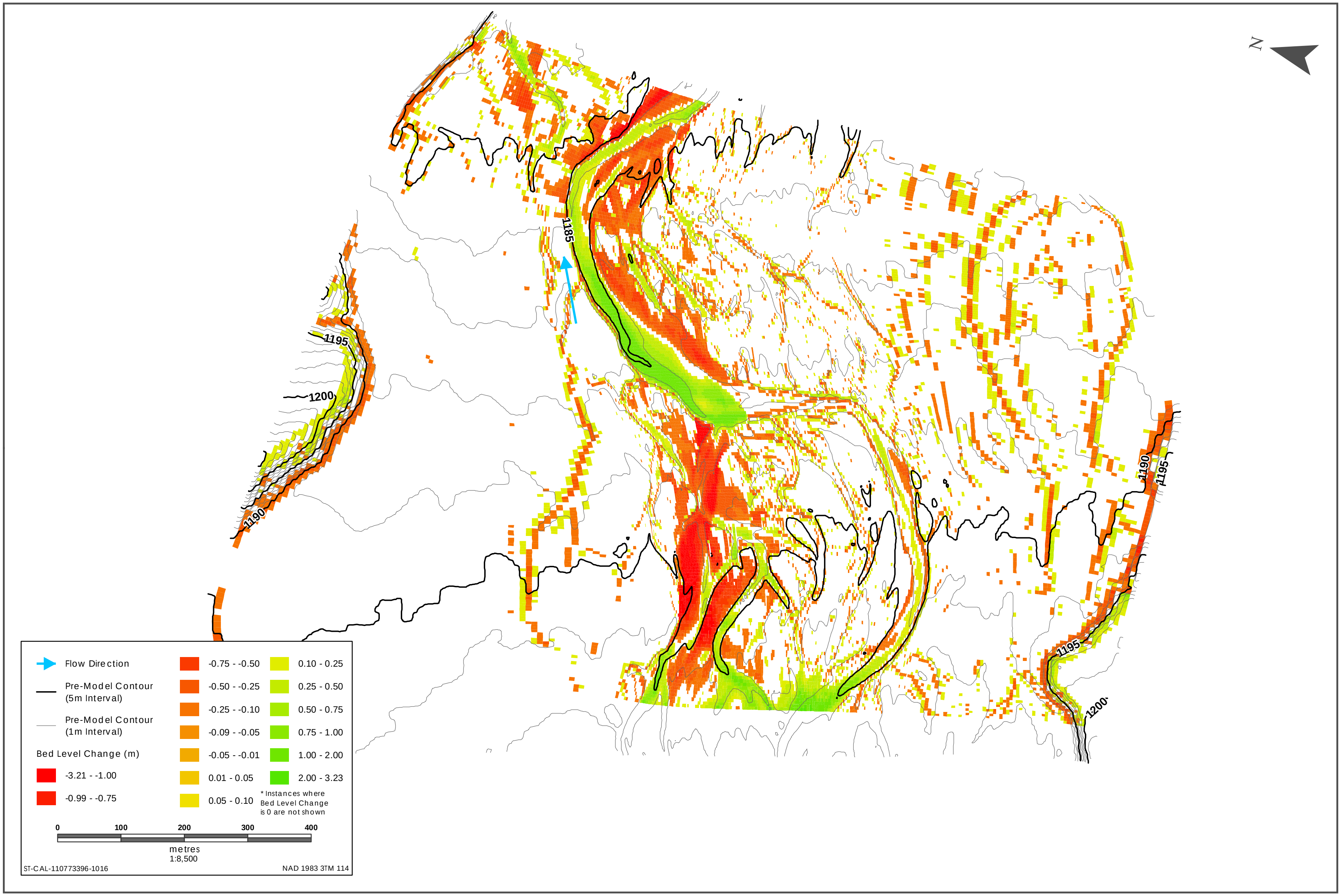


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 100 Year Flood Bathymetry (Existing)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 18

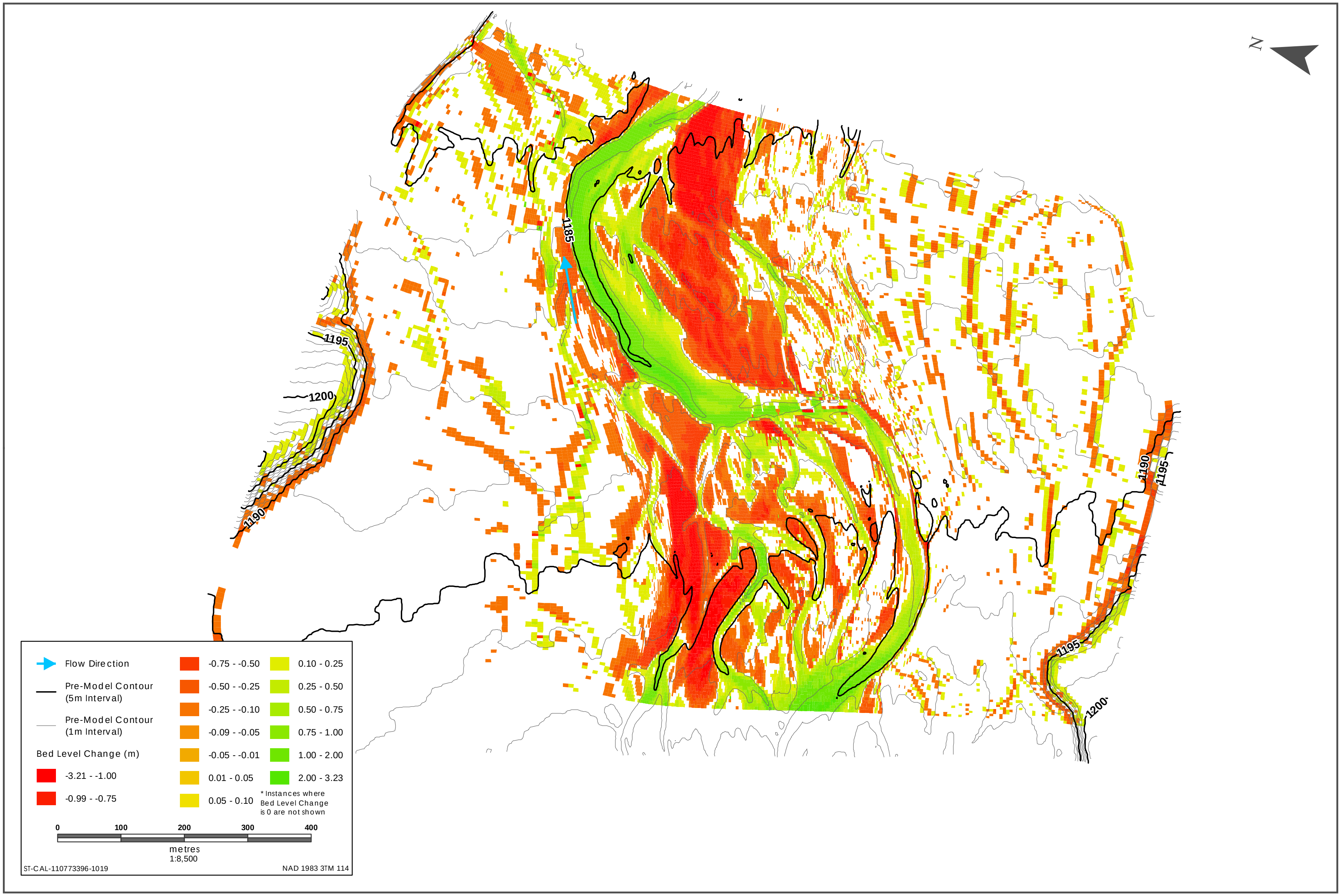


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 100 Year Flood Bathymetry (Project Included)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 19

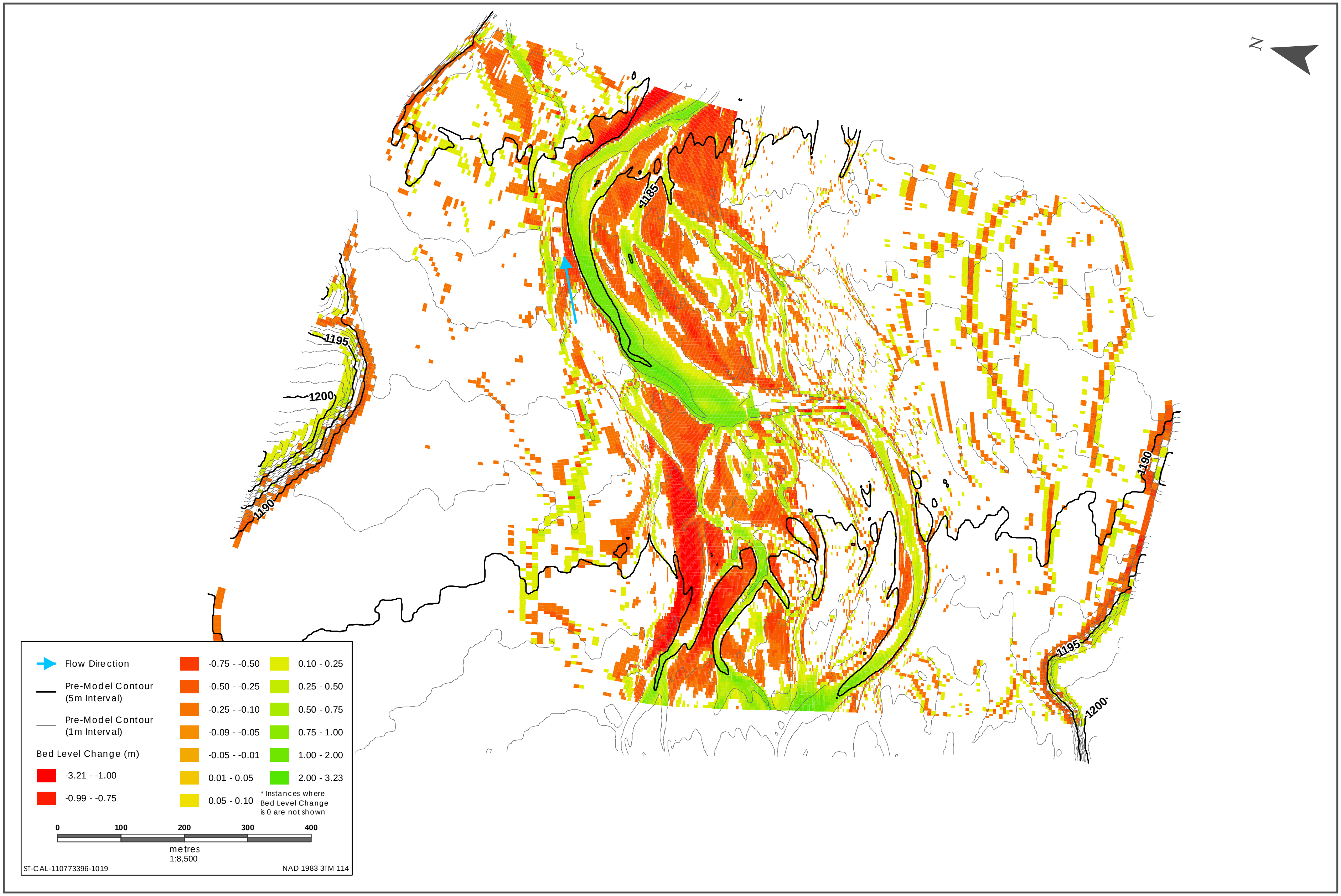


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 2013 Flood Bathymetry Change (Existing)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 20



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post 2013 Flood Bathymetry Change (Project Included)

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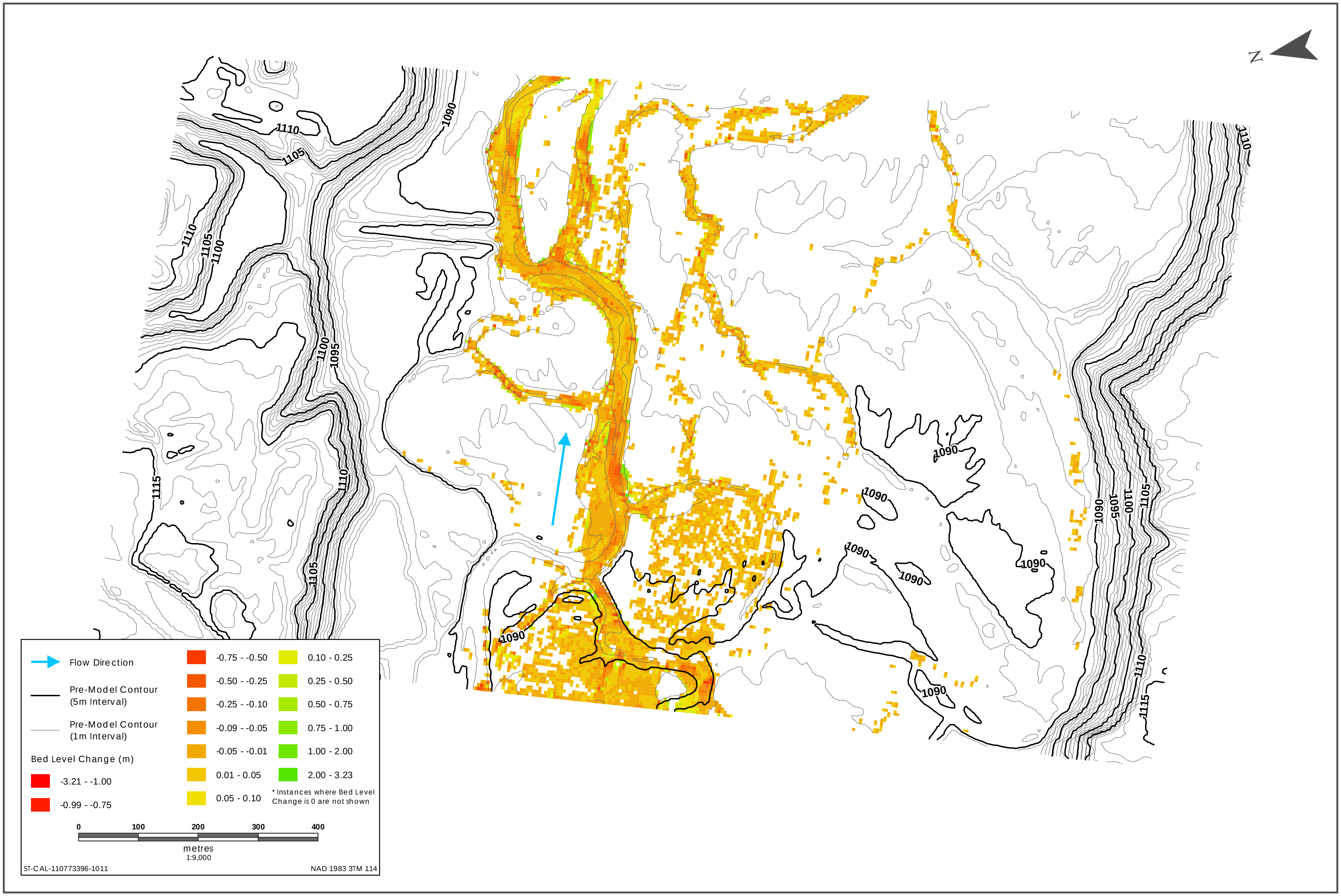
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 21



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:10 Year Post-Flood Bedform (Reach 1)

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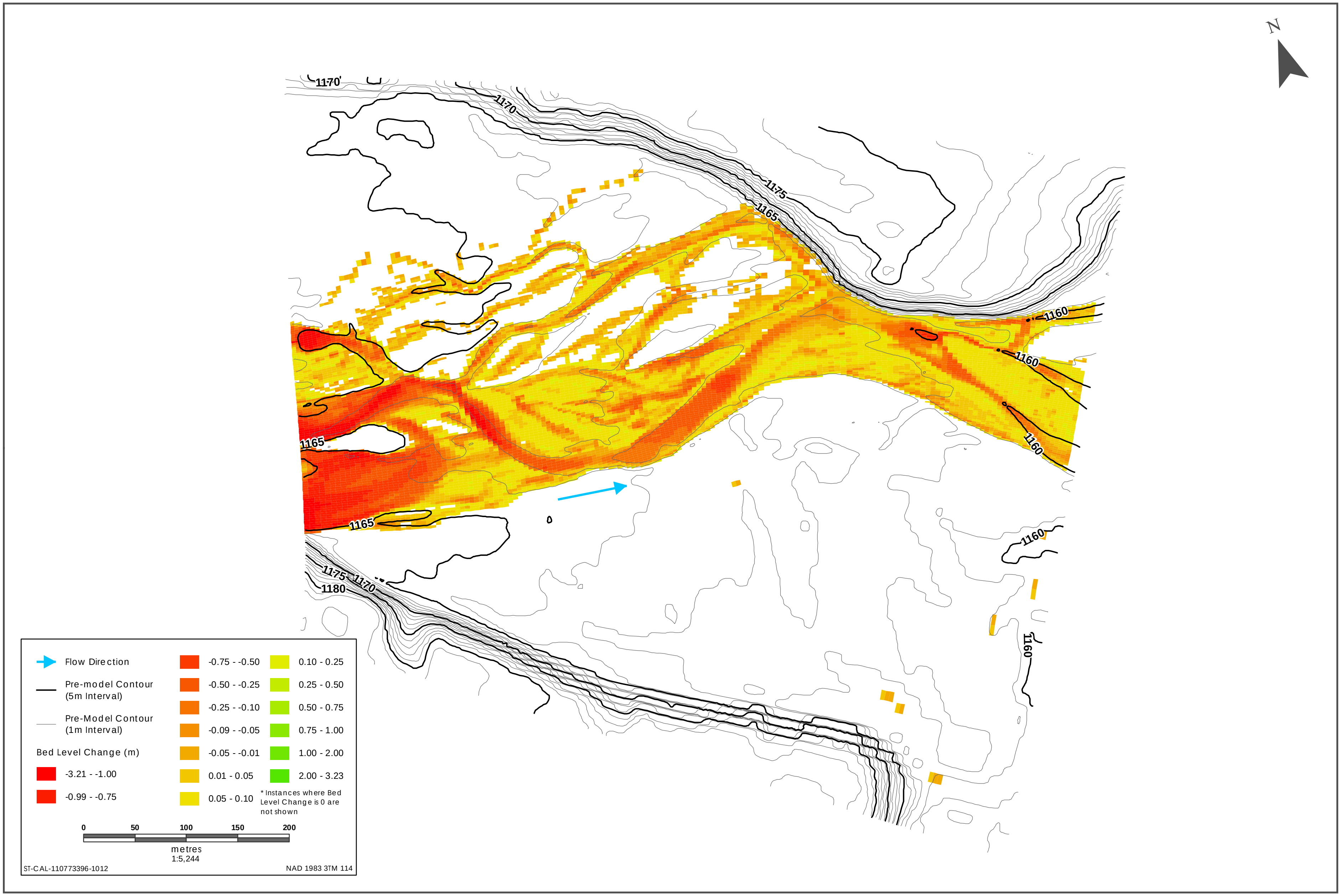
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 22



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:10 Year Post-Flood Bedform (Reach 2)

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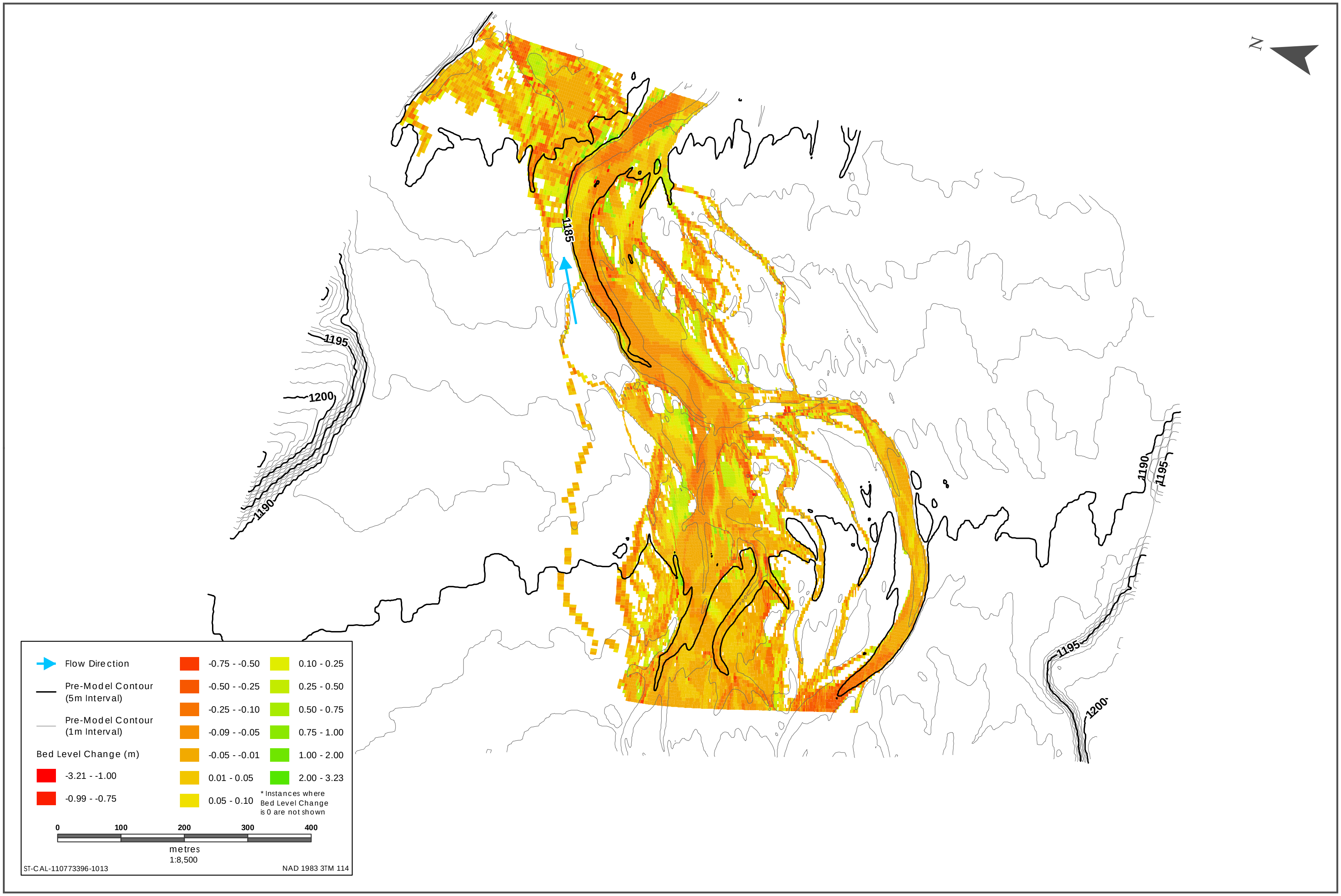
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 23

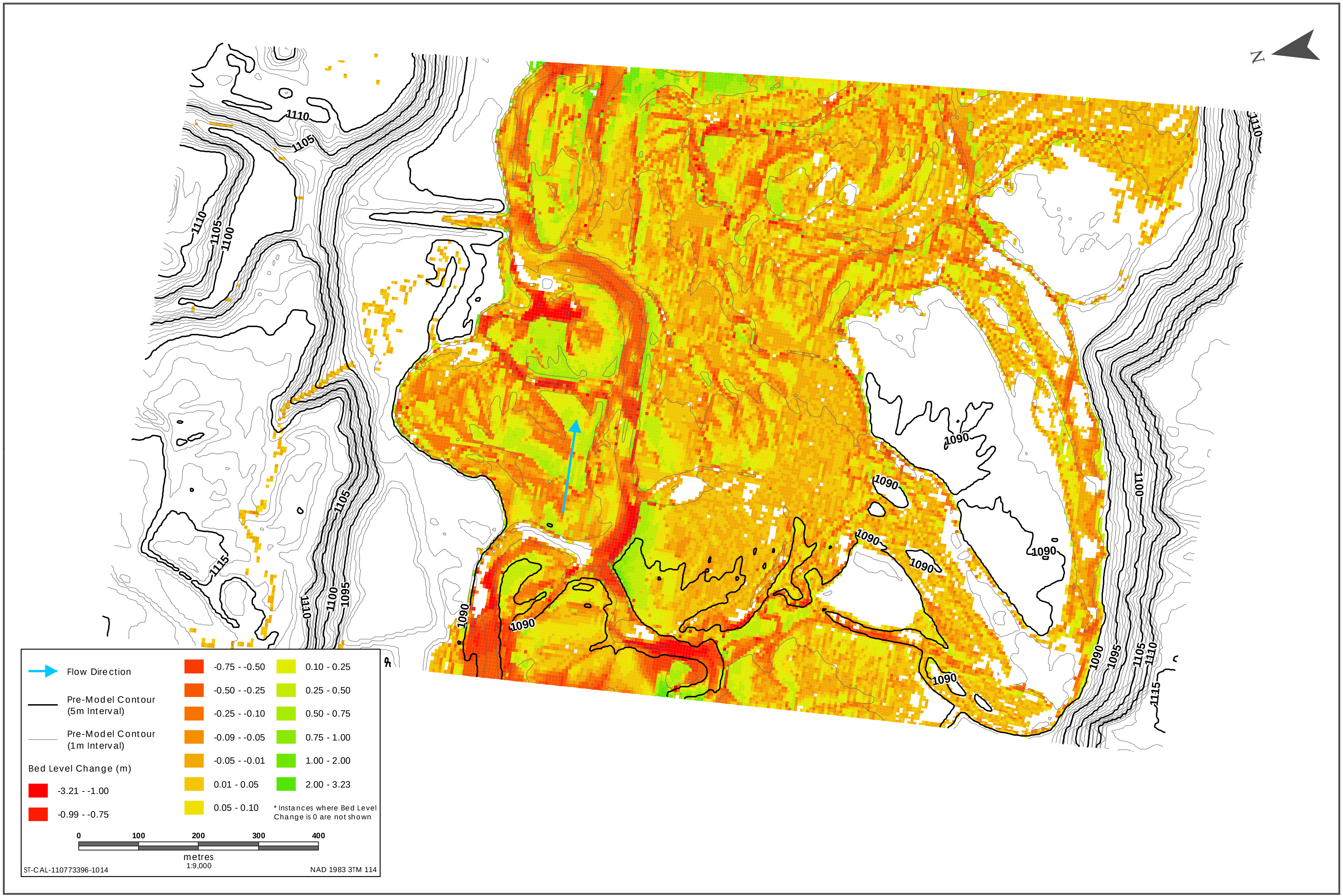


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:10 Year Post-Flood Bedform (Reach 3)

Stantec

Attachment A - Figure 24

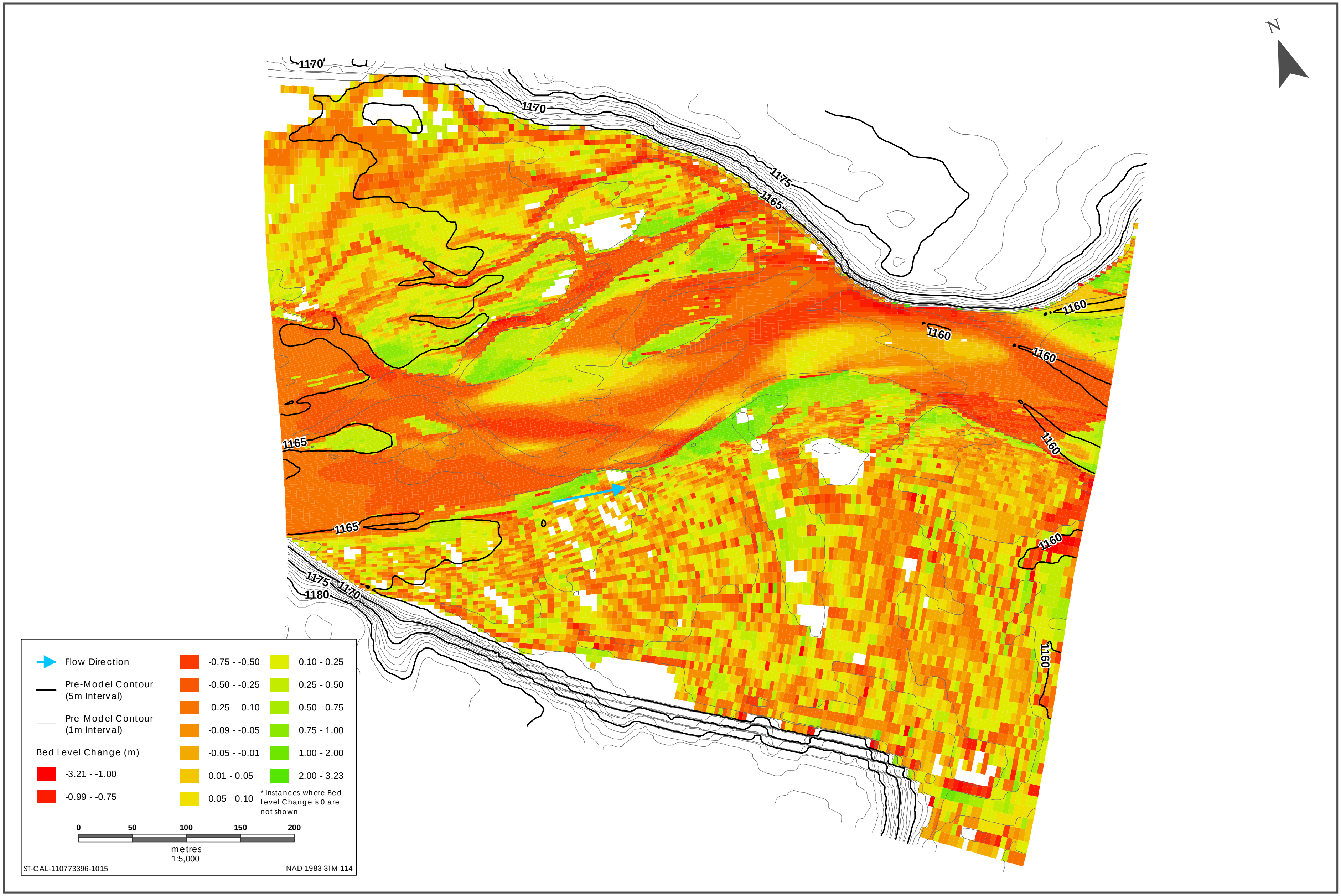


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:100 Year Post-Flood Bedform (Reach 1)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 25



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:100 Year Post-Flood Bedform (Reach 2)

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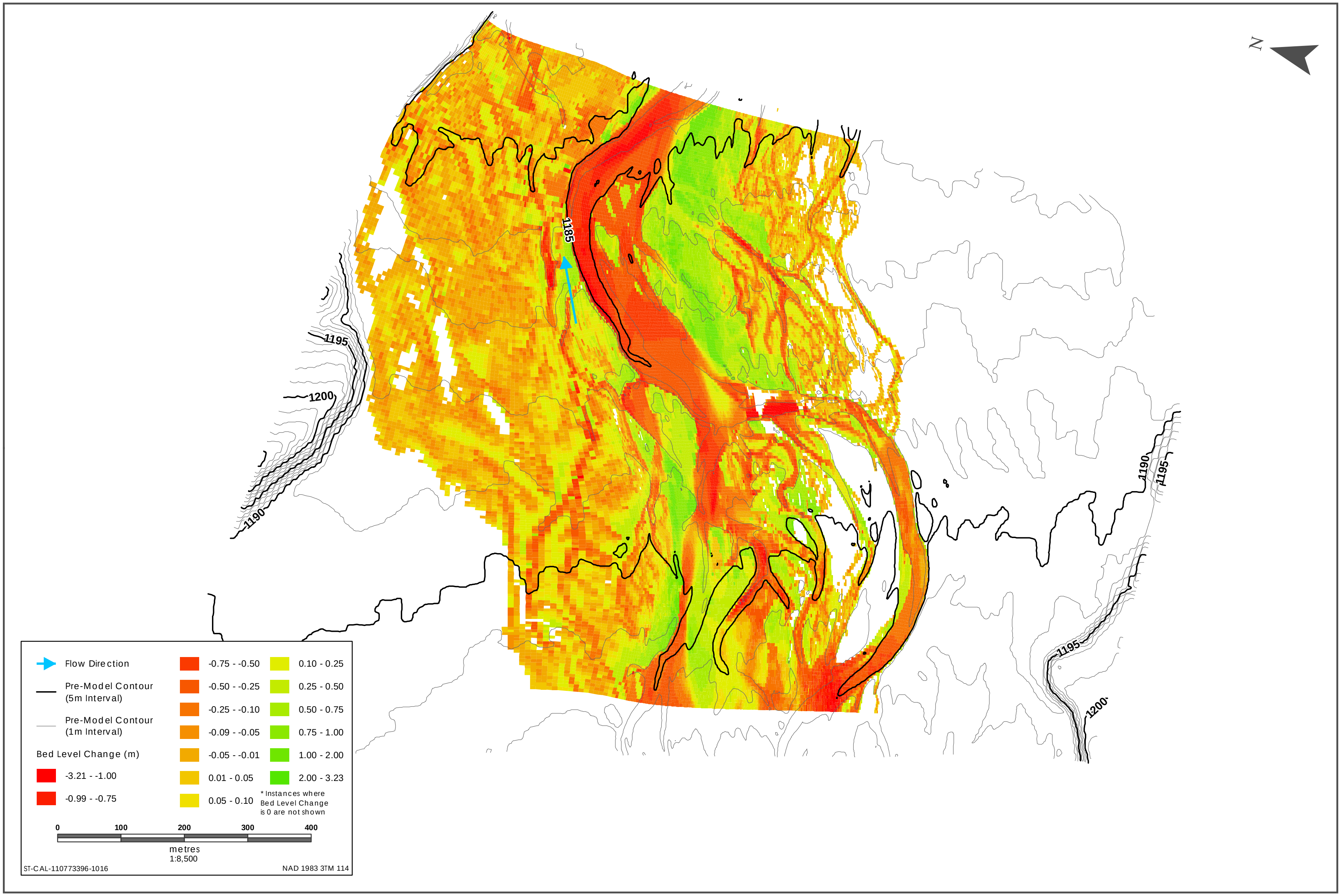
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 26

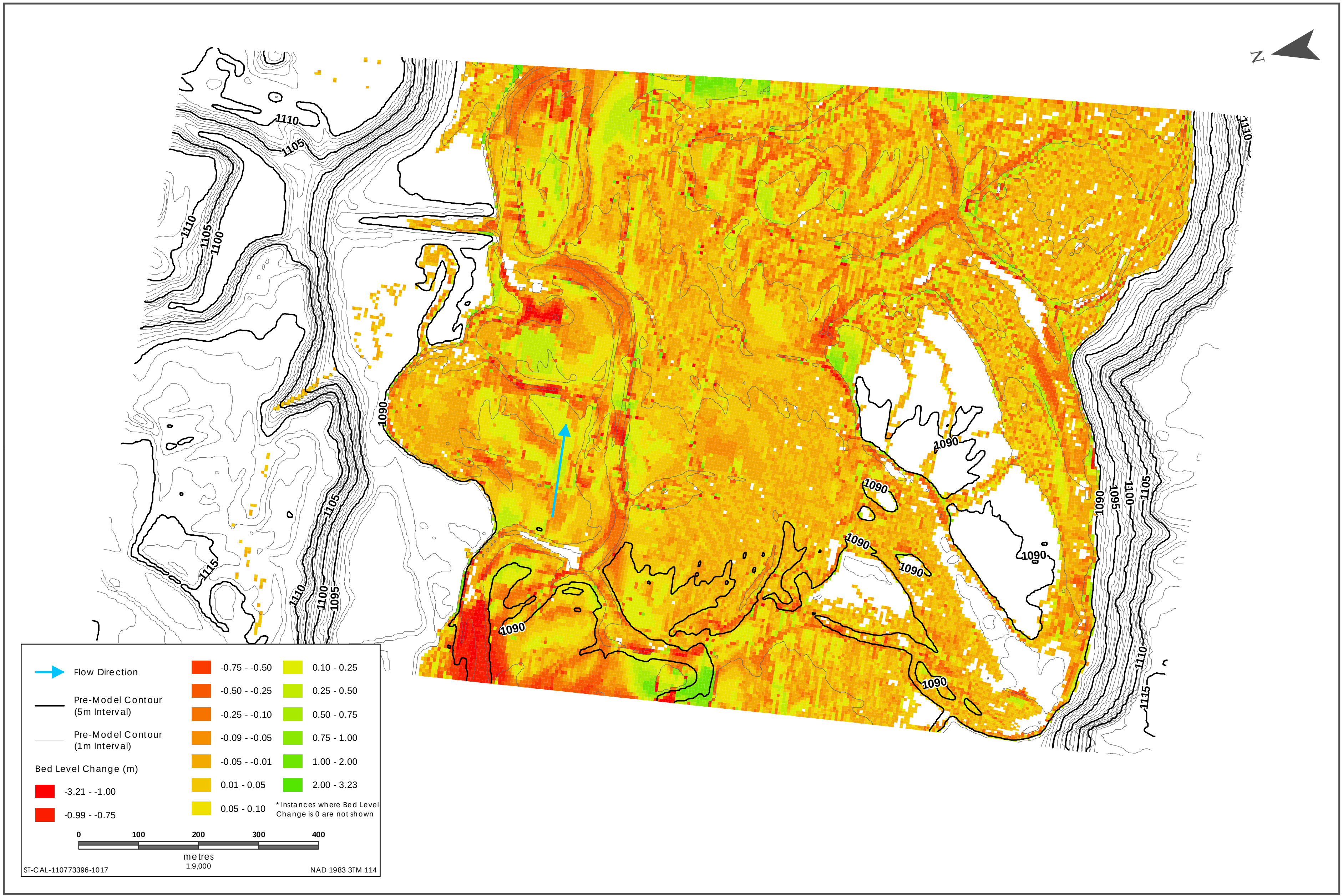


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 1:100 Year Post-Flood Bedform (Reach 3)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 27



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 2013 Flood Post-Flood Bedform (Reach 1)

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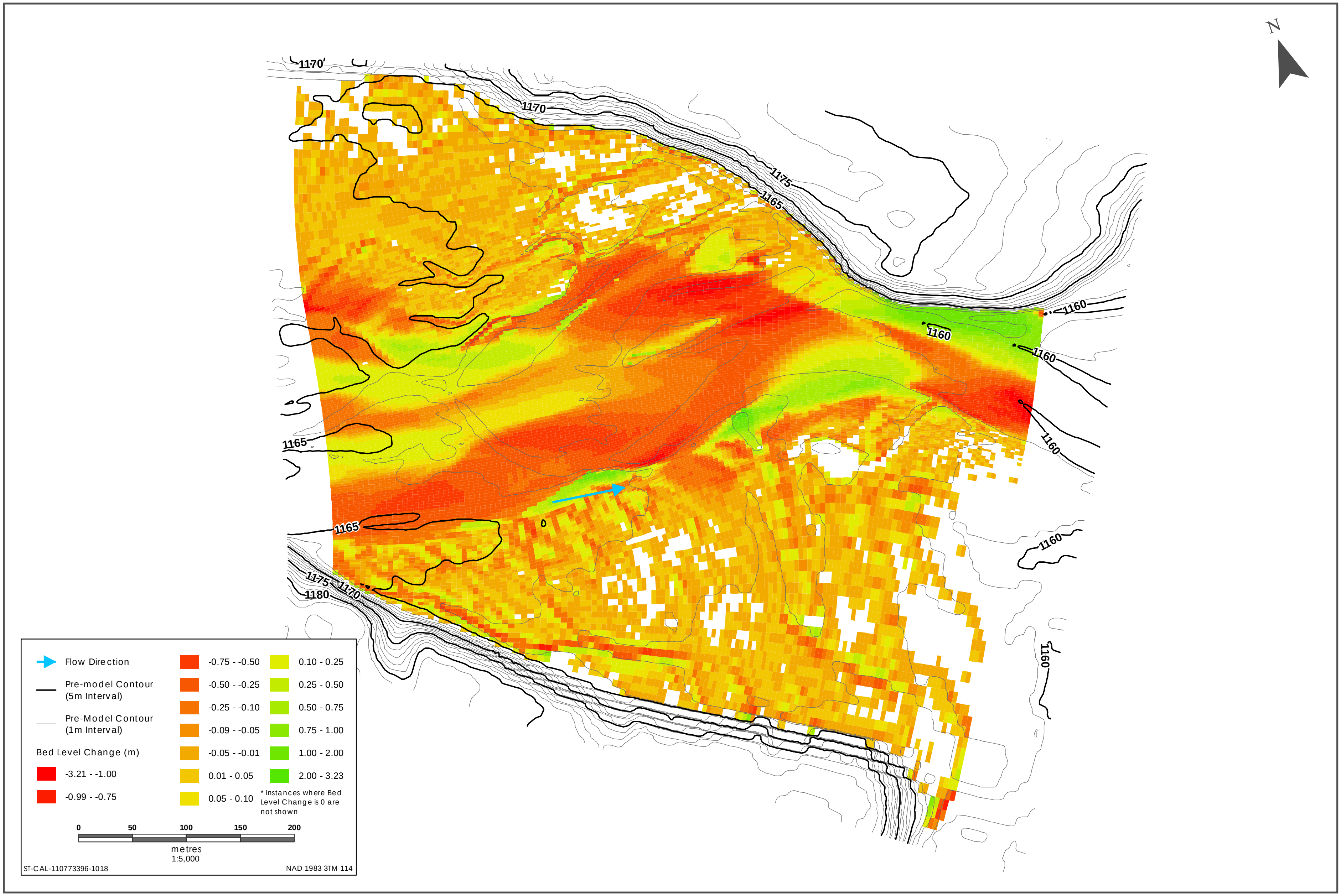
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 28



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 2013 Flood Post-Flood Bedform (Reach 2)

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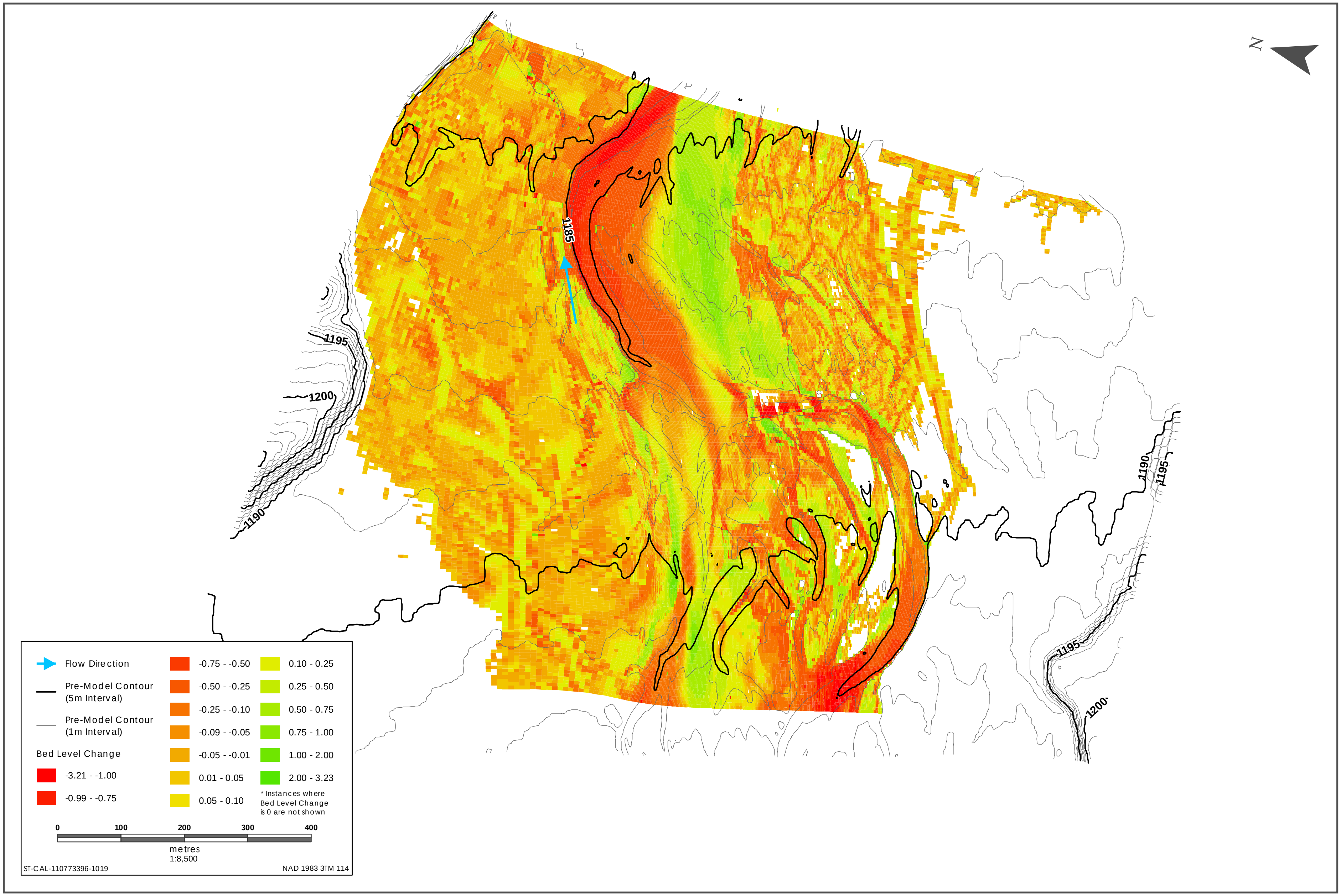
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 29



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Project-Related Changes to 2013 Flood Post-Flood Bedform (Reach 3)

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 30

APPENDIX 23-2 FISH HABITAT SUITABILITY INDEX (HSI) ANALYSIS OF MODELLED SCENARIOS IN THE ELBOW RIVER

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 23-2 Fish Habitat Suitability Index (HSI) Analysis of Modelled Scenarios in the Elbow River
June 2020

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Fish Habitat Suitability Index (HSI) Analysis of Modelled Scenarios in Elbow River
Technical Data Report

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

June 2020

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Abbreviations

AEP	Alberta Environment and Parks
EIA	Environmental Impact Assessment
EMA	Environmental Management Associates
HSC	habitat suitability criteria
HSI	habitat suitability index
LiDAR	light detection and ranging
SSRB	South Saskatchewan River Basin
WUA	weighted usable area

1.0 INTRODUCTION

Alberta Transportation plans to construct the Springbank Off-stream Reservoir Project (the Project) to mitigate the effects of floodwaters from the Elbow River on southern Alberta and the City of Calgary. The Project is situated on the main stem of the Elbow River, between Elbow Falls and Glenmore Reservoir. This section of river supports traditional and recreational brown trout, bull trout, mountain whitefish, rainbow trout, brook trout, and burbot fisheries along with a variety of non-sport fish species.

Construction of the diversion inlet and spillway, flood operations, and post-flood operations will result in changes to physical habitat, flow regime, and water quality in the Elbow River. It is anticipated that these changes will result in harmful alteration, disruption, or destruction of fish habitat. However, these habitat alterations will be mitigated and offset to maintain the productivity of local fisheries (review with Fisheries and Oceans Canada currently in progress).

This technical data report has been prepared to support Supplemental Information Requests associated with the Project's Environmental Impact Assessment (EIA). This report presents a quantitative analysis of potential Project-related effects on habitat suitability for key indicator fish species by applying a habitat suitability index (HSI) approach to modelled channel morphology scenarios and discharges. The purpose of this report is to provide the predicted changes in fish habitat that may occur due to the Project, with specific focus on how predicted flow changes during operation of the Project will influence channel morphology and fish habitat suitability in Elbow River.

2.0 METHODS

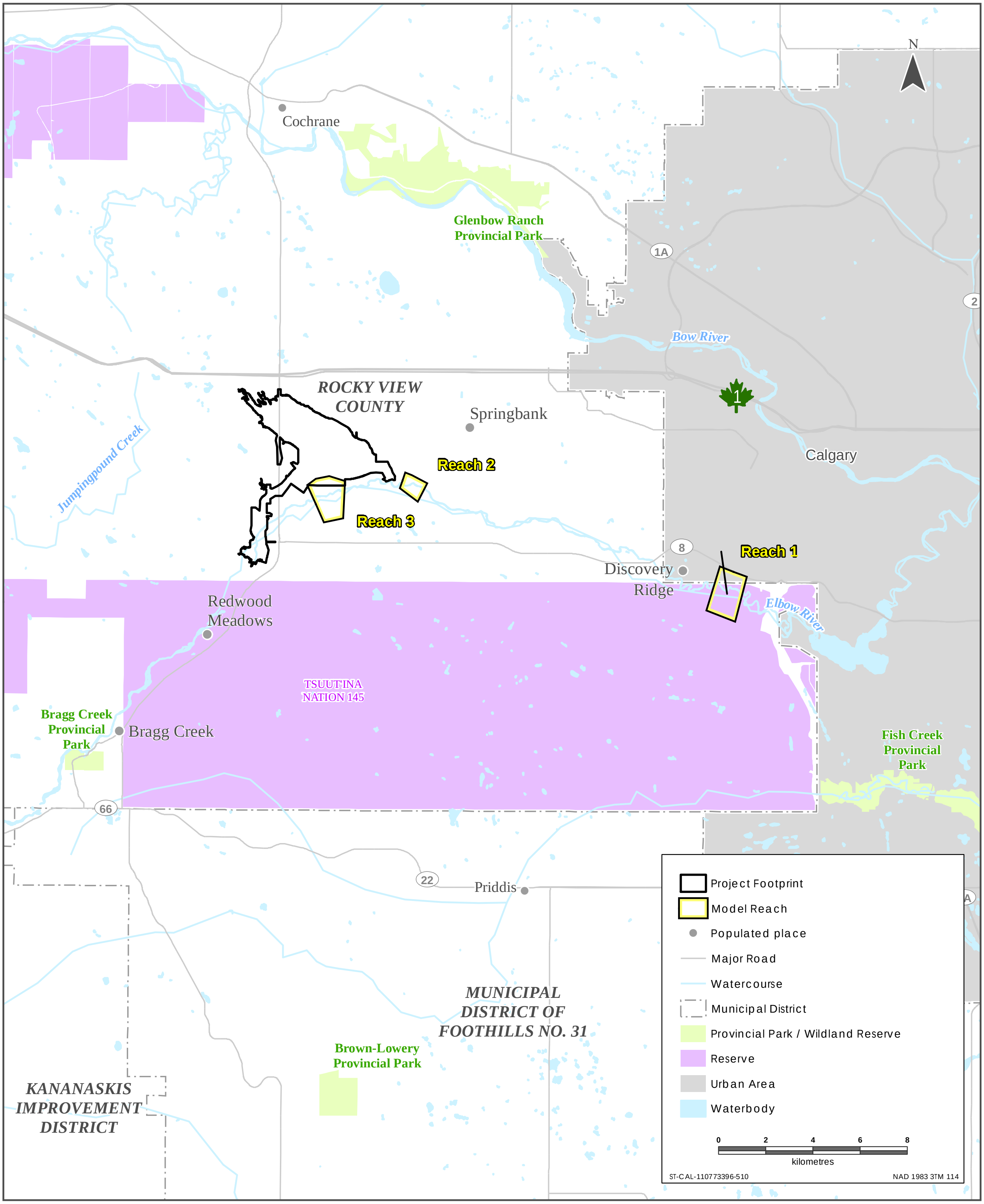
2.1 STUDY AREA

Three representative reaches of the Elbow River were selected for model simulations and subsequent HSI analyses. These reaches are located between the Project site and Glenmore Reservoir to capture potential downstream channel morphology changes over time as a result of the Project (Figure 2-1).

2.2 MODELLING PROCESS

The following describes the nature of the results provided herein:

- Changes to the channel morphology of the Elbow River resulting from three flood scenarios (1:10 year, 1:100 year, and 2013 flood) were modelled using MIKE 21C software for the three representative reaches, with and without the Project (Section 2.2.1).
- Hydraulic variables important to fish (i.e., wetted area, average depth, and average water velocity) were predicted by each MIKE 21 surface morphology dataset using a discharge rate representative of average flows encountered in the Elbow River between August and November (Section 2.2.2), an important period influencing the productivity of key indicator fish species. The composition of substrate materials (i.e., median substrate sizes) was also estimated using the MIKE 21C model.
- HSIs were developed for each of four life stages (i.e., adult, juvenile, fry, and spawning) of four key indicator species (i.e., brown trout, bull trout, mountain whitefish, and rainbow trout) to calculate and compare the suitability of fish habitat between the modelled scenarios, with and without the Project (Section 2.2.3).



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Study Area and Reach Locations

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 2-1

2.2.1 Modelling of Channel Morphology Changes by Floods

MIKE 21C model simulations of the Elbow River were used to assess how bedform may change during three flood flow scenarios: 1:10 year flood; 1:100 year flood, and 2013 flood (i.e., design flood. Changes in bedform were informed by several model inputs including stream hydrographs, sediment loads and gradation, thickness of the surface and subsurface layers, Manning's 'M' roughness factors (an inverse calculation of the 'n' coefficient), and upstream and downstream boundary conditions. Modelling was completed, with and without the Project, to evaluate potential Project effects.

Three representative reaches were modelled (Figure 2-1). Each reach was approximately 1 km long and included at least two river meander lengths to encompass the variety of repeating morphological features (e.g., riffles, runs, pools, flats, glides) present in the river. Selecting three smaller representative reaches allowed the computational mesh of the model to be fine enough to capture morphological details while ensuring the resultant grid was within the available limitations of computational power of the model. Reach 1 was located near the downstream end of the study area, adjacent to the Discovery Ridge community, upstream of Glenmore Reservoir. Reach 2 was located immediately downstream of the diversion outlet. Reach 3 was located between the proposed diversion intake structure and the proposed diversion outlet. All three reaches have similar flow regimes, gradients, alluvial materials, and riparian vegetation.

The surface area of each reach was divided into a grid of curvilinear cells approximately 2 m x 5 m in area through the floodplain, and approximately 5 m x 5 m outside the extent of the 2013 flood area. Each model scenario provided a resultant shapefile containing all the output and attributes that were georeferenced to the curvilinear grid surface to represent changes to the channel morphology for each flood flow scenario, with and without the Project.

Baseline channel morphology used to model each flood scenario was developed based on light detection and ranging (LiDAR) collected in 2015 and channel bathymetry developed using channel transects collected by Alberta Environment and Parks (AEP) in 2015 and 2016.

2.2.2 Baseline and Post-Flood Fish Habitat

Using MIKE 21C, a constant representative discharge was modelled on the baseline (i.e., pre-flood) and post-flood grid surfaces to predict discharge-specific values of wetted area (m^2), average depth (m), and average velocity (m/s) for each grid cell. These hydraulic variables directly influence the suitability of habitat to different fish species and life stages.

A low-flow discharge of 7.4 m^3/s was used for habitat suitability analysis. This flow represents the low-flow conditions that typically occur in the fall and early winter, which is the spawning period of three of the four selected fish species (see Section 2.2.3). The low-flow discharge was calculated as the average of monthly historical flows between August and November, as reported by hydrometric stations at Bragg Creek and Sarcee Bridge (Government of Canada 2020).

MIKE 21C was also used to determine the baseline and post-flood median particle size (i.e., D_{50}; mm) of bottom substrates in each grid cell. Substrate is also an important environmental variable directly influencing the suitability of habitat for fish and these values were also used in determining the habitat suitability of each scenario.

MIKE 21C was used to predict hydraulic variables for one baseline and three peak flow events, with and without the Project, in three reaches of the Elbow River (21 model runs in total). These model outputs were then compared to the habitat preferences of four life stages of four different indicator fish species (see Section 2.2.3), for a total of 336 habitat suitability evaluations.

2.2.3 Habitat Suitability

Key indicator species were selected for HSI analysis based on their known distribution in the assessment area (see Alberta Transportation’s response to AEP Question 69, Appendix 69-1). Habitat suitability was evaluated for adult, juvenile, fry and spawning life stages of the following key indicator species:

- brown trout
- bull trout
- mountain whitefish
- rainbow trout

These key indicator species were selected due to their recreational and traditional importance to the Elbow River fishery, and the abundance of existing information that is available for these species through previous habitat suitability curves that were prepared for the provincial government (Addley et. al. 2003). Furthermore, bull trout is listed as *threatened* under the *Species at Risk Act* (Government of Canada 2019) and evaluation of potential changes to bull trout habitat in Elbow River is important for reviews under the *Species at Risk Act* and *Fisheries Act* for the Project.

Habitat suitability metrics (i.e., water velocity, substrates, water depth) are herein referred to as ‘habitat suitability criteria’ (HSC). HSC values reflect units that are used in an overall HSI numerical index to describe the suitability of habitat to a specific life stage of the key indicator fish species. For example, adult brown trout HSI is calculated as follows:

$$HSI_{ADULT\ BNTR} = HSC_{DEPTH} \text{ x } HSC_{VELOCITY} \text{ x } HSC_{SUBSTRATE}$$

HSCs used in this study have been developed for key indicator species based on observational studies in southern Alberta watersheds and the professional judgement of local fisheries specialists (Addley et al. 2003; EMA 1994; Fernet et al. 1990). HSCs provide environmental-variable associated suitability values ranging between 0 and 1, where a score of 1 is considered most suitable and a score of 0 is considered least suitable for the environmental variable of interest. For each habitat unit, an HSI value was calculated which represented the overall suitability of the habitat unit based on associated HSC values. As with HSC, HSI values range between 0 and 1; scores of 1 are considered most suitable and scores of 0 are considered least suitable. When analyzing the modelled data, each grid cell in the model was considered a habitat unit.

An area-based metric of habitat suitability called the weighted useable area (WUA) was used to compare how the HSI results varied between modelled reaches and varied for flood flow scenarios (with and without the Project). A WUA was calculated for each grid cell (i.e., WUA_{CELL}) as the product of the HSI score for a cell and the spatial area of the cell (e.g., a 100 m^2 grid cell with HSI value of 0.5 had a WUA_{CELL} of 50 m^2).

For each reach, an overall reach-specific WUA was calculated (i.e., WUA_{REACH}) as the sum of all WUA_{CELL} values for the reach. The WUA_{REACH} value from all three modelled reaches were then averaged to obtain a WUA value representing each flood scenario (i.e., $WUA_{SCENARIO}$). The $WUA_{SCENARIO}$ values were the final metric used to compare habitat suitability between different modelled floods for each fish species and life stage.

To compare how individual environmental variables changed between modelled floods, a WUA calculation was made that represented each environmental variable using the variable-associated HSC. A WUA was calculated for each cell as a product of the variable-associated HSC value and the area of the cell (e.g., a 100 m^2 grid cell with $HSC_{VELOCITY}$ value of 0.5 had a $WUA_{VELOCITY}$ of 50 m^2). As a result, WUA values representing depth, velocity, and substrate were calculated, as applicable, for each combination of fish species, life stage, and modelled scenario (i.e., WUA_{DEPTH}, $WUA_{VELOCITY}$, and $WUA_{SUBSTRATE}$, respectively). Model scenarios with higher WUA values for a specific fish species and life stage were considered more suitable to the specific life stage than those with lower WUA values.

For each combination of a modelled surface and modelled discharge, velocity (m/s), depth (m), and substrate (i.e., D50 particle size) were compared with relevant HSI criteria for each key indicator species and life stage. Depth and velocity attributes were compared with HSC curves developed by leading fisheries experts for the South Saskatchewan River basin (Addley et al. 2003). Substrate values were compared with the HSCs developed in Fernett et al. (1990) using observational data collected in Bow River and Crowsnest River.

Substrate suitability was determined by Fernet et al. (1990) and indices from that study were used for each fish species. The D_{50} or median particle size diameter attribute for each grid cell was categorized as belonging to one of the substrate categories described in Table 2-1.

Table 2-1 Particle Sizes and Codes for Substrate HSC Categories

HSC Substrate Category	Particle Size Range (D_{50} in mm)	HSC Substrate Code
Clay\Silt	<0.062	1
Sand	0.062-2.0	2
Small Gravel	2-8	3
Medium Gravel	8-32	4
Large Gravel	32-64	5
Small Cobble	64-128	6
Large Cobble	128-256	7
Small Boulder	256-762	8
Large Boulder	>762	9

D_{50} = median diameter

SOURCE: Fernet et al. 1990

Habitat suitability was calculated in the following steps for each key indicator species and life stage:

- for each grid cell determined in the model to contain surface water, a combined HSI value was calculated as the product of all HSC values
- the useable habitat area for each cell was then calculated by multiplying the combined suitability value by the cell's area
- the WUA was calculated for the study reach by summing the useable habitat areas of each cell in the study reach

The WUA values were considered the final HSI measure of suitability for each study reach (i.e., areas with higher WUA values provide more suitable habitat for carrying out a specific life stage).

A paired t-test was used to determine if inclusion of the Project resulted in statistically significant changes to habitat suitability for each flood scenario, fish species, and life stage. Significance of the t-test was set at $p<0.05$.

Habitat suitability information for each of the key indicator fish species considered in this analysis are described in the sections below.

2.2.3.1 Brown Trout

The brown trout HSI was based on the depth and velocity HSC developed in Addley et al. (2003) for the South Saskatchewan River basin, and the substrate HSC developed by Fernet et al. (1990).

2.2.3.1.1 Adult

HSC curves used to develop the HSI for adult brown trout are presented in Figure 2-2 to Figure 2-4.

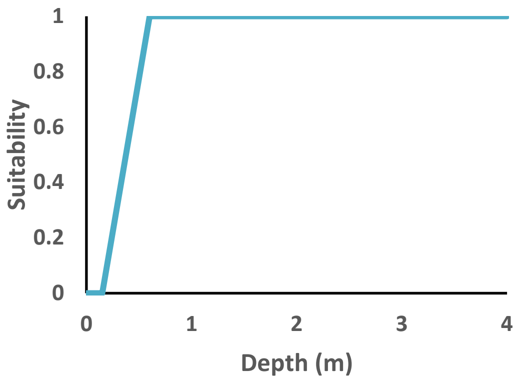


Figure 2-2 Adult Brown Trout Water Depth HSC Curve

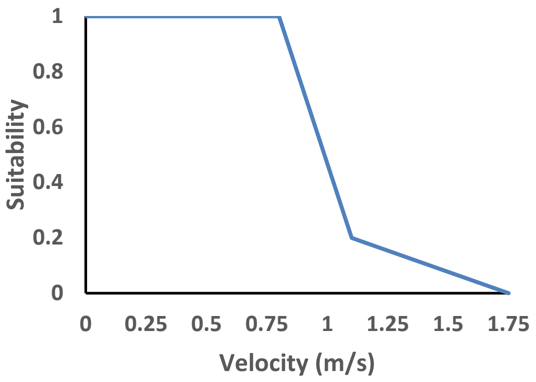


Figure 2-3 Adult Brown Trout Water Velocity HSC Curve

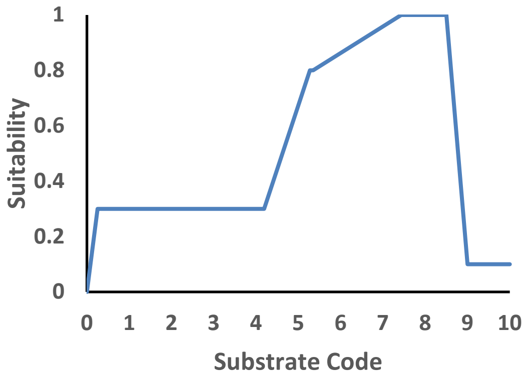


Figure 2-4 Adult Brown Trout Substrate HSC Curve

2.2.3.1.2 Juvenile

Suitability indices used to develop the HSI for juvenile brown trout are presented in Figure 2-5 to Figure 2-7. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).

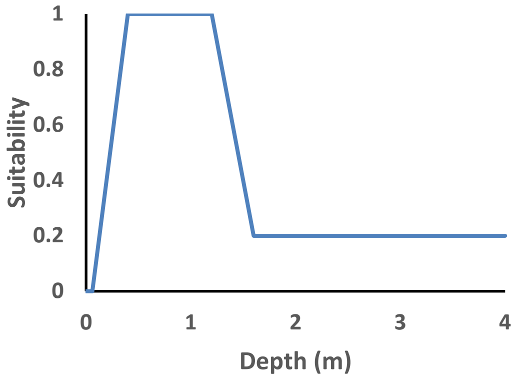


Figure 2-5 Juvenile Brown Trout Depth HSC Curve

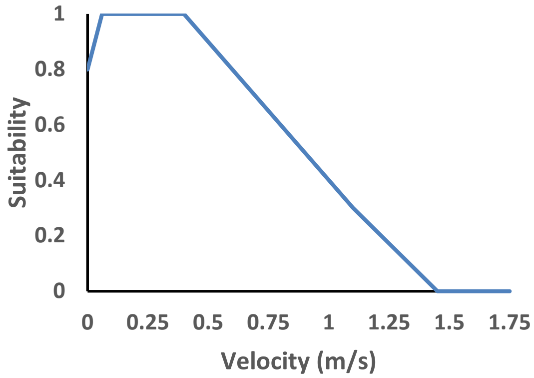


Figure 2-6 Juvenile Brown Trout Velocity HSC Curve

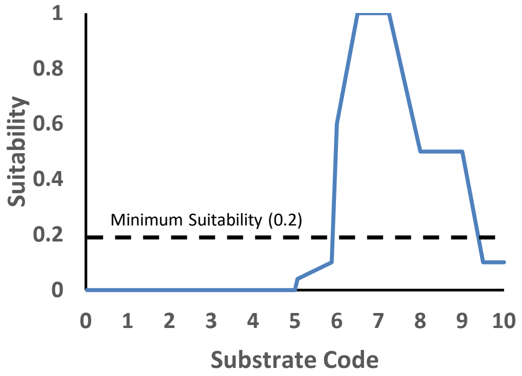
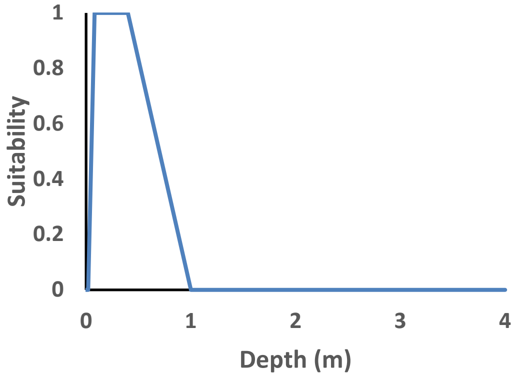


Figure 2-7 Juvenile Brown Trout Substrate HSC Curve

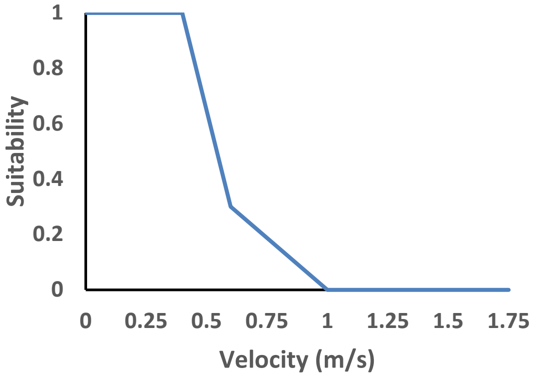
2.2.3.1.3 *Fry*

Suitability indices used to develop the HSI for brown trout fry are presented in Figure 2-8 to Figure 2-10. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



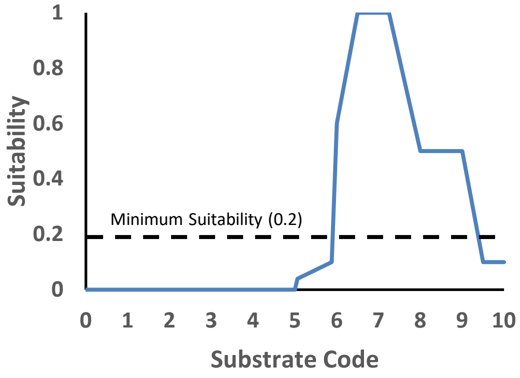
SOURCE: Addley et al. 2003

Figure 2-8 Brown Trout Fry Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-9 Brown Trout Fry Velocity Suitability Criteria

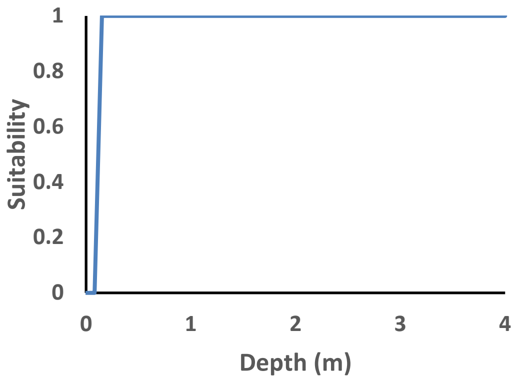


SOURCE: Fernet et al. 1990

Figure 2-10 Brown Trout Fry Substrate Suitability Criteria

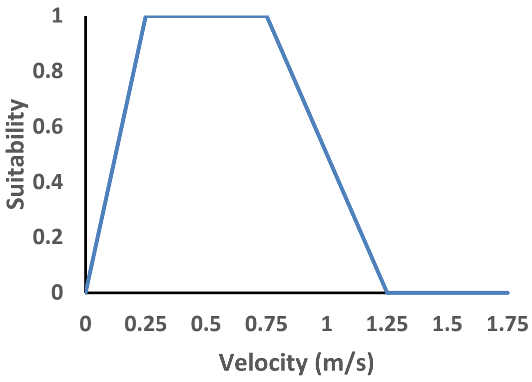
2.2.3.1.4 Spawning

Suitability indices used to develop the HSI for spawning brown trout are presented in Figure 2-11 to Figure 2-13.



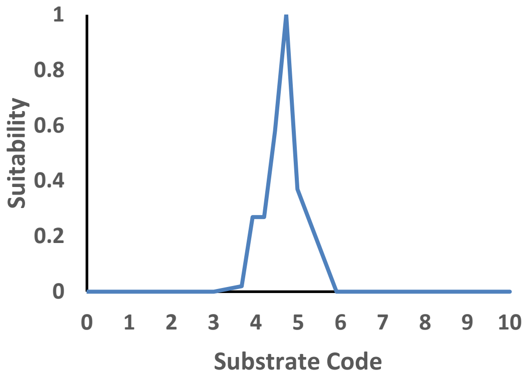
SOURCE: Addley et al. 2003

Figure 2-11 Brown Trout Spawning Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-12 Brown Trout Spawning Velocity Suitability Criteria



SOURCE: Fernet et al. 1990

Figure 2-13 Brown Trout Spawning Substrate Suitability Criteria

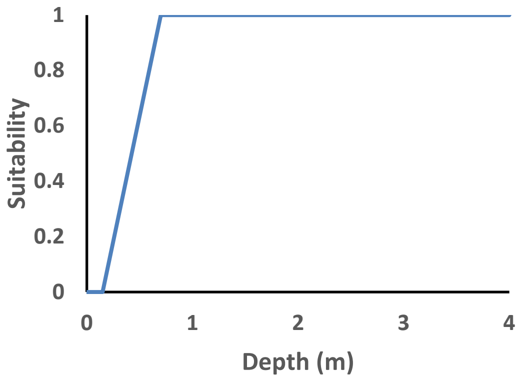
2.2.3.2 Bull Trout

The bull trout HSI for each life stage was based on the depth and velocity indices developed in Addley et al. (2003) for the South Saskatchewan River basin (SSRB). Substrate indices were developed based on literature review of habitat preferences for each life stage or from indices developed for other species (e.g., brown trout) as appropriate.

2.2.3.2.1 Adult

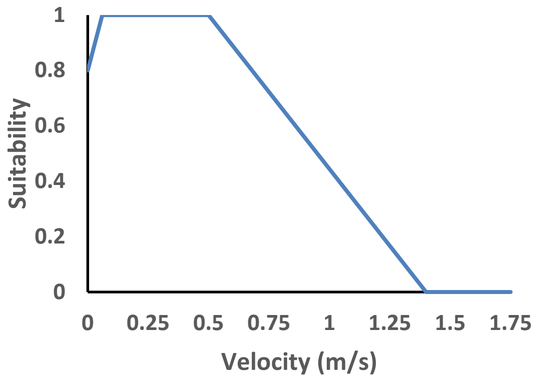
Adult bull trout exhibit high associations with cover and, while foraging, have been observed as rarely straying from overhead cover (Nakano et al. 1992). Adult bull trout are most commonly found in pools and, during the day, associate mostly with large cover in the form of undercut banks, depth/visibility, or boulders (Stewart et al. 2007). As a result, a substrate index is not included for the bull trout HSI because substrate does not appear to be a determining component of adult habitat suitability.

Suitability indices used to develop the HSI for adult bull trout are presented in Figure 2-14 to Figure 2-15.



SOURCE: Addley et al. 2003

Figure 2-14 Bull Trout Adult Depth Suitability Criteria



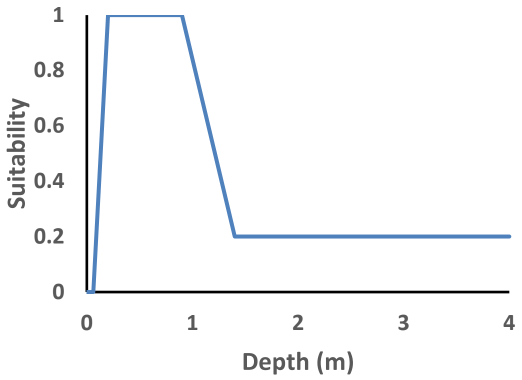
SOURCE: Addley et al. 2003

Figure 2-15 Bull trout Adult Velocity Suitability Criteria

2.2.3.2.2 Juvenile

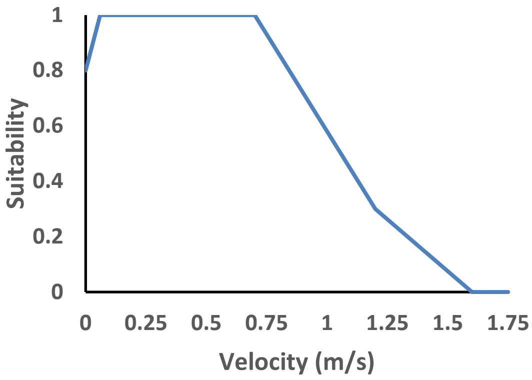
Juvenile bull trout and fry are known to use substrate (i.e., cobble and boulders) as cover and associate with the streambed until they grow larger than 100 mm in length (Stewart et al. 2007). Therefore, a substrate index was developed based on the brown trout fry index (Fernet et al. 1990), which rated cobble substrates as most suitable. However, the substrate index was modified to rate increased suitability for boulders, which provide cover to juvenile bull trout.

Suitability indices used to develop the HSI for juvenile bull trout are presented in Figure 2-16 to Figure 2-18. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



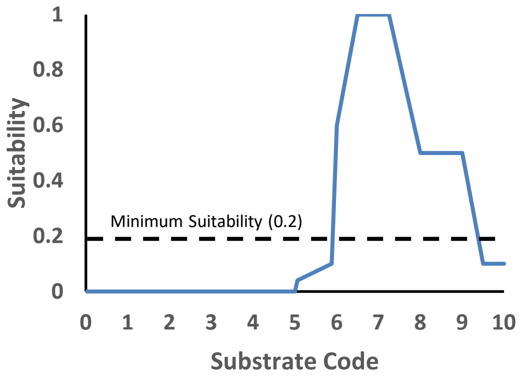
SOURCE: Addley et al. 2003

Figure 2-16 Bull Trout Juvenile Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-17 Bull Trout Juvenile Velocity Suitability Criteria



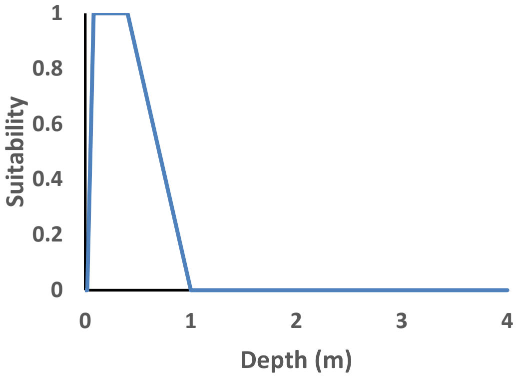
SOURCE: adapted from Fernet et al. 1990

Figure 2-18 Bull Trout Juvenile Substrate Suitability Criteria

2.2.3.2.3 Fry

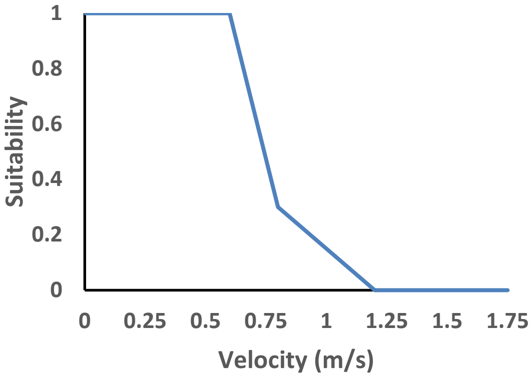
Bull trout fry associate with large cobble substrate (Addley et al. 2003; Stewart et al. 2007), which they use as cover. This is consistent with the substrate suitability index for brown trout fry (Fernet et al. 1990) for which suitability peaked in association with large cobble. Therefore, the brown trout substrate suitability index for fry was adopted for bull trout fry.

Suitability indices used to develop the HSI for bull trout fry are presented in Figure 2-19 to Figure 2-21. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



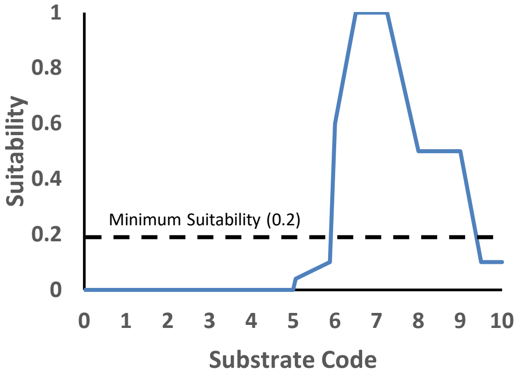
SOURCE: Addley et al. 2003

Figure 2-19 Bull Trout Fry Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-20 Bull Trout Fry Velocity Suitability Criteria



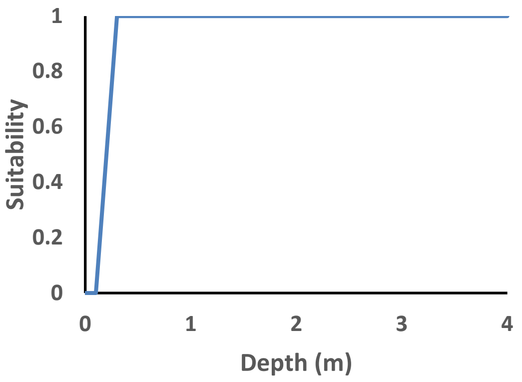
SOURCE: adapted from Fernet et al. 1990

Figure 2-21 Bull Trout Fry Substrate Suitability Criteria

2.2.3.2.4 Spawning

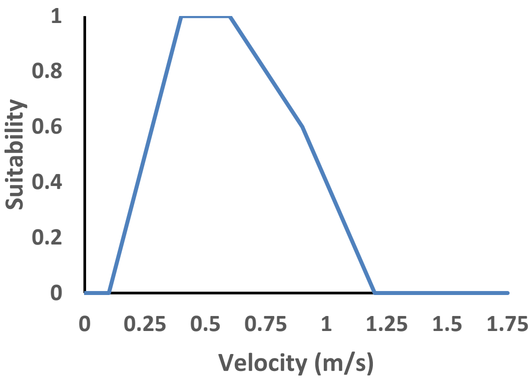
A spawning substrate index with small gravel to small cobble associated with an index value of 1 was used as recommended in the SSRB workshop (Addley et al. 2003).

Suitability indices used to develop the HSI for spawning bull trout are presented in Figure 2-22 to Figure 2-24.



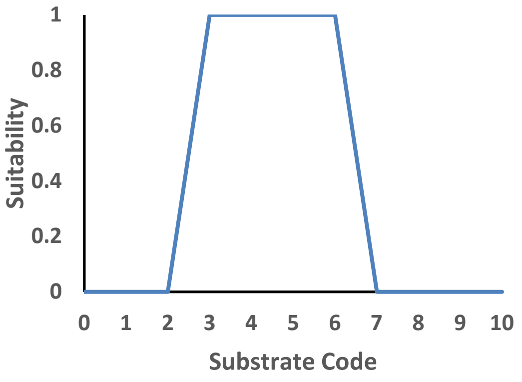
SOURCE: Addley et al. 2003

Figure 2-22 Bull Trout Spawning Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-23 Bull Trout Spawning Velocity Suitability Criteria



SOURCE: derived from Addley et al. 2003 notes

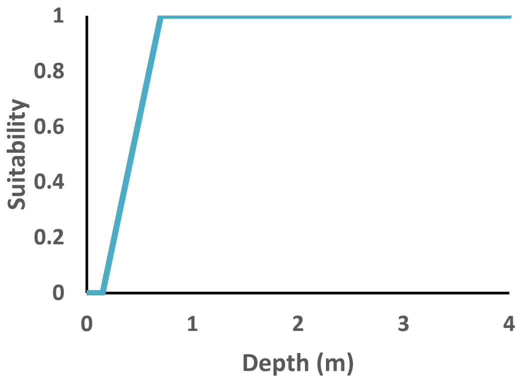
Figure 2-24 Bull Trout Spawning Substrate Suitability Criteria

2.2.3.3 Rainbow Trout

The rainbow trout HSI is based on the depth and velocity indices developed in Addley et al. (2003) for the South Saskatchewan River basin, substrate indices developed by Fernet et al. (1990).

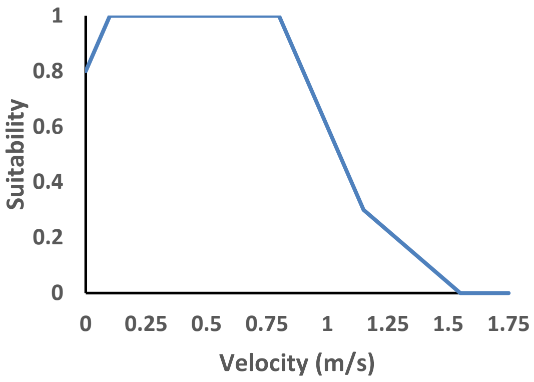
2.2.3.3.1 Adult

Suitability indices used to develop the HSI for adult rainbow trout are presented in Figure 2-25 to Figure 2-27.



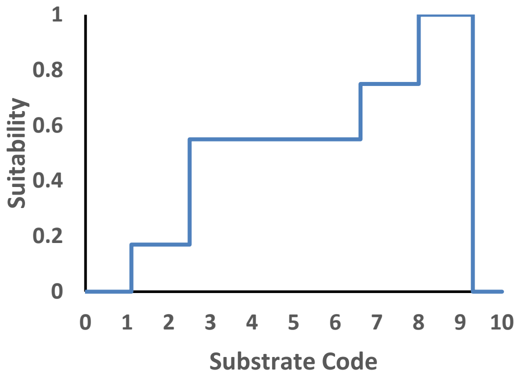
SOURCE: Addley et al. 2003

Figure 2-25 Rainbow Trout Adult Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-26 Rainbow Trout Adult Velocity Suitability Criteria

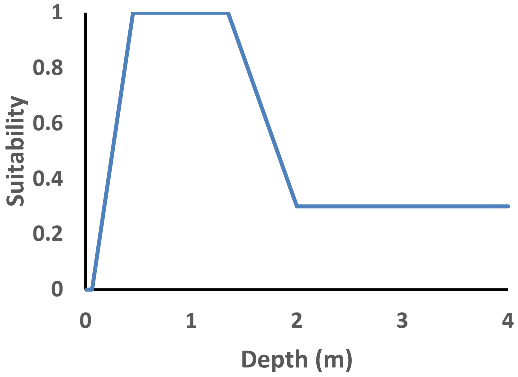


SOURCE: Fernet et al. 1990

Figure 2-27 Rainbow Trout Adult Substrate Suitability Criteria

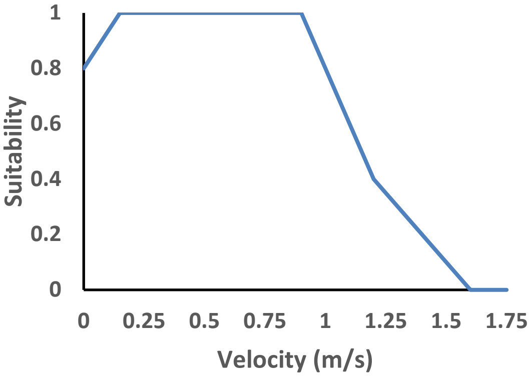
2.2.3.3.2 Juvenile

Suitability indices used to develop the HSI for juvenile rainbow trout are presented in Figure 2-28 to Figure 2-30. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



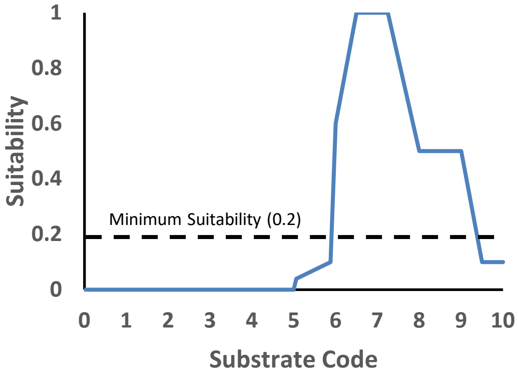
SOURCE: Addley et al. 2003

Figure 2-28 Rainbow Trout Juvenile Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-29 Rainbow Trout Juvenile Velocity Suitability Criteria

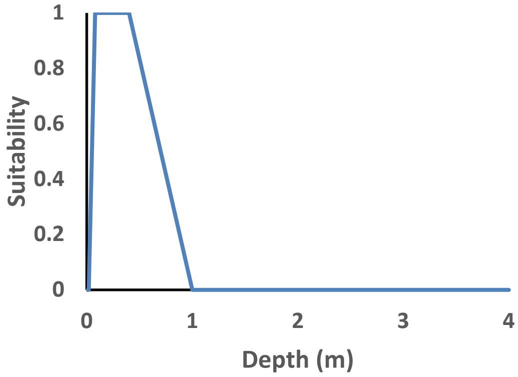


SOURCE: Fernet et al. 1990

Figure 2-30 Rainbow Trout Juvenile Substrate Suitability Criteria

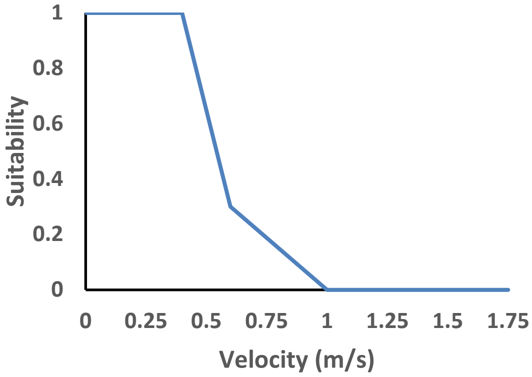
2.2.3.3.3 Fry

Suitability indices used to develop the HSI for rainbow trout fry are presented in Figure 2-31 to Figure 2-33. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



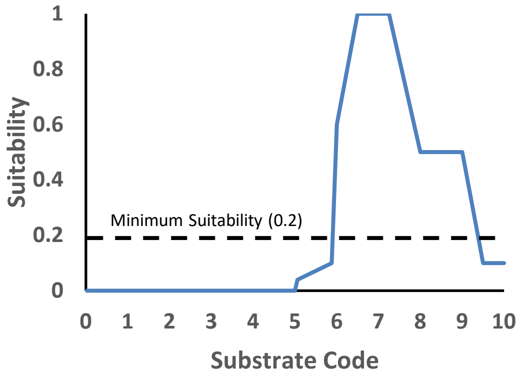
SOURCE: Addley et al. 2003

Figure 2-31 Rainbow Trout Fry Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-32 Rainbow Trout Fry Velocity Suitability Criteria

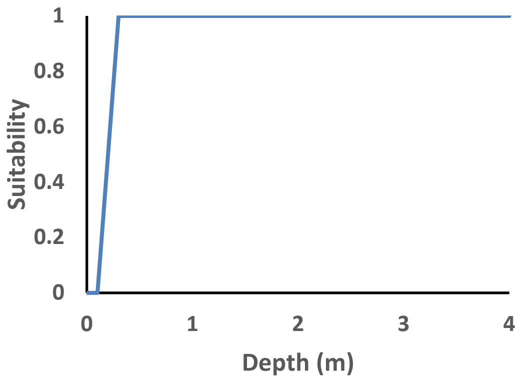


SOURCE: Fernet et al. 1990

Figure 2-33 Rainbow Trout Fry Substrate Suitability Criteria

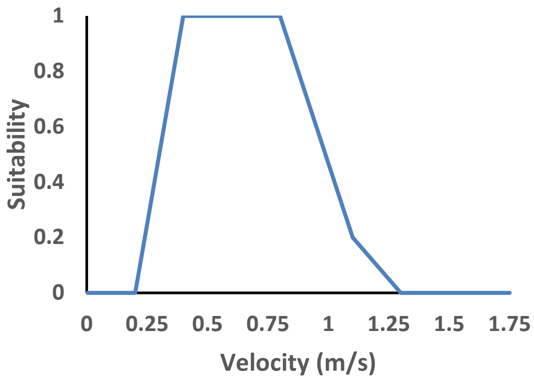
2.2.3.3.4 Spawning

Suitability indices used to develop the HSI for spawning rainbow trout are presented in Figure 2-34 to Figure 2-36.



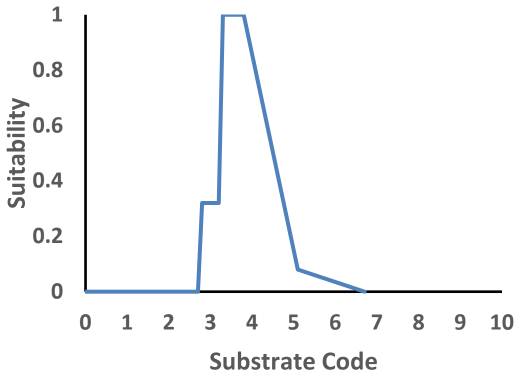
SOURCE: Addley et al. 2003

Figure 2-34 Rainbow Trout Spawning Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-35 Rainbow Trout Spawning Velocity Suitability Criteria



SOURCE: Fernet et al. 1990

Figure 2-36 Rainbow Trout Spawning Substrate Suitability Criteria

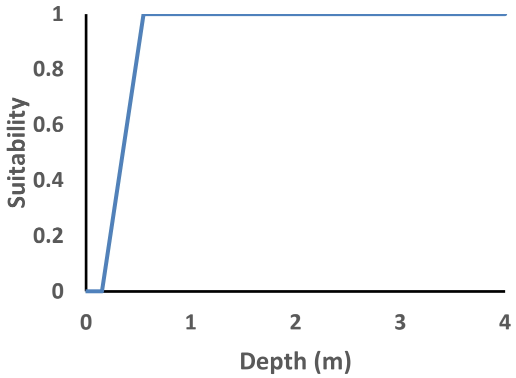
2.2.3.4 Mountain Whitefish

The mountain whitefish HSI is based on the depth and velocity indices developed in Addley et al. (2003) for the South Saskatchewan River basin, and the substrate indices, where applicable, developed by Environmental Management Associates (EMA) for Bow River (EMA 1994).

Substrate as cover is important to fry and juvenile life stages and their association with this type of cover is reflected in the substrate indices for mountain whitefish (EMA 1994).

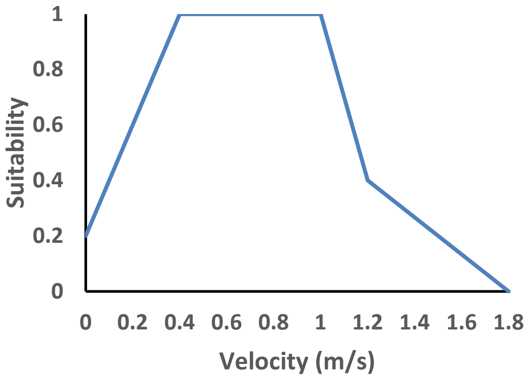
2.2.3.4.1 Adult

Adult mountain whitefish in Bow River do not appear to display a preference for any substrate type (EMA 1994). Therefore, an index of substrate is not included for the adult mountain whitefish HSI. Suitability indices used to develop the HSI for adult mountain whitefish are presented in Figure 2-37 and Figure 2-38.



SOURCE: Addley et al. 2003

Figure 2-37 Mountain Whitefish Adult Depth Suitability Criteria

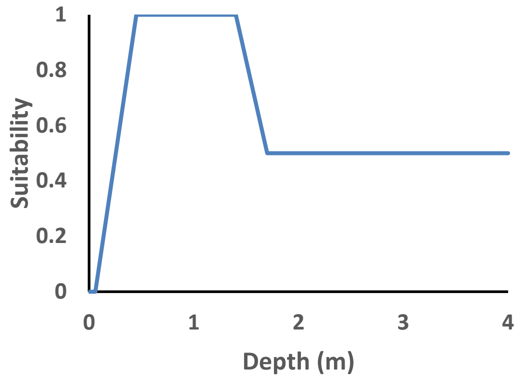


SOURCE: Addley et al. 2003

Figure 2-38 Mountain Whitefish Adult Velocity Suitability Criteria

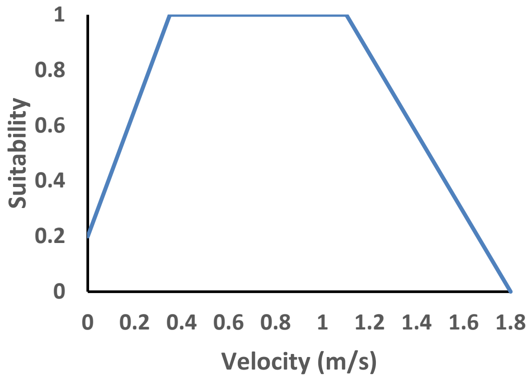
2.2.3.4.2 Juvenile

Suitability indices used to develop the HSI for juvenile mountain whitefish are presented in Figure 2-39 to Figure 2-41. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



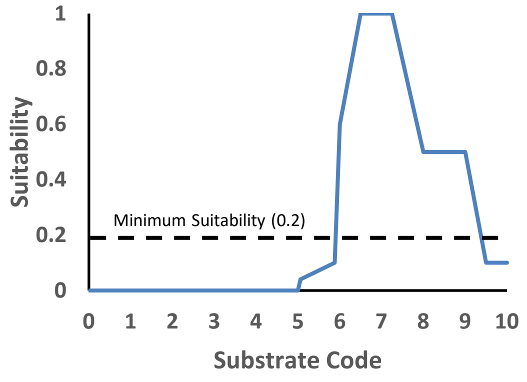
SOURCE: Addley et al. 2003

Figure 2-39 Mountain Whitefish Juvenile Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-40 Mountain Whitefish Juvenile Velocity Suitability Criteria

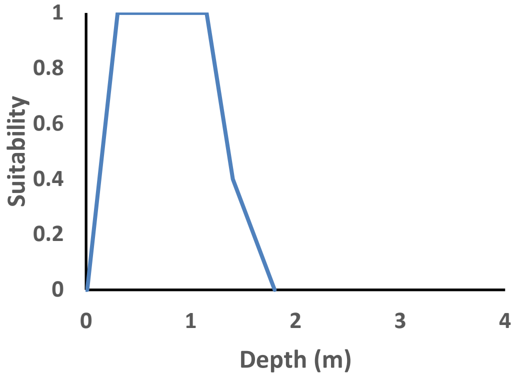


SOURCE: EMA 1994

Figure 2-41 Mountain Whitefish Juvenile Substrate Suitability Criteria

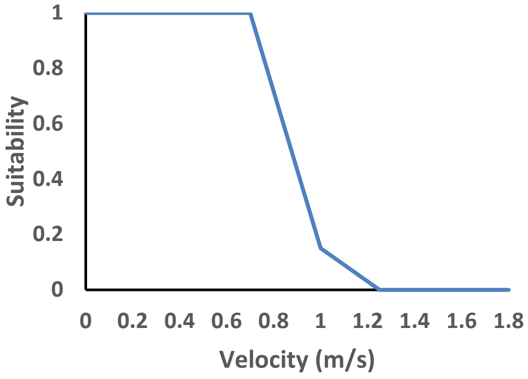
2.2.3.4.3 Fry

Suitability indices used to develop the HSI for mountain whitefish fry are presented in Figure 2-42 to Figure 2-44. A minimum value of 0.2 was applied to the substrate HSC (see Section 2.2.4).



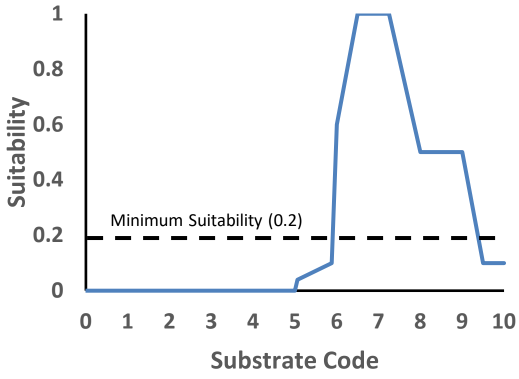
SOURCE: Addley et al. 2003

Figure 2-42 Mountain Whitefish Fry Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-43 Mountain Whitefish Fry Velocity Suitability Criteria

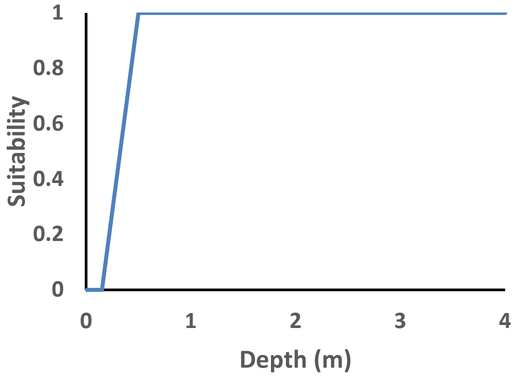


SOURCE: EMA 1994

Figure 2-44 Mountain Whitefish Fry Substrate Suitability Criteria

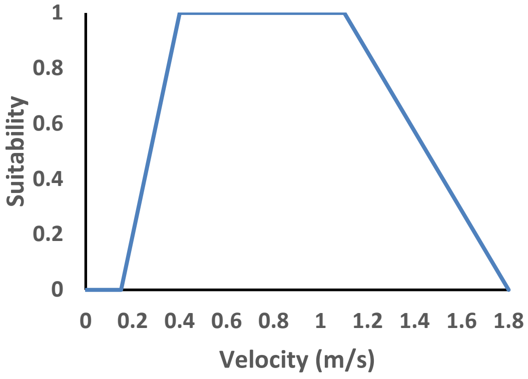
2.2.3.4.4 Spawning

Suitability indices used to develop the HSI for spawning mountain whitefish are presented in Figure 2-45 to Figure 2-47.



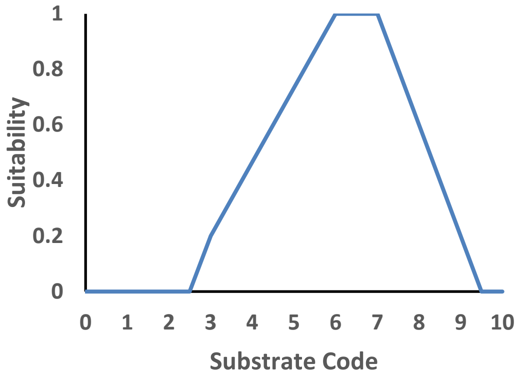
SOURCE: Addley et al. 2003

Figure 2-45 Mountain Whitefish Spawning Depth Suitability Criteria



SOURCE: Addley et al. 2003

Figure 2-46 Mountain Whitefish Spawning Velocity Suitability Criteria



SOURCE: EMA 1994

Figure 2-47 Mountain Whitefish Spawning Substrate Suitability Criteria

2.2.4 Sources of Uncertainty

A number of assumptions were made developing the MIKE 21C model and HSI metrics that may be potential sources of uncertainty when drawing conclusions from modelled results. The following lists of these assumptions have been provided to allow the reader to be aware of these potential sources of uncertainty.

- Representative reaches were selected to represent a variety of baseline habitats in the study area. However, limitations in the MIKE 21C model prevented the selection of areas where the valley was markedly wide. Reviewers should be careful in extrapolating results to these specific areas.
- The upstream and downstream extent of each representative reach was designated using an artificial boundary within the MIKE 21C model. Changes to channel morphology near these extents were not considered representative of natural flood conditions. The model must adjust to account for boundary conditions at each model extent. Therefore, the results for each reach was clipped where aggradation or degradation was influenced by the artificial boundaries. Clipping was done based on the professional judgement of Stantec's water engineering specialists familiar with the model and results.
- Substrate composition of the baseline (i.e., pre-flood) model surface was developed based on historical bed material sampling completed in the Elbow River (Alberta Transportation EIA Volume 4, Appendix J - Hydrology) and included substrates ranging in size between small and large gravel. However, larger substrates (i.e., cobble and boulder) are important components of habitat suitability criteria for juvenile and fry life stages of all key indicator fish species. As a result, the absence of cobble and larger substrates renders the HSI score as zero, regardless of other habitat suitability components. In other words, a score of zero based on the modelled substrate results is used as a multiplier for juvenile and fry HSI and results in an overall score of zero for juvenile and fry. A detailed habitat assessment completed in the fall of 2019 showed that cobble and larger substrate are prevalent in baseflow channels (Alberta Transportation's response to AEP Question 69, Appendix 69-1). To overcome the substrate suitability score of zero, a minimum HSC value of 0.2 was applied to the substrate HSC of the juvenile and fry stage of each key indicator species so that non-zero WUA values could be attained for comparison of Project effects. Given the small range of substrate sizes included in the model, comparisons made in these situations are more reflective of suitability differences in velocity and depth.

- Spawning by bull trout typically occurs in areas influenced by groundwater, which stabilizes temperatures throughout the egg incubation period (Baxter 1997; Baxter and McPhail 1999; Baxter and Hauer 2000; Ripley et al. 2005). However, groundwater is excluded as a modelling and HSI suitability factor. As a result, the HSI cannot reduce the suitability of any habitat where groundwater inputs are insufficient for bull trout eggs and fry. Thus, the availability of bull trout spawning habitat is likely an overestimate in each modelled scenario. Project-based comparisons of bull trout spawning habitat do not consider differences in groundwater conditions.
- Habitat suitability criteria were selected from available sources based on the relevance of species and geographic location. With the exception of bull trout depth and velocity, suitability criteria were developed using the professional judgement of leading fisheries specialists in south Alberta. Criteria were also based on existing studies (Addley et al., 2003; Fernet et al., 1990; EMA, 1994) which used field-verified observations in south Alberta watersheds to develop suitability criteria. However, suitability indices were not developed specifically for the Elbow River watershed.

3.0 RESULTS

Results of the MIKE 21C model, with and without the Project, are presented Appendix 23-1.

Summary figures showing baseline (i.e., pre-flood; Figures 1, 2, and 3) and post-flood modelled surfaces (Figures 4 to 21) are presented in Attachment A. Each figure displays bathymetry (i.e., wetted area and depth) associated with a modelled discharge of 7.4 m^3/s, representing low flow fall and early winter conditions, for each post-flood flow scenario. Summary parameters for modelled habitat variables, by flood, are summarized in Table 3-1 and further discussed, by species, below.

Following a 1:10 year flood (Attachment A: Figure 4 to 9), depth, velocity, and substrate at a modelled discharge of 7.4 m^3/s were largely similar in Reaches 1 and 3 for scenarios with and without the Project (Table 3-1). However, average and maximum depths, as well as average substrate size, were markedly higher in Reach 2 with the Project compared to without the Project. As can be seen in Attachment A, Figure 6 and 7, the predicted effect of the Project on the channel in Reach 2 during the 1:10 year flood scenario is to cause less channel braiding; as a result, water is distributed via a narrower and deeper main channel. In contrast, without the Project, water is conveyed across more channels (and a larger surface area) which are characterized as having overall lower depths and velocities. The wetted surface was lower for all reaches with the Project.

Following a 1:100 year flood (Attachment A: Figure 10 to 15), substrates were largely similar in all three reaches with and without the Project (Table 3-1). Wetted area and average and maximum depths and velocities were similar in Reach 2 with and without the Project. However, Reach 1 and 3 presented contrasting differences in wetted surface area with Reach 1 having a larger wetted area with the Project and Reach 3 having a smaller surface area with the Project compared to without the Project after a 1:100 year flood. As seen in Attachment A, Figures 10 and 11, flooding caused more channel braiding in Reach 1 with inclusion of the Project, resulting in a larger wetted surface area, as well as markedly lower average and maximum water velocities when compared to the scenario without the Project. The resulting morphology in Reach 3 with the Project had much higher sinuosity, a higher average depth, average velocity, and maximum velocity, as well as a lower maximum depth than in Reach 3 without the Project.

Table 3-1 Summary of Habitat Variables for Modelled Floods

Reach ID	Modelled Flood	Wetted Area (m^2)	Depth (m)				Velocity (m/s)				D_{50} (mm)			
			Ave	SD	Min	Max	Ave	SD	Min	Max	Ave	SD	Min	Max
Reach 1	Baseline Surface	73,737	0.25	0.19	0.00020	1.21	0.20	0.22	<0.00000	1.46	-	-	-	-
	1:10 Year Flood (without the Project)	87,777	0.31	0.27	0.00140	1.73	0.29	0.32	<0.00000	1.33	20	9	4	52
	1:10 Year Flood (with the Project)	73,005	0.30	0.26	0.00330	1.73	0.29	0.31	<0.00000	1.30	20	8	4	53
	1:100 Year Flood (without the Project)	73,124	0.31	0.29	0.00020	1.72	0.18	0.19	<0.00000	1.55	19	9	4	52
	1:100 Year Flood (with the Project)	112,920	0.22	0.20	0.00020	1.79	0.08	0.10	<0.00000	0.93	19	7	4	53
	2013 Flood (without the Project)	152,258	0.26	0.29	0.00010	1.64	0.23	0.25	<0.00000	1.51	18	9	4	53
	2013 Flood (with the Project)	114,917	0.27	0.28	0.00010	1.94	0.21	0.25	<0.00000	1.67	20	8	4	53
Reach 2	Baseline Surface	20,792	0.25	0.18	0.00020	1.00	0.43	0.29	<0.00000	1.90	-	-	-	-
	1:10 Year Flood (without the Project)	54,539	0.15	0.13	0.00010	0.63	0.55	0.28	<0.00000	1.48	18	12	4	53
	1:10 Year Flood (with the Project)	29,221	0.26	0.21	0.00010	1.13	0.54	0.35	<0.00000	1.76	23	9	4	53
	1:100 Year Flood (without the Project)	83,948	0.11	0.12	0.00020	1.21	0.52	0.31	<0.00000	1.46	23	11	4	53
	1:100 Year Flood (with the Project)	87,869	0.10	0.11	0.00020	1.21	0.51	0.32	<0.00000	1.56	24	8	4	53

Table 3-1 Summary of Habitat Variables for Modelled Floods

Reach ID	Modelled Flood	Wetted Area (m^2)	Depth (m)				Velocity (m/s)				D_{50} (mm)			
			Ave	SD	Min	Max	Ave	SD	Min	Max	Ave	SD	Min	Max
Reach 2 (cont'd)	2013 Flood (without the Project)	48,161	0.16	0.25	0.00020	1.51	0.42	0.26	<0.00000	1.26	18	5	4	51
	2013 Flood (with the Project)	58,313	0.11	0.11	0.00010	0.87	0.46	0.22	<0.00000	1.03	19	7	4	46
Reach 3	Baseline Surface	44,693	0.27	0.24	0.00010	1.22	0.48	0.35	<0.00000	2.86	-	-	-	-
	1:10 Year Flood (without the Project)	145,954	0.12	0.14	0.00010	1.37	0.37	0.35	<0.00000	1.32	24	11	4	53
	1:10 Year Flood (with the Project)	116,308	0.13	0.14	0.00010	1.53	0.41	0.35	<0.00000	1.40	23	11	4	53
	1:100 Year Flood (without the Project)	245,566	0.07	0.11	0.00010	1.42	0.27	0.30	<0.00000	1.24	25	10	4	53
	1:100 Year Flood (with the Project)	105,625	0.13	0.12	0.00010	0.89	0.47	0.35	<0.00000	1.53	24	9	4	52
	2013 Flood (without the Project)	450,049	0.05	0.10	0.00010	2.53	0.22	0.26	<0.00000	1.45	23	11	4	53
	2013 Flood (with the Project)	316,164	0.07	0.11	0.00010	1.57	0.26	0.28	0.00000	1.35	24	11	4	53

NOTE:
Baseline (pre-flood) scenarios given standard D_{50} values. Therefore, grid-level D_{50} values reflecting baseline conditions were not calculated and HSI also are not completed for baseline (no Project) scenarios.

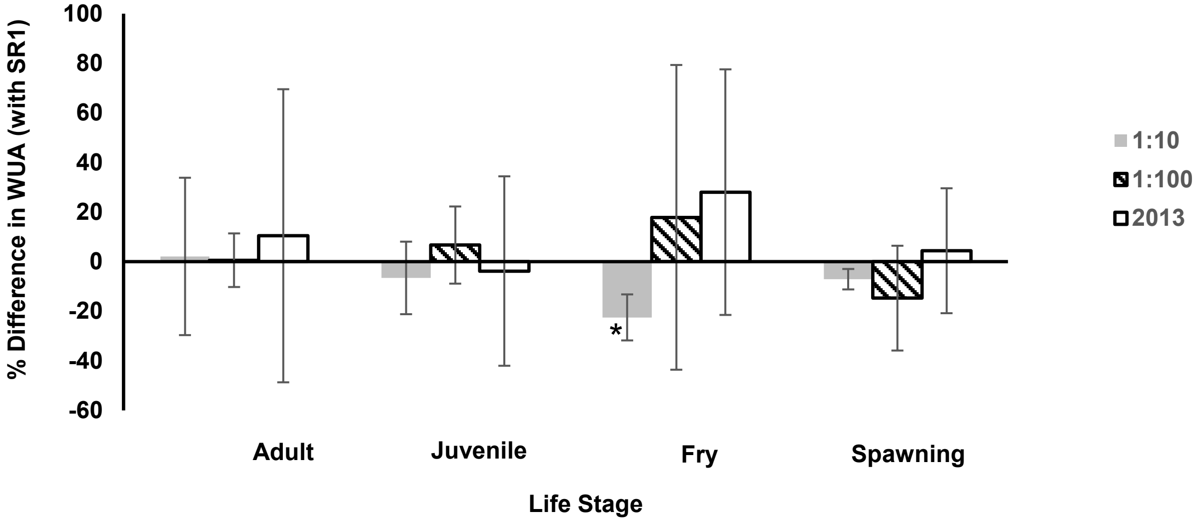
Following the 2013 flood (Attachment A: Figure 16 and 21), water velocity and substrate (size and distribution) at a modelled discharge of 7.4 m^3/s were largely similar for scenarios in all three reaches with and without the Project (Table 3-1). Reach 2 presented more variation than the other reaches in terms of changes in water velocity and substrates; maximum water velocity and maximum substrate sizes were lower with inclusion of the Project than without the Project. As seen in Attachment A, Figure 18 and 19, the scenario without the Project resulted in a single defined main channel with low sinuosity and a relatively homogenous thalweg depth while the scenario with the Project resulted in wider main channel with a comparatively discontinuous and heterogenous thalweg depth. Reach 2 presented markedly higher average and maximum depths without the Project than with the Project. No trend in wetted surface area was identified between reaches; smaller surface areas were predicted in Reach 1 and Reach 3 with the Project while a larger surface area was predicted in Reach 2 with the Project. Lower maximum depths were predicted in Reach 2 and 3 with the Project although average depths were similar with and without the Project.

Because substrates in post-flood modelled scenarios represented the period immediately following the flood, cobble and larger substrate materials were covered with gravels. As a result, substrates in all scenarios ranged between 4 mm (medium gravel) and 53 mm (large gravel).

Following large floods channels may incise into large bars that were deposited during the high flows. The large bars are often composed of finer gravel. During incision, winnowing of the finer gravel during smaller floods or flows below bankfull may will increase the percentage of larger material left on the bed. Seasonal freshets and minor floods are not controlled by the Project (operation only occurs when flood exceeds a 1 in 7-year flood event). These annual events have shear stresses high enough to entrain fine gravels at the bed surface, material leaving larger gravels and cobbles in place. This process is known as self-armoring and may expose larger underlying gravels and cobble/boulder over time, making them available to fish and increasing habitat suitability to certain fish species and life stages in scenarios both with and without the Project.

3.1 BROWN TROUT

Results of habitat suitability analyses for all brown trout life stages and all post-flood scenarios are summarized in Figure 3-1 showing the percentage change in WUA with and without the Project.



NOTE: The asterisk (*) identifies differences found to be statistically significant. Error bars represent standard deviation of the means.

Figure 3-1 **Mean percent Difference in Habitat Suitability (i.e., WUA), with the Project vs without the Project, for Brown Trout Life Stages**

3.1.1 Adult

Results of HSI analyses for adult brown trout are summarized in Table 3-2 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-3 to Table 3-5.

No statistically significant differences in adult brown trout habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-2; Figure 3-1). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project is not predicted to negatively or positively influence adult brown trout habitat suitability.

Table 3-2 Summary of WUA Values for the Adult Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

	Reach 1		**Reach 2**		**Reach 3**		**Average % Change (St Dev)**	**Paired *t* Test**	
Flood	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**WUA (m^2)**		***t***	***p****
1:10 year flood (without the Project)	10,024	-17.7	1,767	38.7	3,887	-14.7	2.1 (31.7)	0.7804	0.5169
1:10 year flood (with the Project)	8,252		2,451		3,315				
1:100 year flood (without the Project)	8,736	6.4	1,328	-11.9	2,184	7.2	0.6 (10.8)	0.8725	0.4749
1:100 year flood (with the Project)	9,299		1,170		2,341				
2013 flood (without the Project)	13,922	-17.3	2,177	-29.7	1,374	78.3	10.4 (59.1)	0.6561	0.5791
2013 flood (with the Project)	11,510		1,531		2,450				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-3 Summary of WA$_{\text{VELOCITY}}$ Values for the Adult Brown Trout Life Stage in each Reach, for Each Post-Flood Scenario

Flood	WA$_{\text{VELOCIY}}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	84,366	50,371	137,562
1:10 year flood (with the Project)	70,962	25,395	108,083
1:100 year flood (without the Project)	72,747	79,077	235,443
1:100 year flood (with the Project)	112,910	82,505	97,727
2013 flood (without the Project)	149,847	47,085	209,249
2013 flood (with the Project)	113,043	57,881	207,339

Table 3-4 Summary of WA$_{\text{DEPTH}}$ Values for the Adult Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

Flood	WA$_{\text{DEPTH}}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	30,478	6,326	12,992
1:10 year flood (with the Project	24,370	8,777	11,098
1:100 year flood (without the Project)	24,978	5,143	7,124
1:100 year flood (with the Project)	25,240	4,724	8,406
2013 flood (without the Project)	40,839	4,983	5,254
2013 flood (with the Project)	33,247	3,609	8,802

Table 3-5 Summary of WA$_{\text{SUBSTRATE}}$ Values for the Adult Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

Flood	WA$_{\text{SUBSTRATE}}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	33,240	21,811	64,331
1:10 year flood (with the Project)	27,666	11,894	52,064
1:100 year flood (without the Project)	27,598	37,980	108,968
1:100 year flood (with the Project)	40,341	36,364	45,053
2013 flood (without the Project)	56,845	16,565	98,516
2013 flood (with the Project)	43,943	20,914	104,437

3.1.2 Juvenile

Results of HSI analyses for juvenile brown trout are summarized in Table 3-6 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-7 to Table 3-9.

No statistically significant differences in juvenile brown trout habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-6; Figure 3-1). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence juvenile brown trout habitat suitability.

Table 3-6 Summary of WUA Values for the Juvenile Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
Flood	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**		***t***	***p******
1:10 year flood (without the Project)	14,125	-16.3	3,481	10.3	7,826	-13.6	-6.6 (14.6)	1.3068	0.3213
1:10 year flood (with the Project)	11,820		3,838		6,759				
1:100 year flood (without the Project)	12,615	24.2	3,138	-5.7	5,502	1.6	6.7 (15.6)	0.953	0.4412
1:100 year flood (with the Project)	15,664		2,961		5,588				
2013 flood (without the Project)	23,129	-20.5	4,725	-30.8	4,104	39.9	-3.8 (38.2)	0.825	0.4961
2013 flood (with the Project)	18,378		3,272		5,742				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-7 Summary of $WA_{VELOCITY}$ Values for the Juvenile Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

Flood	$WA_{VELOCIY}$ (m²)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	73,567	43,371	118,499
1:10 year flood (with the Project)	60,993	22,944	93,324
1:100 year flood (without the Project)	67,277	67,837	207,673
1:100 year flood (with the Project)	103,532	70,718	83,375
2013 flood (without the Project)	137,259	42,228	189,267
2013 flood (with the Project)	102,858	50,922	188,046

Table 3-8 Summary of WA_{DEPTH} Values for the Juvenile Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

Flood	WA_{DEPTH} (m²)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	47,481	15,591	30,919
1:10 year flood (with the Project)	39,471	14,419	26,813
1:100 year flood (without the Project)	38,328	13,530	22,063
1:100 year flood (with the Project)	4,7124	13,139	22,911
2013 flood (without the Project)	73,863	12,092	17,383
2013 flood (with the Project)	57,099	9,632	22,988

Table 3-9 Summary of $WA_{SUBSTRATE}$ Values for the Juvenile Brown Trout Life Stage in Each Reach, for Each Post-Flood Scenario

Flood	$WA_{SUBSTRATE}$ (m²)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	33,742	19,887	62,482
1:10 year flood (with the Project)	28,031	12,067	50,076
1:100 year flood (without the Project)	12,615	36,600	105,414
1:100 year flood (with the Project)	41,826	36,595	44,702
2013 flood (without the Project)	57,425	17,789	94,784
2013 flood (with the Project)	44,560	21,647	98,793

3.1.3 Fry

Results of HSI analyses for brown trout fry are summarized in Table 3-10 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-11 to Table 3-13.

A statistically significant reduction in WUA for brown trout fry with inclusion of the Project was identified for the 1:10 year flood scenario (paired t test, t (2)=10.05, $p<0.05$).

For the 1:10 year flood scenario, inclusion of the Project corresponded with decreases in WUA, $WA_{VELOCITY}$, WA_{DEPTH}, and $WA_{SUBSTRATE}$ values for all reaches. Inclusion of the Project corresponded with decreases in wetted surface areas in all reaches as well as marked increases in maximum depth and velocity in Reach 2 and 3. High depths and velocities (i.e., > 1 m and 1 m/s, respectively) correspond with low suitability values, including depths and velocities considered unsuitable to brown trout fry (i.e., > 1 m and 1 m/s, respectively).

No statistically significant differences in brown trout fry habitat suitability, with and without the Project, were identified for the 1:100 year and 2013 modelled flood scenarios.

Table 3-10 WUA Values for the Brown Trout Fry Life Stage for each Reach, for Each Flood Scenario

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
Flood	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p*[*]
1:10 year flood (without the Project)	10,302	-14.5	3,718	-32.7	8,488	-20.3	-22.5 (9.3)	10.0466	0.0098
1:10 year flood (with the Project)	8,809		2,503		6,765				
1:100 year flood (without the Project)	9,167	87.0	4,140	-3.0	9,691	-30.4	17.9 (61.5)	0.4994	0.6670
1:100 year flood (with the Project)	17,147		4,014		6,744				
2013 flood (without the Project)	17,629	-22.7	2,817	76.3	8,526	30.5	28.0 (49.5)	0.1177	0.9170
2013 flood (with the Project)	13,633		4,966		11,124				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-11 Summary of WA$_{\text{VELOCITY}}$ Values for the Brown Trout Fry Life Stage in Each Reach, for Each Post-Flood Scenario

	WA$_{\text{VELOCIY}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	70,984	31,229	106,648
1:10 year flood (with the Project)	58,522	18,375	78,170
1:100 year flood (without the Project)	69,637	51,651	203,232
1:100 year flood (with the Project)	112,429	55,318	68,481
2013 flood (without the Project)	137,344	35,365	183,324
2013 flood (with the Project)	103,732	40,979	175,573

Table 3-12 Summary of WA$_{\text{DEPTH}}$ Values for the Brown Trout Fry Life Stage in Each Reach, for Each Post-Flood Scenario

	WA$_{\text{DEPTH}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	66,441	40,778	80,522
1:10 year flood (with the Project)	57,361	22,299	70,763
1:100 year flood (without the Project)	49,144	50,595	85,166
1:100 year flood (with the Project)	86,191	50,334	70,138
2013 flood (without the Project)	102,038	26,680	74,853
2013 flood (with the Project)	78,822	41,449	92,073

Table 3-13 Summary of WA$_{\text{SUBSTRATE}}$ Values for the Brown Trout Fry Life Stage in Each Reach, for Each Post-Flood Scenario

	WA$_{\text{SUBSTRATE}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	17,555	11,048	29,191
1:10 year flood (with the Project)	14,601	5,844	23,262
1:100 year flood (without the Project)	9,167	16,790	48,065
1:100 year flood (with the Project)	22,584	17,574	21,125
2013 flood (without the Project)	30,452	9,632	43,162
2013 flood (with the Project)	22,983	11,663	42,577

3.1.4 Spawning

Results of HSI analyses for brown trout spawning are summarized in Table 3-14 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-15 to Table 3-17.

No statistically significant differences in brown trout spawning habitat suitability, with and without the Project, were predicted for the three modelled flood scenarios (Table 3-14; Figure 3-1). Although not statistically significant, a relatively low p value for Project-related changes to habitat suitability was identified in the 1:10 year flood scenario (p=0.1322) for which suitability decreased in all three reaches.

For spawning, brown trout generally prefer habitat with sufficient depth (>0.15 m), a defined range of velocity (0.25-0.75 m/s), and medium-sized gravel (8-32 mm). For the 1:10 year flood scenario, decreases in WUA were encountered in all reaches and corresponded with lower $WA_{VELOCITY}$, WA_{DEPTH}, and $WA_{SUBSTRATE}$ values.

Table 3-14 WUA Values for the Brown Trout Spawning Life Stage in Each Reach, by Flood

	Reach 1		**Reach 2**		**Reach 3**		**Average % Change (St Dev)**	**Paired *t* Test**	
Flood	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**		***t***	***p******
1:10 year flood (without the Project)	8,617	-10.4	4,628	-8.3	9,030	-2.5	-7.1 (4.1)	2.4703	0.1322
1:10 year flood (with the Project)	7,719		4,242		8,807				
1:100 year flood (without the Project)	6,097	-38.8	4,589	-6.3	7,985	0.9	-14.7 (21.1)	1.1327	0.3749
1:100 year flood (with the Project)	3,734		4,299		8,059				
2013 flood (without the Project)	11,648	-24.7	3,686	19.4	6,874	18.5	4.4 (25.2)	0.2283	0.8407
2013 flood (with the Project)	8,772		4,400		8,146				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-15 Summary of WA$_{\text{VELOCITY}}$ Values for the Brown Trout Spawning Life Stage in Each Reach, Post-Flood

	WA$_{\text{VELOCIY}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	43,869	46,047	78,920
1:10 year flood (with the Project)	38,064	22,294	72,823
1:100 year flood (without the Project)	36,139	59,154	115,067
1:100 year flood (with the Project)	32,421	58,814	69,519
2013 flood (without the Project)	82,978	40,273	106,956
2013 flood (with the Project)	54,959	51,436	136,762

Table 3-16 Summary of WA$_{\text{DEPTH}}$ Values for the Brown Trout Spawning Life Stage in Each Reach, Post-Flood

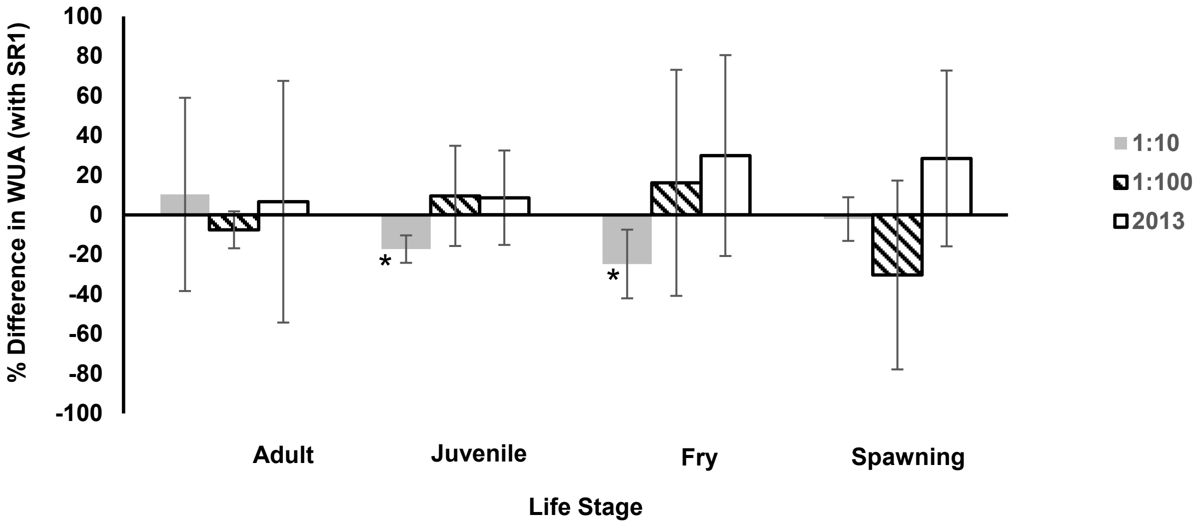
	WA$_{\text{DEPTH}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	63,203	27,008	55,768
1:10 year flood (with the Project)	54,141	19,816	48,498
1:100 year flood (without the Project)	48,446	25,230	46,161
1:100 year flood (with the Project)	69,337	24,825	43,501
2013 flood (without the Project)	89,207	17,147	38,768
2013 flood (with the Project)	71,775	17,620	43,097

Table 3-17 Summary of WA$_{\text{SUBSTRATE}}$ Values for the Brown Trout Spawning Life Stage in Each Reach, Post-Flood

	WA$_{\text{SUBSTRATE}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	23,161	12,808	40,464
1:10 year flood (with the Project)	19,189	8,313	31,949
1:100 year flood (without the Project)	18,493	23,441	67,944
1:100 year flood (with the Project)	29,479	24,936	29,875
2013 flood (without the Project)	39,102	13,112	60,576
2013 flood (with the project)	30,558	15,224	61,634

3.2 BULL TROUT

Results of habitat suitability analyses for adult and spawning bull trout life stages and post-flood scenarios is summarized in Figure 3-2 showing the percentage change in WUA with and without the Project.



NOTE: The asterisk (*) identifies differences found to be statistically significant. Error bars represent standard deviation of the means.

Figure 3-2 **Mean Percent Difference in Habitat Suitability (i.e., WUA), with the Project vs without the Project for Bull Trout Life Stages**

3.2.1 Adult

Results of HSI analyses for adult bull trout are summarized in Table 3-18, for channel morphology, for each flood. The individual weighted areas for velocity, depth, and substrate are provided in Table 3-19 to Table 3-21.

No statistically significant differences in adult bull trout habitat suitability, with and without the Project, were predicted for the three modelled flood scenarios (Table 3-18; Figure 3-2). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence adult bull trout habitat suitability compared to results without the Project.

Table 3-18 WUA Values for the Adult Bull Trout Life Stage in Each Reach, by Each Post-Flood Scenario

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	23,369	-19.9	3,408	66.5	7,917	-15.6	10.3 (48.7)	0.6046	0.6069
1:10 year flood (with the Project)	18,711		5,673		6,685				
1:100 year flood (without the Project)	21,051	-9.0	2,772	-15.9	4,479	2.5	-7.5 (9.3)	1.2399	0.3408
1:100 year flood (with the Project)	19,151		2,330		4,590				
2013 flood (without the Project)	32,537	-17.4	4,578	-38.6	2,978	75.9	6.6 (60.9)	0.7526	0.5302
2013 flood (with the Project)	26,889		2,813		5,237				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-19 Summary of $WA_{VELOCITY}$ Values for the Bull Trout Adult Life Stage in Each Reach, for Each Post-Flood Scenario.

	$WA_{VELOCIY}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	75,455	45,773	122,149
1:10 year flood (with the Project)	62,702	23,906	96,773
1:100 year flood (without the Project)	67,883	71,321	212,027
1:100 year flood (with the Project)	103,668	74,153	86,822
2013 flood (without the Project)	139,189	43,634	192,723
2013 flood (with the Project)	104,337	53,574	193,215

Table 3-20 Summary of WA_{DEPTH} Values for the Bull Trout Adult Life Stage in Each Reach, for Each Post-Flood Scenario

	WA_{DEPTH} (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	26,916	5,178	10,871
1:10 year flood (with the Project)	21,285	7,504	9,317
1:100 year flood (without the Project)	22,423	4,311	6,122
1:100 year flood (with the Project)	21,523	3,950	6,936
2013 flood (without the Project)	36,384	4,717	4,480
2013 flood (with the Project)	29,377	3,029	7,442

Table 3-21 Summary of $WA_{SUBSTRATE}$ Values for the Bull Trout Adult Life Stage in Each Reach, for Each Post-Flood Scenario

	$WA_{SUBSTRATE}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	3,265	4,974	12,447
1:10 year flood (with the Project)	2,714	2,710	10,403
1:100 year flood (without the Project)	2,672	6,817	19,996
1:100 year flood (with the Project)	4,216	6,942	9,069
2013 Flood (without the Project)	5,671	4,439	19,996
2013 Flood (with the Project)	4,290	5,391	19,996

3.2.2 Juvenile

Results of HSI analyses for juvenile bull trout are summarized in Table 3-22 for for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-23 to Table 3-25.

A statistically significant reduction in WUA for juvenile bull trout with inclusion of the Project was identified for the 1:10 year flood scenario (paired t test, t (2)=10.2209, $p<0.05$).

For the 1:10 year flood scenario, inclusion of the Project corresponded with decreases in WUA, $WA_{VELOCITY}$, WA_{DEPTH}, and $WA_{SUBSTRATE}$ values for all reaches. Inclusion of the Project corresponded with decreases in wetted surface areas in all reaches as well as marked increases in maximum depth and velocity in Reach 2 and 3. High depths and velocities (i.e., > 1.4 m and 1.2 m/s, respectively) correspond with low suitability values.

No statistically significant differences in juvenile bull trout habitat suitability, with and without the Project, were identified for the 1:100 year and 2013 modelled flood scenarios.

Table 3-22 WUA Values for the Juvenile Bull Trout Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	10519	-13.6	4225	-25.2	8453	-12.9	-17.2 (6.9)	10.2209	0.0094
1:10 year flood (with the Project)	9093		3161		7364				
1:100 year flood (without the Project)	8590	38.7	3801	-4.4	6830	-5.5	9.6 (25.2)	0.7713	0.5212
1:100 year flood (with the Project)	11916		3634		6451				
2013 flood (without the Project)	15108	-18.8	2660	23.5	5478	-21.3	8.7 (23.8)	0.277	0.8078
2013 flood (with the Project)	12275		3283		6646				

Table 3-23 Summary of $WA_{VELOCITY}$ Values for the Bull Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	$WA_{VELOCIY}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	78,355	50,070	129,393
1:10 year flood (with the Project)	65,336	25,603	103,763
1:100 year flood (without the Project)	68,468	77,183	218,991
1:100 year flood (with the Project)	103,728	80,017	93,708
2013 flood (without the Project)	141,834	46,277	198,464
2013 flood (with the Project)	106,210	57,041	199,807

Table 3-24 Summary of WA_{DEPTH} Values for the Bull Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	WA_{DEPTH} (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	59,274	25,027	51,637
1:10 year flood (with the Project)	50,768	19,043	44,891
1:100 year flood (without the Project)	45,686	23,932	40,704
1:100 year flood (with the Project)	66,071	23,544	40,420
2013 flood (without the Project)	83,231	14,372	34,122
2013 flood (with the Project)	67,670	17,059	39,555

Table 3-25 Summary of $WA_{SUBSTRATE}$ Values for the Bull Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	$WA_{SUBSTRATE}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	17,555	11,048	29,191
1:10 year flood (with the Project)	14,601	5,844	23,262
1:100 year flood (without the Project)	8,590	16,790	48,065
1:100 year flood (with the Project)	22,584	17,574	21,125
2013 flood (without the Project)	30,452	9,632	43,162
2013 flood (with the Project)	22,983	11,663	42,577

3.2.3 Fry

Results of HSI analyses for bull trout fry are summarized in Table 3-26 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-27 to Table 3-29.

A statistically significant reduction in WUA for bull trout fry with inclusion of the Project was identified for the 1:10 year flood scenario (paired t test, t (2)=6.6303, $p<0.05$).

For the 1:10 year flood scenario, inclusion of the Project corresponded with decreases in WUA, $WA_{VELOCITY}$, WA_{DEPTH}, and $WA_{SUBSTRATE}$ values for all reaches. Inclusion of the Project corresponded with decreases in wetted surface areas in all reaches as well as marked increases in maximum depth and velocity in Reach 2 and 3. High depths and velocities (i.e., > 1 m and >1.2 m/s, respectively) correspond with low suitability values for bull trout fry.

No statistically significant differences in bull trout fry habitat suitability, with and without the Project, were identified for the 1:100 year and 2013 modelled flood scenarios.

Table 3-26 WUA Values for the Bull Trout Fry Life Stage in Each Reach, by Flood

	Reach 1		**Reach 2**		**Reach 3**		**Average % Change (St Dev)**	**Paired *t* Test**	
Flood	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**	**WUA (m^2)**	**% Change**		***t***	**p^***
1:10 year flood (without the Project)	11,641	-12.9	5,639	-44.6	11,226	-16.7	-24.7 (17.3)	6.6303	0.0220
1:10 year flood (with the Project)	10,143		3,127		9,350				
1:100 year flood (without the Project)	9,574	80.0	6,974	-2.2	13,205	-29.3	16.2 (56.9)	0.3564	0.7556
1:100 year flood (with the Project)	17,232		6,822		9,332				
2013 flood (without the Project)	19,050	-22.4	3,977	78.6	11,215	33.5	29.9 (50.6)	0.3388	0.7670
2013 flood (with the Project)	14,785		7,102		14,972				

Table 3-27 Summary of $WA_{VELOCITY}$ Values for the Bull Trout Fry Life Stage in Each Reach, Post-Flood

	$WA_{VELOCIY}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	78,866	41,656	121,255
1:10 year flood (with the Project)	65,940	22,054	91,976
1:100 year flood (without the Project)	71,800	67,907	221,176
1:100 year flood (with the Project)	112,881	71,392	82,011
2013 flood (without the Project)	145,104	41,353	197,028
2013 flood (with the Project)	109,910	52,309	195,649

Table 3-28 Summary of WA_{DEPTH} Values for the Bull Trout Fry Life Stage in Each Reach, Post-Flood

	WA_{DEPTH} (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	66,441	40,778	80,522
1:10 year flood (with the Project)	57,361	22,299	70,763
1:100 year flood (without the Project)	49,144	50,595	85,166
1:100 year flood (with the Project)	86,191	50,334	70,138
2013 flood (without the Project)	102,038	26,680	74,853
2013 flood (with the Project)	78,822	41,449	92,073

Table 3-29 Summary of $WA_{SUBSTRATE}$ Values for the Bull Trout Fry Life Stage in Each Reach, Post-Flood

	$WA_{SUBSTRATE}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	17,555	11,048	29,191
1:10 year flood (with the Project)	14,601	5,844	23,262
1:100 year flood (without the Project)	9,574	16,790	48,065
1:100 year flood (with the Project)	22,584	17,574	21,125
2013 flood (without the Project)	30,452	9,632	43,162
2013 Flood (with the Project)	22,983	11,663	42,577

3.2.4 Spawning

Results of HSI analyses for bull trout spawning are summarized in Table 3-30 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-31 to Table 3-33. No statistically significant differences in bull trout spawning habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-30; Figure 3-2). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence bull trout spawning habitat suitability.

Table 3-30 WUA Values for the Bull Trout Spawning Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	19,092	-11.0	7,060	10.2	12,324	-5.5	-2.1 (11.0)	0.8405	0.4891
1:10 year flood (with the Project)	16,993		7,780		11,651				
1:100 year flood (without the Project)	8,433	-84.4	5,502	-11.2	8,884	4.8	-30.2 (47.5)	1.0316	0.4107
1:100 year flood (with the Project)	1,318		4,886		9,312				
2013 flood (without the Project)	18,599	-21.9	3,676	61.4	6,786	45.8	28.5 (44.3)	0.1915	0.8658
2013 flood (with the Project)	14,533		5,933		9,895				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-31 Summary of $WA_{VELOCITY}$ Values for the Bull Trout Spawning Life Stage in Each Reach, Post-Flood

Scenario	$WA_{VELOCIY}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	32,816	37,579	58,210
1:10 year flood (with the Project)	29,612	17,426	53,844
1:100 year flood (without the Project)	20,413	47,670	79,315
1:100 year flood (with the Project)	10,507	47,138	54,747
2013 flood (without the Project)	52,553	30,169	68,677
2013 flood (with the Project)	34,409	43,656	101,065

Table 3-32 Summary of WA_{DEPTH} Values for the Bull Trout Spawning Life Stage in Each Reach, Post-Flood

Flood	WA_{DEPTH} (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	38,980	10,800	26,431
1:10 year flood (with the Project)	32,979	11,737	22,236
1:100 year flood (without the Project)	31,470	11,554	18,579
1:100 year flood (with the Project)	34,681	10,893	18,568
2013 flood (without the Project)	50,838	8,522	14,777
2013 flood (with the Project)	40,676	7,597	18,541

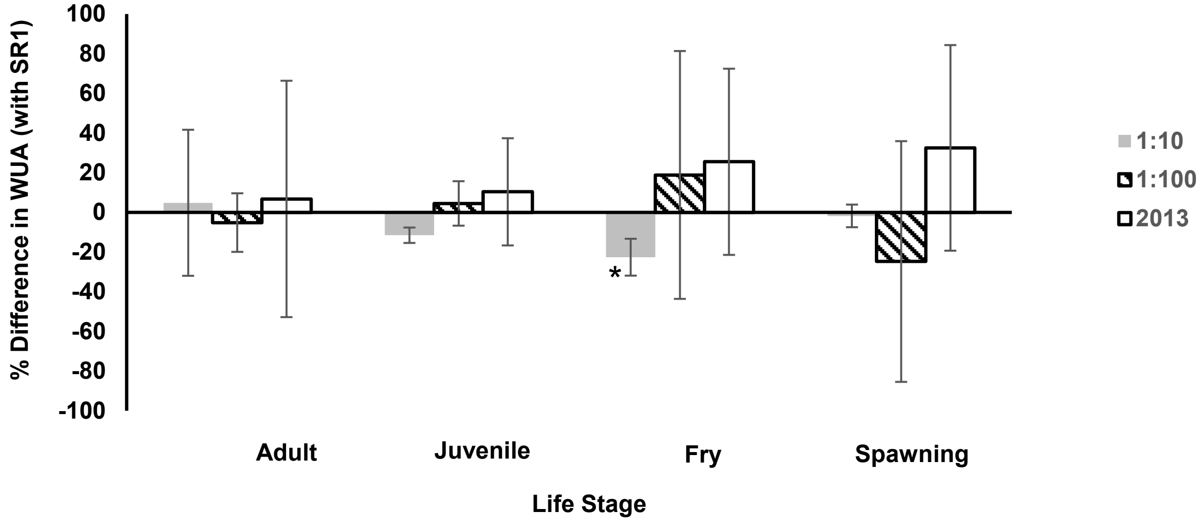
Table 3-33 Summary of $WA_{SUBSTRATE}$ Values for the Bull Trout Spawning Life Stage in Each Reach, Post-Flood

Scenario	$WA_{SUBSTRATE}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 Year Flood (without the Project)	87,777	54,539	145,954
1:10 Year Flood (with the Project)	73,005	29,221	116,308
1:100 Year Flood (without the Project)	73,124	83,948	240,326
1:100 Year Flood (with the Project)	112,920	87,869	105,625
2013 Flood (without the Project)	152,258	48,161	215,808
2013 Flood (with the Project)	114,917	58,313	212,884

3.3 RAINBOW TROUT

Results of habitat suitability analyses for all rainbow trout life stages, except juveniles, and post-flood scenarios is summarized in Figure 3-3 showing the percentage change in WUA with and without the Project.

The juvenile life stages were not included because the model predicted no suitable habitat (in all floods) due to a lack of larger substrates.



NOTE: The asterisk (*) identifies differences found to be statistically significant. Error bars represent standard deviation of the means.

Figure 3-3 Mean Percent Difference in Habitat Suitability (i.e., WUA), with the Project vs without the Project, for Rainbow Life Stages

3.3.1 Adult

Results of HSI analyses for adult rainbow trout are summarized in Table 3-34 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-35 to Table 3-37.

No statistically significant differences in adult rainbow trout habitat suitability, with and without the Project, were predicted for the three modelled flood scenarios (Table 3-2; Figure 3-3). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence adult rainbow trout habitat suitability.

Table 3-34 WUA Values for the Adult Rainbow Trout Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	13,562	-19.4	2,360	47.2	4,866	-13.3	4.8 (36.8)	0.6046	0.6069
1:10 year flood (with the Project)	10,931		3,474		4,220				
1:100 year flood (without the Project)	11,533	-11.3	1,789	-15.8	2,714	11.7	-5.1 (14.8)	1.2399	0.3408
1:100 year flood (with the Project)	10,228		1,506		3,032				
2013 flood (without the Project)	18,285	-18.9	2,554	-35.6	1,845	74.9	6.8 (59.6)	0.7526	0.5302
2013 flood (with the Project)	14,825		1,644		3,227				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-35 Summary of WA$_{VELOCITY}$ Values for the Rainbow Trout Adult Life Stage in Each Reach, Post-Flood

Flood	WA$_{VELOCIY}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	78,412	50,954	130,244
1:10 year flood (with the Project)	65,707	25,774	105,042
1:100 year flood (without the Project)	67,896	77,719	218,034
1:100 year flood (with the Project)	101,495	80,462	95,227
2013 flood (without the Project)	140,939	46,866	196,726
2013 flood (with the Project)	104,963	57,402	199,207

Table 3-36 Summary of WA$_{DEPTH}$ Values for the Rainbow Trout Adult Life Stage in Each Reach, Post-Flood

Flood	WA$_{DEPTH}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	26,916	5,178	10,871
1:10 year flood (with the Project)	21,285	7,504	9,317
1:100 year flood (without the Project)	22,423	4,311	6,122
1:100 year flood (with the Project)	21,523	3,950	6,936
2013 flood (without the Project)	36,384	4,717	4,480
2013 flood (with the Project)	29,377	3,029	7,442

Table 3-37 Summary of WA$_{SUBSTRATE}$ Values for the Rainbow Trout Adult Life Stage in Each Reach, Post-Flood

Flood	WA$_{SUBSTRATE}$ (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	48,277	29,996	80,275
1:10 year flood (with the Project)	40,153	16,071	63,970
1:100 year flood (without the Project)	40,218	46,172	132,179
1:100 year flood (with the Project)	62,106	48,328	58,094
2013 flood (without the Project)	83,742	26,489	118,695
2013 flood (with the Project)	63,204	32,072	117,086

3.3.2 Juvenile

Results of HSI analyses for juvenile rainbow trout are summarized in Table 3-38 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-39 to Table 3-41.

No statistically significant differences in juvenile rainbow trout habitat suitability, with and without the Project, were identified for the three modelled flood scenarios. Although not statistically significant, a relatively low p value for Project-related changes to habitat suitability was identified in the 1:10 year flood scenario (p=0.1476) for which suitability decreased in all three reaches.

Table 3-38 WUA Values for the Juvenile Rainbow Trout Life Stage in Each Reach, by Flood

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
Flood	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	7,764	-14.9	2,552	-7.3	4,840	-12.4	-11.5 (3.9)	2.3053	0.1476
1:10 year flood (with the Project)	6,609		2,367		4,239				
1:100 year flood (without the Project)	5,751	15.0	2,096	-7.3	3,407	5.9	4.5 (11.2)	1.0185	0.4156
1:100 year flood (with the Project)	6,612		1,942		3,607				
2013 flood (without the Project)	10,551	-19.6	1,443	18.0	2,651	32.8	10.4 (27.0)	0.3514	0.7588
2013 flood (with the Project)	8,478		1,702		3,520				

Table 3-39 Summary of WA$_{VELOCITY}$ Values for the Rainbow Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	WA$_{VELOCIY}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	76,431	51,370	127,587
1:10 year flood (with the Project)	64,746	26,156	103,341
1:100 year flood (without the Project)	62,068	75,923	206,658
1:100 year flood (with the Project)	89,193	78,549	95,684
2013 flood (without the Project)	132,115	45,333	182,970
2013 flood (with the Project)	97,656	56,042	189,210

Table 3-40 Summary of WA$_{DEPTH}$ Values for the Rainbow Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	WA$_{DEPTH}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	43,352	13,965	27,746
1:10 year flood (with the Project)	36,004	13,472	23,935
1:100 year flood (without the Project)	34,177	12,097	18,977
1:100 year flood (with the Project)	42,727	11,674	20,324
2013 flood (without the Project)	60,577	8,457	15,293
2013 flood (with the Project)	48,944	8,663	20,310

Table 3-41 Summary of WA$_{SUBSTRATE}$ Values for the Rainbow Trout Juvenile Life Stage in Each Reach, Post-Flood

Flood	WA$_{SUBSTRATE}$ (m^2)		
	Reach 1	Reach 2	Reach 3
1:10 year flood (without the Project)	17,555	11,048	29,191
1:10 year flood (with the Project)	14,601	5,844	23,262
1:100 year flood (without the Project)	5,751	16,790	48,065
1:100 year flood (with the Project)	22,584	17,574	21,125
2013 flood (without the Project)	30,452	9,632	43,162
2013 flood (with the Project)	22,983	11,663	42,577

3.3.3 Fry

Results of HSI analyses for rainbow trout fry are summarized in Table 3-42 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-43 to Table 3-45.

A statistically significant reduction in WUA for rainbow trout fry with inclusion of the Project was identified for the 1:10 year flood scenario (paired t test, t (2)=9.5227, p<0.05).

For the 1:10 year flood scenario, inclusion of the Project corresponded with decreases in WUA, $WA_{VELOCITY}$, WA_{DEPTH}, and $WA_{SUBSTRATE}$ values for all reaches. Inclusion of the Project corresponded with decreases in wetted surface areas in all reaches as well as marked increases in maximum depth and velocity in Reach 2 and 3. High depths and velocities (i.e., > 1 m and >1 m/s, respectively) correspond with low suitability values rainbow trout fry.

No statistically significant differences in rainbow trout fry habitat suitability, with and without the Project, were identified for the 1:100 year and 2013 modelled flood scenarios.

Table 3-42 WUA Values for the Rainbow Trout Fry Life Stage in Each Reach, by Flood

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired *t* Test	
Flood	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	10,131	-14.6	3,575	-32.8	8,294	-20.4	-22.6 (9.3)	9.5227	0.0108
1:10 year flood (with the Project)	8,657		2,403		6,599				
1:100 year flood (without the Project)	9,036	89.4	3,993	-3.0	9,312	-29.7	18.9 (62.5)	0.5300	0.6491
1:100 year flood (with the Project)	17,111		3,872		6,548				
2013 flood (without the Project)	17,382	-22.6	2,736	71.1	8,237	28.0	25.5 (46.9)	0.0525	0.9629
2013 flood (with the Project)	13,445		4,682		10,546				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-43 Summary of $WA_{VELOCITY}$ Values for the Rainbow Trout Fry Life Stage in Each Reach, Post-Flood

	$WA_{VELOCIY}$ (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	69,905	30,248	105,305
1:10 year flood (with the Project)	57,631	17,754	77,061
1:100 year flood (without the Project)	68,959	50,468	200,815
1:100 year flood (with the Project)	112,238	54,156	67,154
2013 flood (without the Project)	135,867	34,805	181,415
2013 flood (with the Project)	102,613	38,959	170,993

Table 3-44 Summary of WA_{DEPTH} Values for the Rainbow Trout Fry Life Stage in Each Reach, Post-Flood

	WA_{DEPTH} (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	66,441	40,778	80,522
1:10 year flood (with the Project)	57,361	22,299	70,763
1:100 year flood (without the Project)	49,144	50,595	85,166
1:100 year flood (with the Project)	86,191	50,334	70,138
2013 flood (without the Project)	102,038	26,680	74,853
2013 flood (with the Project)	78,822	41,449	92,073

Table 3-45 Summary of $WA_{SUBSTRATE}$ Values for the Rainbow Trout Fry Life Stage in Each Reach, Post-Flood

	$WA_{SUBSTRATE}$ (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	17,555	11,048	29,191
1:10 year flood (with the Project)	14,601	5,844	23,262
1:100 year flood (without the Project)	9,036	16,790	48,065
1:100 year flood (with the Project)	22,584	17,574	21,125
2013 flood (without the Project)	30,452	9,632	43,162
2013 flood (with the Project)	22,983	11,663	42,577

3.3.4 Spawning

Results of HSI analyses for rainbow trout spawning are summarized in Table 3-46 for for each modelled flood scenario. No statistically significant differences in rainbow trout spawning habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-46). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence rainbow trout spawning habitat suitability.

Table 3-46 WUA Values for the Rainbow Trout Spawning Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired t Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p*[*]
1:10 year flood (without the Project)	19,246	7.7	9,220	3.6	14,586	-1.2	-1.8 (5.7)	1.0112	0.4184
1:10 year flood (with the Project)	17,758		9,554		14,409				
1:100 year flood (without the Project)	7,100	-91.6	7,029	-9.5	10,579	26.8	-24.8 (60.7)	0.5305	0.6488
1:100 year flood (with the Project)	595		6,361		13,416				
2013 flood (without the Project)	17,844	-24.0	3,579	77.8	8,637	43.8	32.5 (51.8)	0.2993	0.7929
2013 flood (with the Project)	13,559		6,363		12,418				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-47 Summary of WA$_{\text{VELOCITY}}$ Values for the Rainbow Trout Spawning Life Stage in Each Reach, Post-Flood

	WA$_{\text{VELOCIY}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	31,292	37,883	58,309
1:10 year flood (with the Project)	28,479	16,742	54,095
1:100 year flood (without the Project)	15,333	49,178	74,810
1:100 year flood (with the Project)	5,515	48,597	55,841
2013 flood (without the Project)	43,496	28,702	63,132
2013 flood (with the Project)	29,263	43,343	94,169

Table 3-48 Summary of WA$_{\text{DEPTH}}$ Values for the Rainbow Trout Spawning Life Stage in Each Reach, Post-Flood

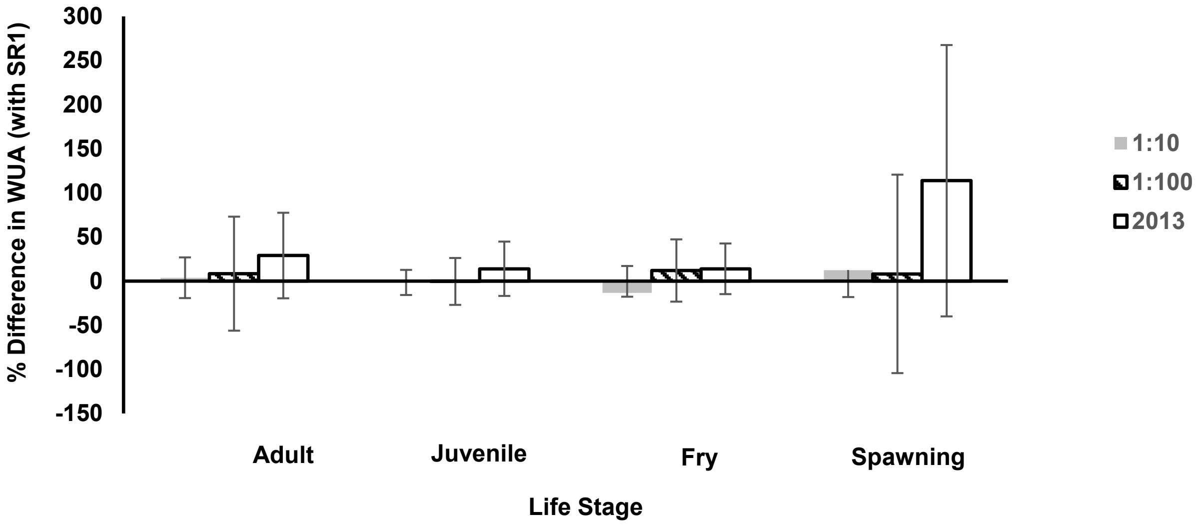
	WA$_{\text{DEPTH}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	48,143	16,928	33,770
1:10 year flood (with the Project)	40,554	15,698	29,526
1:100 year flood (without the Project)	38,169	13,852	21,252
1:100 year flood (with the Project)	51,267	13,498	25,193
2013 flood (without the Project)	69,533	8,881	17,701
2013 flood (with the Project)	56,797	9,449	23,629

Table 3-49 Summary of WA$_{\text{SUBSTRATE}}$ Values for the Rainbow Trout Spawning Life Stage in Each Reach, Post-Flood

	WA$_{\text{SUBSTRATE}}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	75,764	40,204	108,305
1:10 year flood (with the Project)	62,779	24,676	83,568
1:100 year flood (without the Project)	61,331	60,276	174,069
1:100 year flood (with the Project)	102,703	72,553	83,616
2013 flood (without the Project)	130,747	46,760	153,556
2013 flood (with the Project)	98,724	52,836	138,115

3.4 MOUNTAIN WHITEFISH

Results of habitat suitability analyses for all mountain whitefish life stages and post-flood scenarios is summarized in Figure 3-4 showing the percentage change in WUA with and without the Project.



NOTE: Error bars represent standard deviation of the means. No statistically significant differences were identified for all scenarios and life stages.

Figure 3-4 **Mean Percent Difference in Habitat Suitability (i.e., WUA), with the Project vs without the Project, for Mountain Whitefish Life Stages**

3.4.1 Adult

Results of HSI analyses for adult mountain whitefish are summarized in Table 3-26 for each modelled flood scenario. No statistically significant differences in adult mountain whitefish habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-50; Figure 3-4). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence adult mountain whitefish habitat suitability.

Table 3-50 WUA Values for the Adult Mountain Whitefish Life Stage in Each Reach, by Flood

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired t Test	
Flood	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	23,369	-16.7	6,398	28.8	9,108	-0.6	3.8 (23.1)	0.4184	0.7163
1:10 year flood (with the Project)	19,461		8,239		9,052				
1:100 year flood (without the Project)	12,648	-39.8	3,820	-16.8	3,872	81.8	8.4 (64.6)	0.3520	0.7585
1:100 year flood (with the Project)	7,620		3,178		7,041				
2013 flood (without the Project)	24,028	-19.8	2,736	29.6	3,449	77.2	29.0 (48.5)	0.1922	0.8653
2013 flood (with the Project)	19,272		3,546		6,110				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-51 Summary of $WA_{VELOCITY}$ Values for the Mountain Whitefish Adult Life Stage in Each Reach, Post-Flood

	$WA_{VELOCIY}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	50,489	47,230	90,647
1:10 year flood (with the Project)	43,174	23,275	80,259
1:100 year flood (without the Project)	36,905	63,838	130,376
1:100 year flood (with the Project)	40,066	64,285	77,217
2013 flood (without the Project)	84,705	38,692	118,713
2013 flood (with the Project)	59,357	50,417	140,517

Table 3-52 Summary of WA_{DEPTH} Values for the Mountain Whitefish Adult Life Stage in Each Reach, Post-Flood

	WA_{DEPTH} (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	32,398	7,105	14,366
1:10 year flood (with the Project)	26,095	9,508	12,257
1:100 year flood (without the Project)	26,328	5,659	7,747
1:100 year flood (with the Project)	27,547	5,230	9,395
2013 flood (without the Project)	43,563	5,131	5,759
2013 flood (with the Project)	35,514	3,980	9,685

Table 3-53 Summary of $WA_{SUBSTRATE}$ Values for the Mountain Whitefish Adult Life Stage in Each Reach, Post-Flood

	$WA_{SUBSTRATE}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	3,265	4,974	12,447
1:10 year flood (with the Project)	2,714	2,710	10,403
1:100 year flood (without the Project)	2,672	6,817	19,996
1:100 year flood (with the Project)	4,216	6,942	9,069
2013 flood (without the Project)	5,671	4,439	19,996
2013 flood (with the Project)	4,290	5,391	19,996

3.4.2 Juvenile

Results of HSI analyses for juvenile mountain whitefish are summarized in Table 3-54 for each modelled flood scenario. No statistically significant differences in juvenile mountain whitefish habitat suitability, with and without the Project, were identified for the three modelled flood scenarios (Table 3-54; Figure 3-4).

The individual useable weighted areas for velocity, depth, and substrate are provided in Table 3-55 to Table 3-57. Although not statistically significant, a relatively low p value for Project-related changes to habitat suitability was identified in the 1:10 year flood scenario (p=0.1476) for which suitability decreased in all three reaches.

Table 3-54 WUA Values for the Juvenile Mountain Whitefish Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired t Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		*t*	*p**
1:10 year flood (without the Project)	25,987	-15.1	10,025	13.3	17,823	-2.8	-1.5 (14.2)	2.3053	0.1476
1:10 year flood (with the Project)	22,072		11,361		17,322				
1:100 year flood (without the Project)	15,012	-24.4	8,947	-4.9	12,063	28.2	-0.4 (26.6)	1.0185	0.4156
1:100 year flood (with the Project)	11,356		8,506		15,463				
2013 flood (without the Project)	30,055	-21.5	5,543	30.4	10,927	33.1	14.0 (30.8)	0.3514	0.7588
2013 flood (with the Project)	23,585		7,229		14,541				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-55 Summary of WAVELOCITY Values for the Mountain Whitefish Juvenile Life Stage in Each Reach, Post-Flood

Flood	WAVELOCIY (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	52,523	49,218	94,496
1:10 year flood (with the Project)	44,611	25,068	83,997
1:100 year flood (without the Project)	38,956	65,849	135,152
1:100 year flood (with the Project)	42,264	66,484	80,185
2013 flood (without the Project)	89,447	40,357	124,035
2013 flood (with the Project)	62,314	51,528	146,482

Table 3-56 Summary of WADEPTH Values for the Mountain Whitefish Juvenile Life Stage in Each Reach, Post-Flood

Flood	WADEPTH (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	43,087	13,845	27,593
1:10 year flood (with the Project)	35,763	13,362	23,834
1:100 year flood (without the Project)	34,033	12,050	18,946
1:100 year flood (with the Project)	42,446	11,633	20,226
2013 flood (without the Project)	60,200	8,453	15,273
2013 flood (with the Project)	48,667	8,609	20,248

Table 3-57 Summary of WASUBSTRATE Values for the Mountain Whitefish Juvenile Life Stage in Each Reach, Post-Flood

Flood	WASUBSTRATE (m^2)		
	Reach 1	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	77,382	50,225	130,474
1:10 year flood (with the Project)	64,188	26,878	103,081
1:100 year flood (without the Project)	15,012	75,142	216,928
1:100 year flood (with the Project)	99,525	80,515	96,178
2013 flood (without the Project)	132,050	43,841	193,629
2013 flood (with the Project)	101,716	51,375	193,159

3.4.3 Fry

Results of HSI analyses for mountain whitefish fry are summarized in Table 3-58 for each modelled flood scenario. The individual useable weighted areas for velocity, depth, and substrate are provided in Table 3-59 to Table 3-61.

No statistically significant differences in mountain whitefish fry habitat suitability, with and without the Project, were identified for the three modelled flood scenarios. Although not statistically significant, a relatively low p value for Project-related changes to habitat suitability was identified in the 1:10 year flood scenario (p=0.1092) for which suitability decreased in all three reaches.

Table 3-58 WUA Values for the Mountain Whitefish Fry Life Stage in Each Reach, by Flood

	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired t Test	
Flood	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		t	p^*
1:10 year flood (without the Project)	47,029	-14.2	14,514	-9.1	33,906	-17.3	-13.5 (4.2)	2.7722	0.1092
1:10 year flood (with the Project)	40,355		13,194		28,033				
1:100 year flood (without the Project)	39,431	51.5	16,233	1.0	31,706	-16.5	12.0 (35.3)	0.6542	0.5801
1:100 year flood (with the Project)	59,736		16,398		26,484				
2013 flood (without the Project)	73,770	-18.7	13,260	25.6	25,614	35.0	14.0 (28.7)	0.0713	0.9496
2013 flood (with the Project)	59,942		16,654		34,580				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-59 Summary of $WA_{VELOCITY}$ Values for the Mountain Whitefish Fry Life Stage in Each Reach, Post-Flood

	$WA_{VELOCIY}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	81,860	46,804	130,267
1:10 year flood (with the Project)	68,892	23,666	100,819
1:100 year flood (without the Project)	72,388	74,505	229,722
1:100 year flood (with the Project)	112,902	77,920	90,602
2013 flood (without the Project)	148,048	45,050	203,484
2013 flood (with the Project)	111,698	56,579	202,974

Table 3-60 Summary of WA_{DEPTH} Values for the Mountain Whitefish Fry Life Stage in Each Reach, Post-Flood

	WA_{DEPTH} (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	56,447	24,137	48,617
1:10 year flood (with the Project)	47,634	18,288	42,472
1:100 year flood (without the Project)	44,300	24,677	41,348
1:100 year flood (with the Project)	63,131	24,302	38,641
2013 flood (without the Project)	83,198	15,037	35,620
2013 flood (with the Project)	66,262	18,633	44,747

Table 3-61 Summary of $WA_{SUBSTRATE}$ Values for the Mountain Whitefish Fry Life Stage in Each Reach, Post-Flood

	$WA_{SUBSTRATE}$ (m^2)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	81,971	55,241	133,161
1:10 year flood (with the Project)	67,938	28,259	104,449
1:100 year flood (without the Project)	39,431	76,122	220,169
1:100 year flood (with the Project)	106,897	84,204	99,600
2013 flood (without the Project)	139,811	47,821	195,760
2013 flood (with the Project)	107,596	55,125	191,528

3.4.4 Spawning

Results of HSI analyses for mountain whitefish spawning are summarized in Table 3-62 for each modelled flood scenario. The individual weighted useable areas for velocity, depth, and substrate are provided in Table 3-63 to Table 3-65. No statistically significant differences in mountain whitefish spawning habitat suitability with and without the Project were identified for the three modelled flood scenarios (Table 3-62; Figure 3-4). Suitability for specific reaches increased in some scenarios and decreased in others but overall, the Project was not found to negatively or positively influence mountain whitefish spawning habitat suitability.

Table 3-62 WUA Values for the Mountain Whitefish Spawning Life Stage in Each Reach, by Flood

Flood	Reach 1		Reach 2		Reach 3		Average % Change (St Dev)	Paired t Test	
	WUA (m^2)	% Change	WUA (m^2)	% Change	WUA (m^2)	% Change		t	p^*
1:10 year flood (without the Project)	9,256	-15.5	3,046	45.3	4,185	7.9	12.6 (30.6)	0.1121	0.921
1:10 year flood (with the Project)	7,822		4,425		4,516				
1:100 year flood (without the Project)	2,337	-93.5	1,957	-11.0	1,608	129.0	8.2 (112.4)	0.0881	0.9379
1:100 year flood (with the Project)	153		1,742		3,682				
2013 flood (without the Project)	7,722	-21.4	475	281.1	1,691	81.6	113.8 (153.8)	0.3541	0.7571
2013 flood (with the Project)	6,072		1,810		3,071				

NOTE:
* Project considered to have a statistically significant effect where p values <0.05

Table 3-63 Summary of $WA_{VELOCITY}$ Values for the Mountain Whitefish Spawning Life Stage in Each Reach, Post-Flood

	$WA_{VELOCIY}$ (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	36,264	43,238	69,197
1:10 year flood (with the Project)	31,900	21,114	64,666
1:100 year flood (without the Project)	18,127	54,943	84,183
1:100 year flood (with the Project)	7,525	54,663	65,643
2013 flood (without the Project)	51,042	31,513	73,969
2013 flood (with the Project)	34,025	44,980	104,837

Table 3-64 Summary of WA_{DEPTH} Values for the Mountain Whitefish Spawning Life Stage in Each Reach, Post-Flood

	WA_{DEPTH} (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	34,420	8,081	16,028
1:10 year flood (with the Project)	27,932	10,325	13,674
1:100 year flood (without the Project)	27,759	6,272	8,485
1:100 year flood (with the Project)	30,256	5,841	10,636
2013 flood (without the Project)	46,745	5,293	6,392
2013 flood (with the Project)	38,086	4,430	10,722

Table 3-65 Summary of $WA_{SUBSTRATE}$ Values for the Mountain Whitefish Spawning Life Stage in Each Reach, Post-Flood

	$WA_{SUBSTRATE}$ (m²)		
Flood	**Reach 1**	**Reach 2**	**Reach 3**
1:10 year flood (without the Project)	41,969	24,927	74,950
1:10 year flood (with the Project)	34,840	14,863	59,720
1:100 year flood (without the Project)	34,138	43,624	125,800
1:100 year flood (with the Project)	52,813	44,846	54,288
2013 flood (without the Project)	71,449	22,829	112,772
2013 flood (with the Project)	55,330	27,303	115,693

4.0 CONCLUSIONS

Changes to fish habitat suitability was highly variable amongst modelled reaches of the Elbow River. For specific flood scenarios, the Project resulted in increases to habitat suitability for specific reaches and decreases in suitability for others. Statistically significant changes to habitat suitability were identified for 1:10 year flood scenario. This included statistically significant decreases in habitat suitability with inclusion of the Project for the brown trout fry life stage, the bull trout juvenile and fry life stages, as well as the rainbow trout fry life stage. In all cases, changes to fish habitat suitability with inclusion of the Project were related to decreases in total wetted surface areas combined with higher depths and velocities in some areas which are generally less suitable to juvenile and fry life stages of key indicator species. For all other combinations of flood scenarios, fish species, and life stage, Project inclusion did not result in a statistically significant change to fish habitat suitability.

5.0 CLOSURE

This technical data report has been prepared for Alberta Transportation by Stantec Consulting Ltd. to support Elbow River pre-construction monitoring activities for the Springbank Off-stream Reservoir Project. The results of this report may also be used for responding to ongoing Information Requests as part of the EIA process.

Closure
June 2020

6.0 REFERENCES

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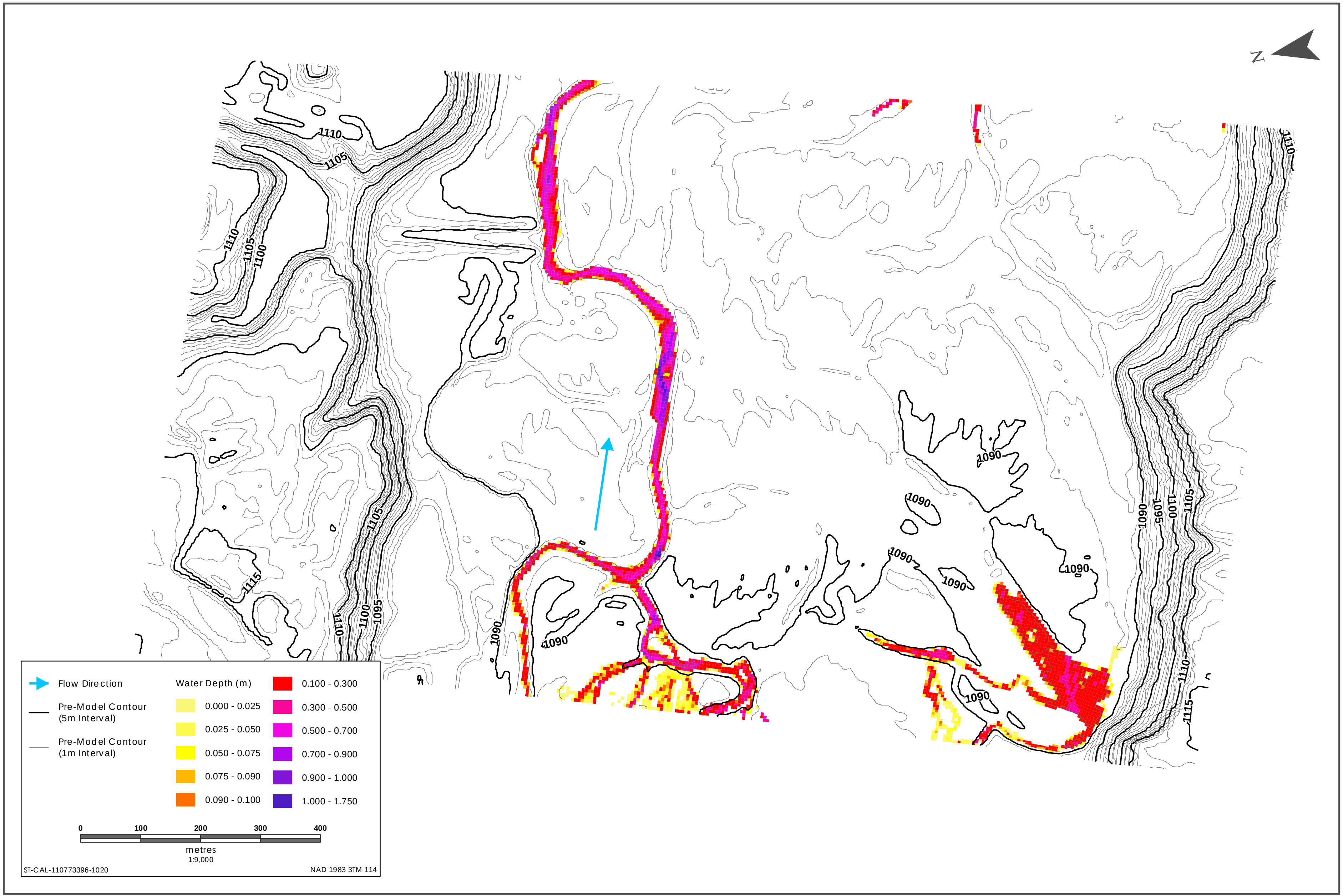
Attachment A BATHYMETRIC MAPS OF 7.4 M^3/S DISCHARGE ON BASELINE AND POST-FLOOD MODELLED SURFACES



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Baseline Bathymetry at 7.4 m³/s Discharge

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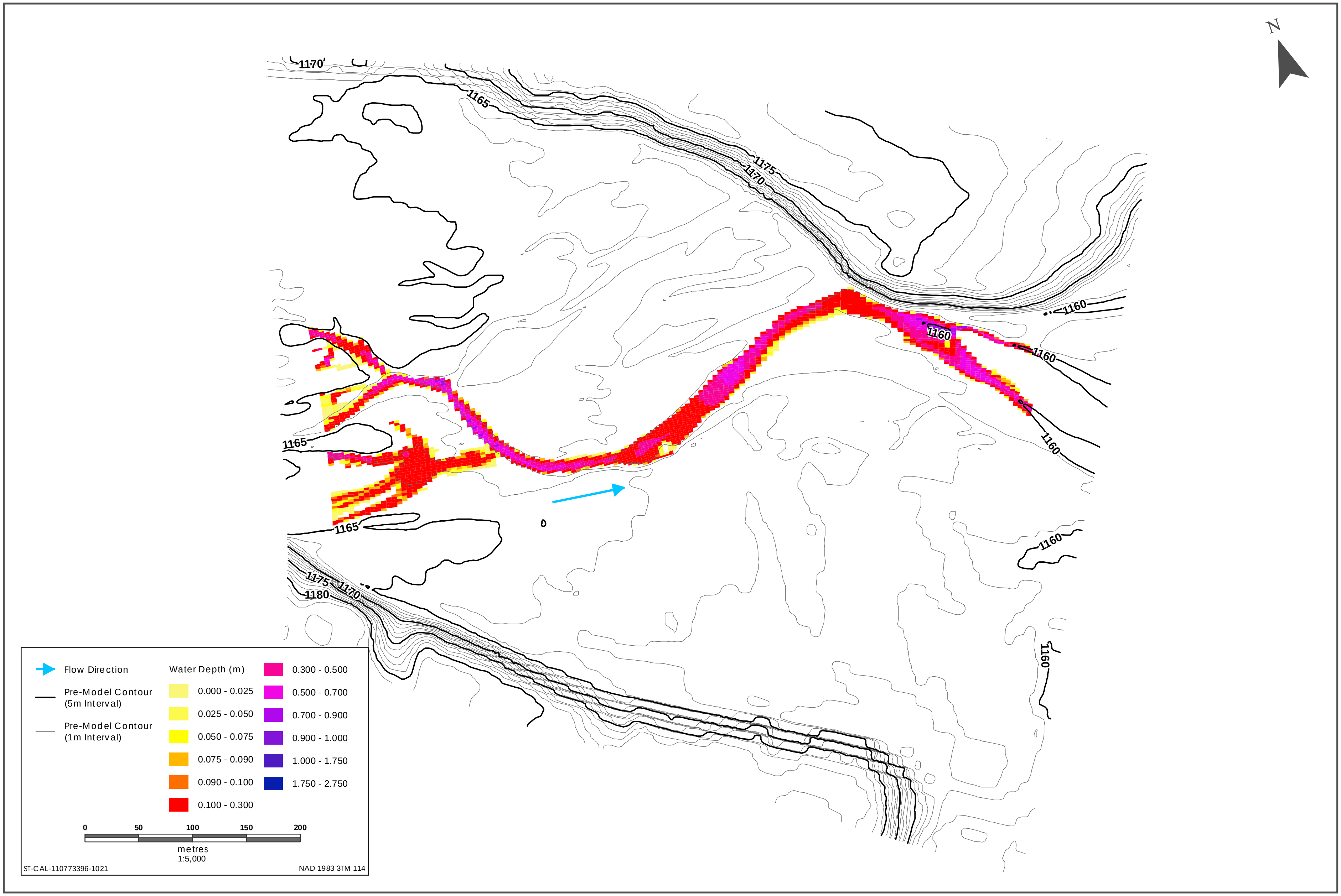
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 1



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Baseline Bathymetry at 7.4 m³/s Discharge

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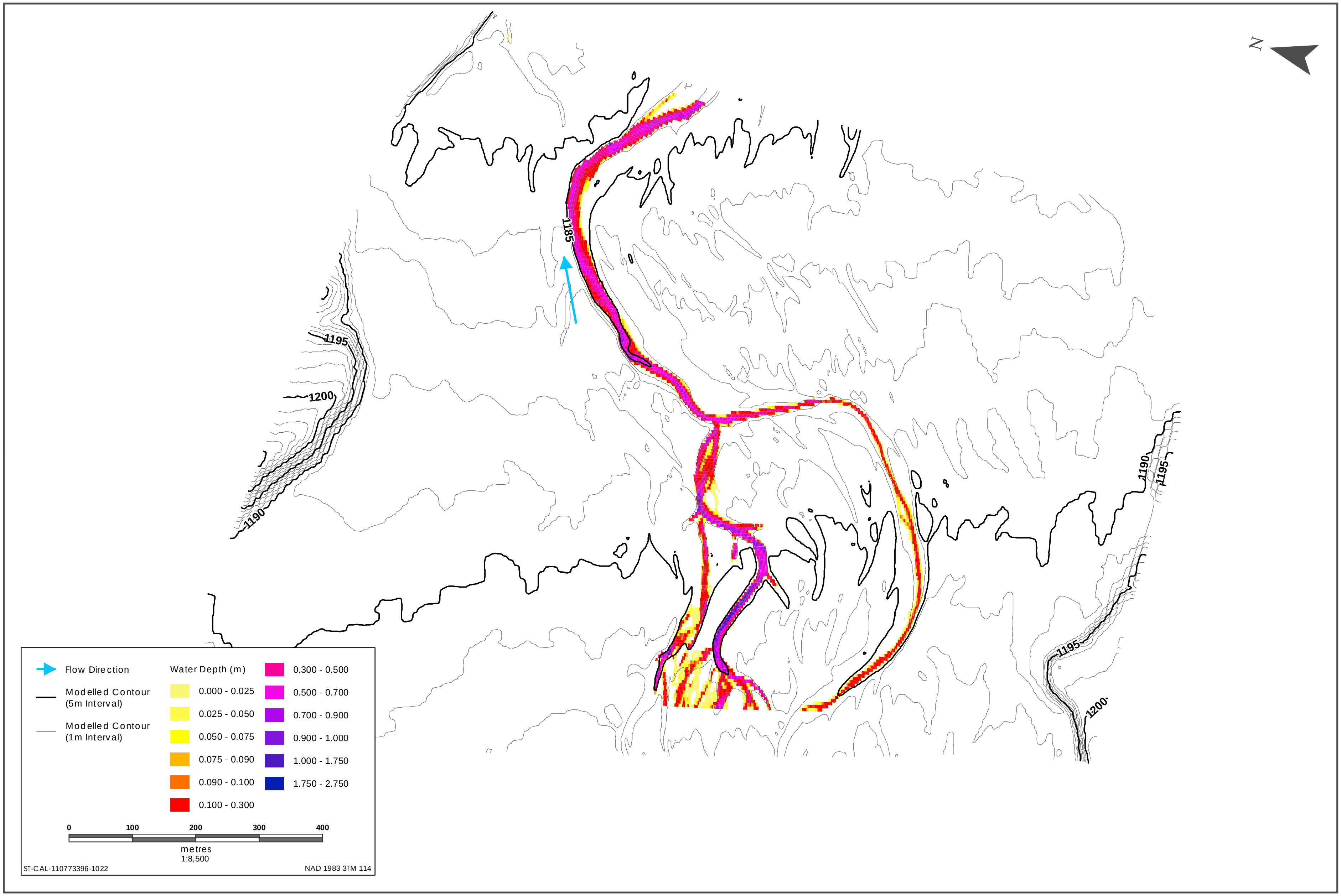
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 2



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Baseline Bathymetry 7.4 m³/s Discharge

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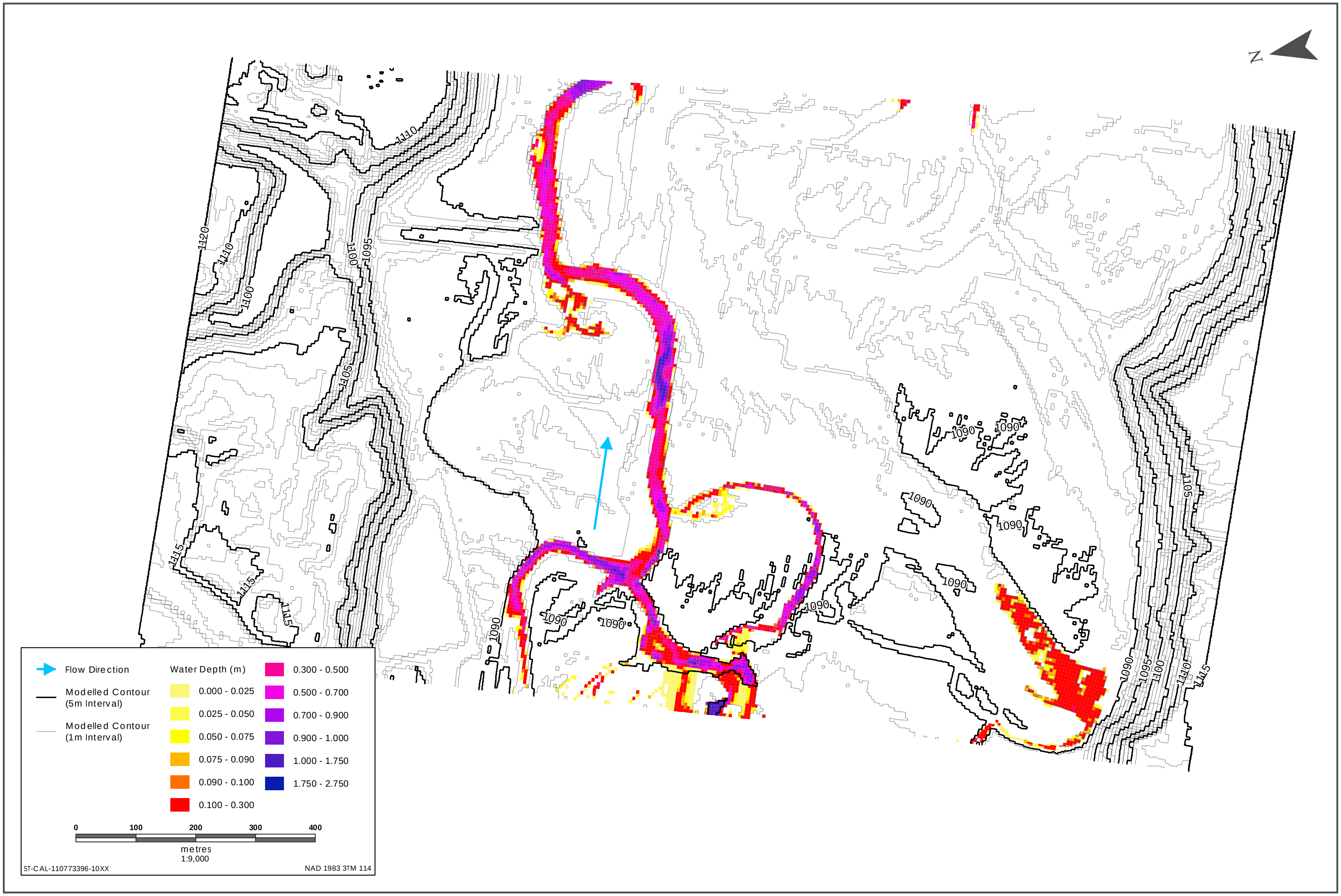
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 3



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m^3/s Discharge (1:10 Year Flood, Project Omitted)

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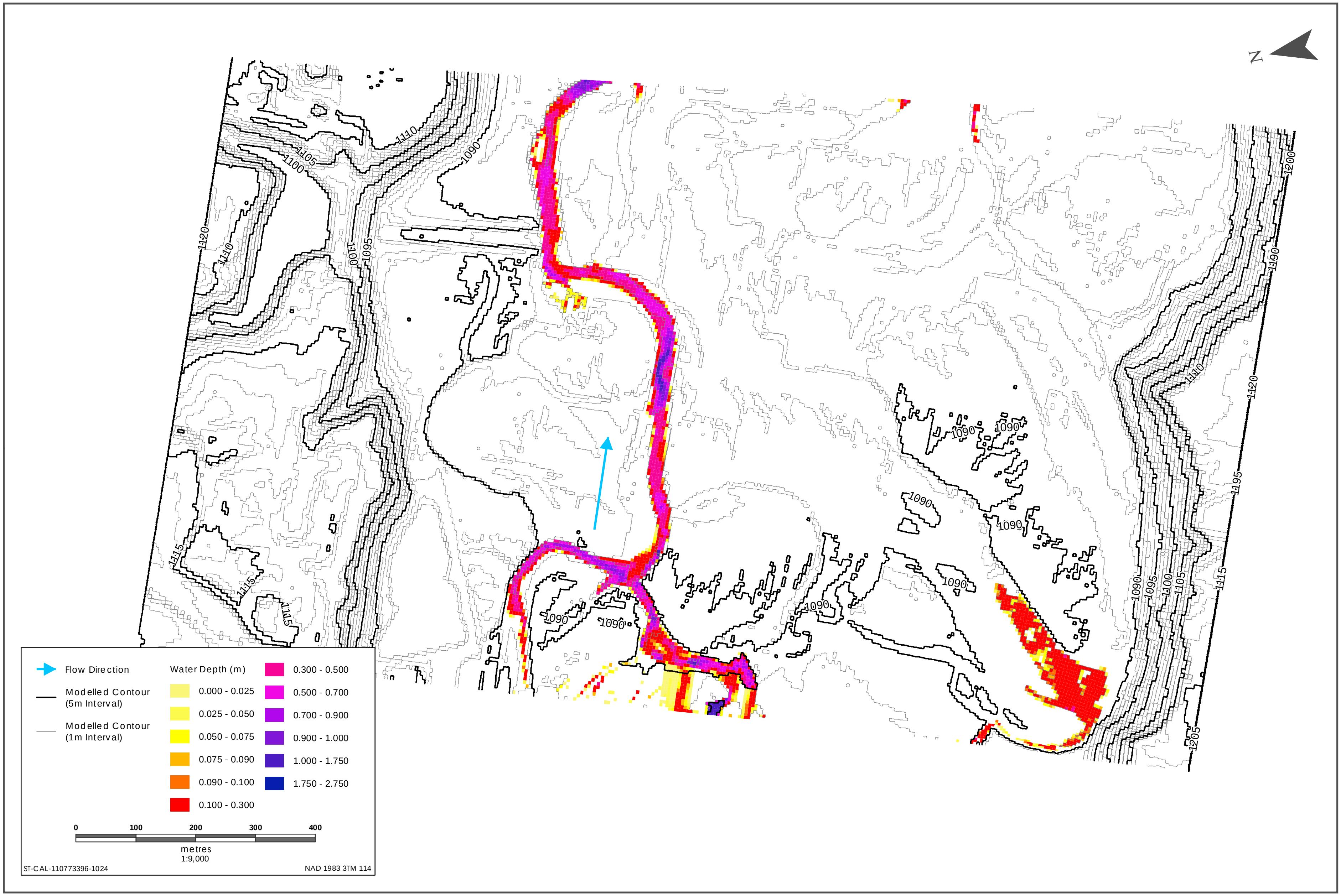
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 4



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:10 Year Flood, Project Included)

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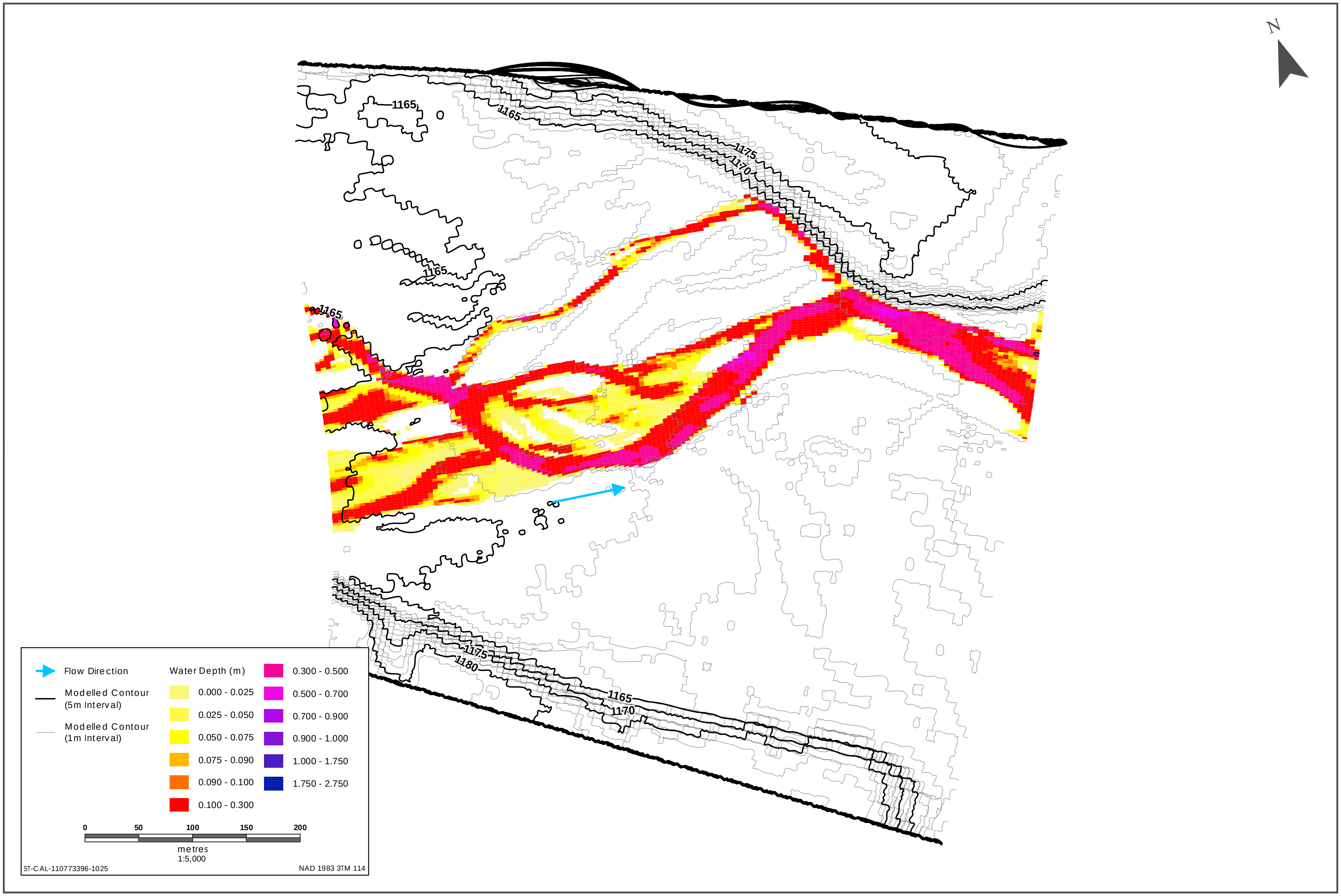
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 5



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:10 Year Flood, Project Omitted)

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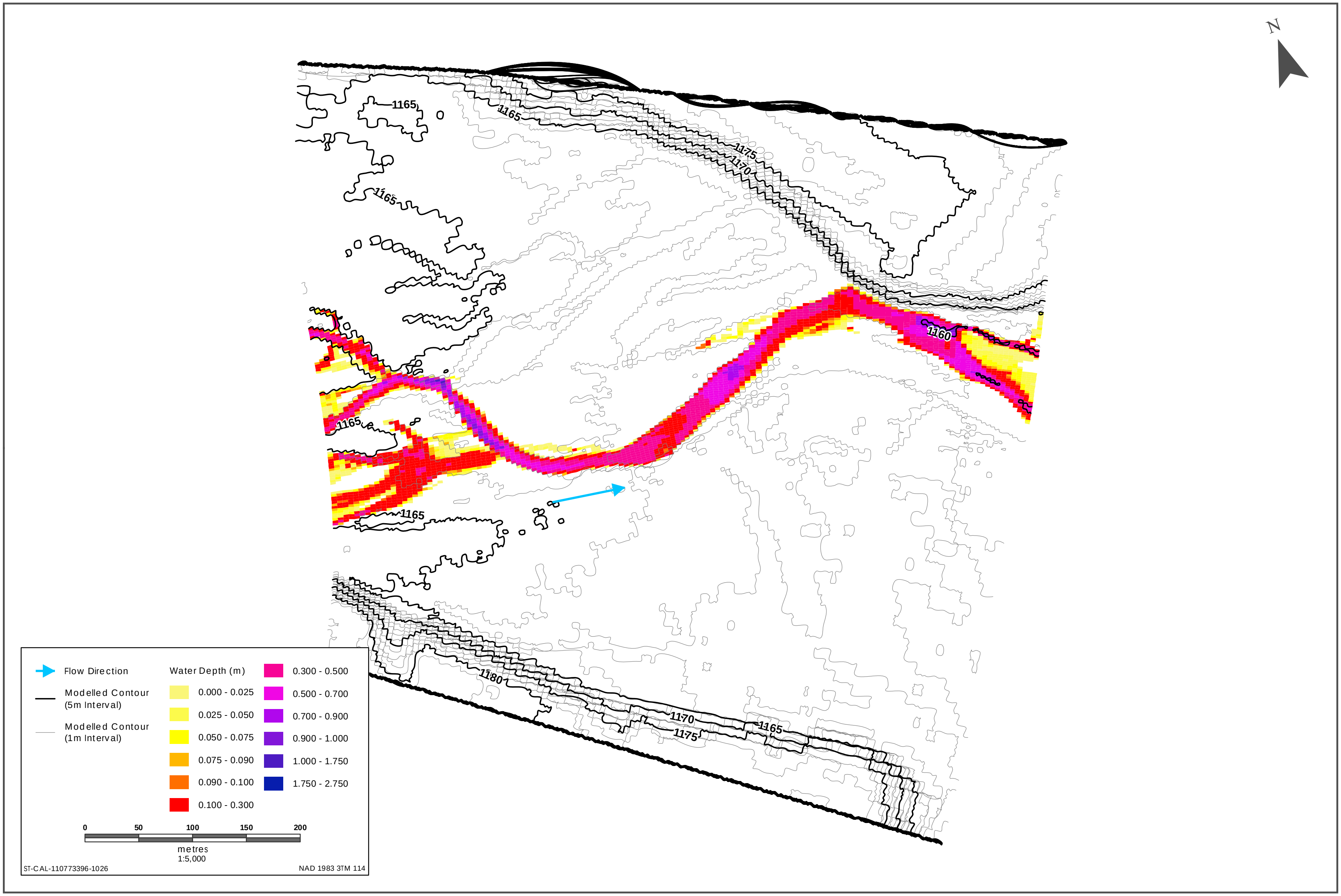
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 6



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:10 Year Flood, Project Included)

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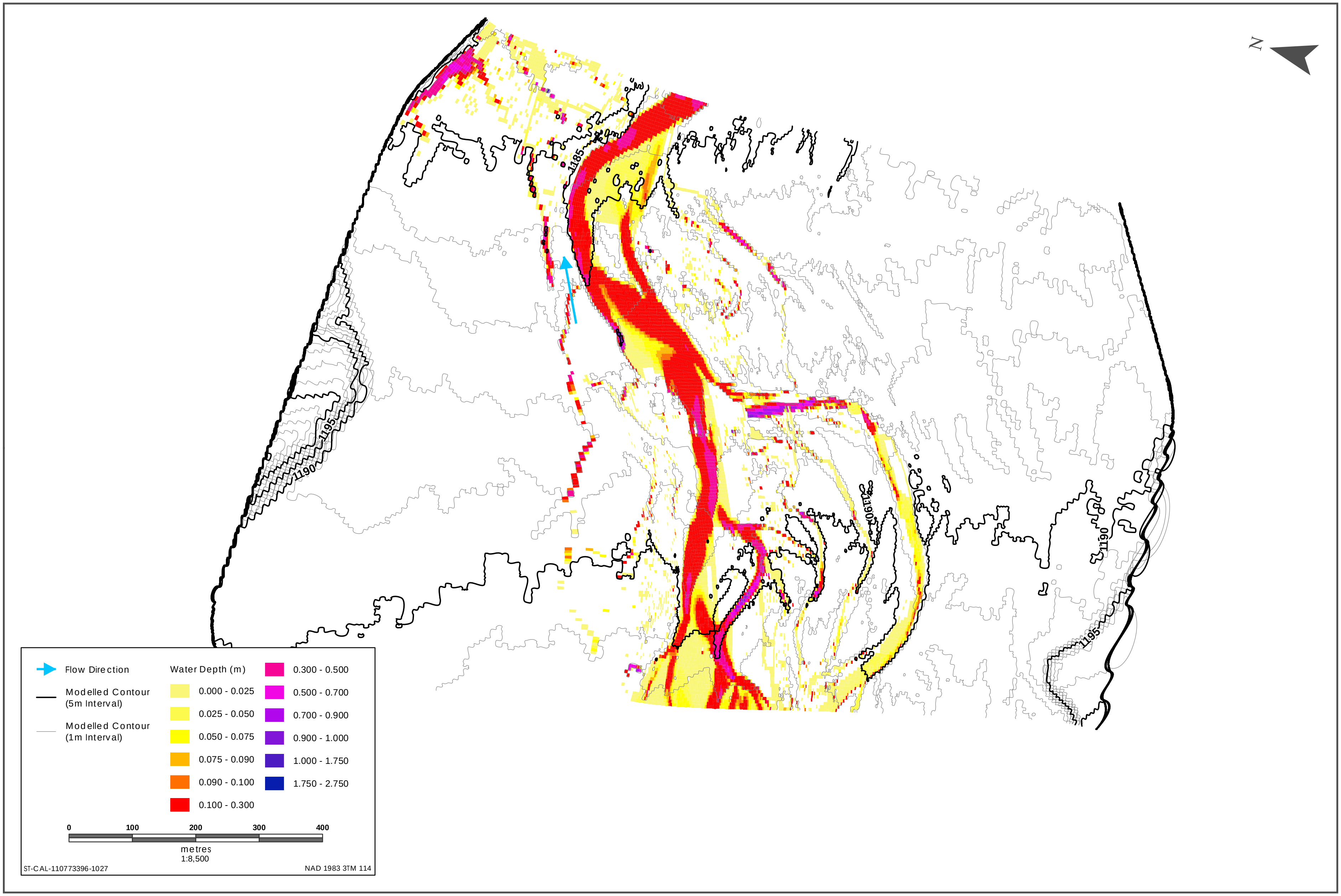
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 7

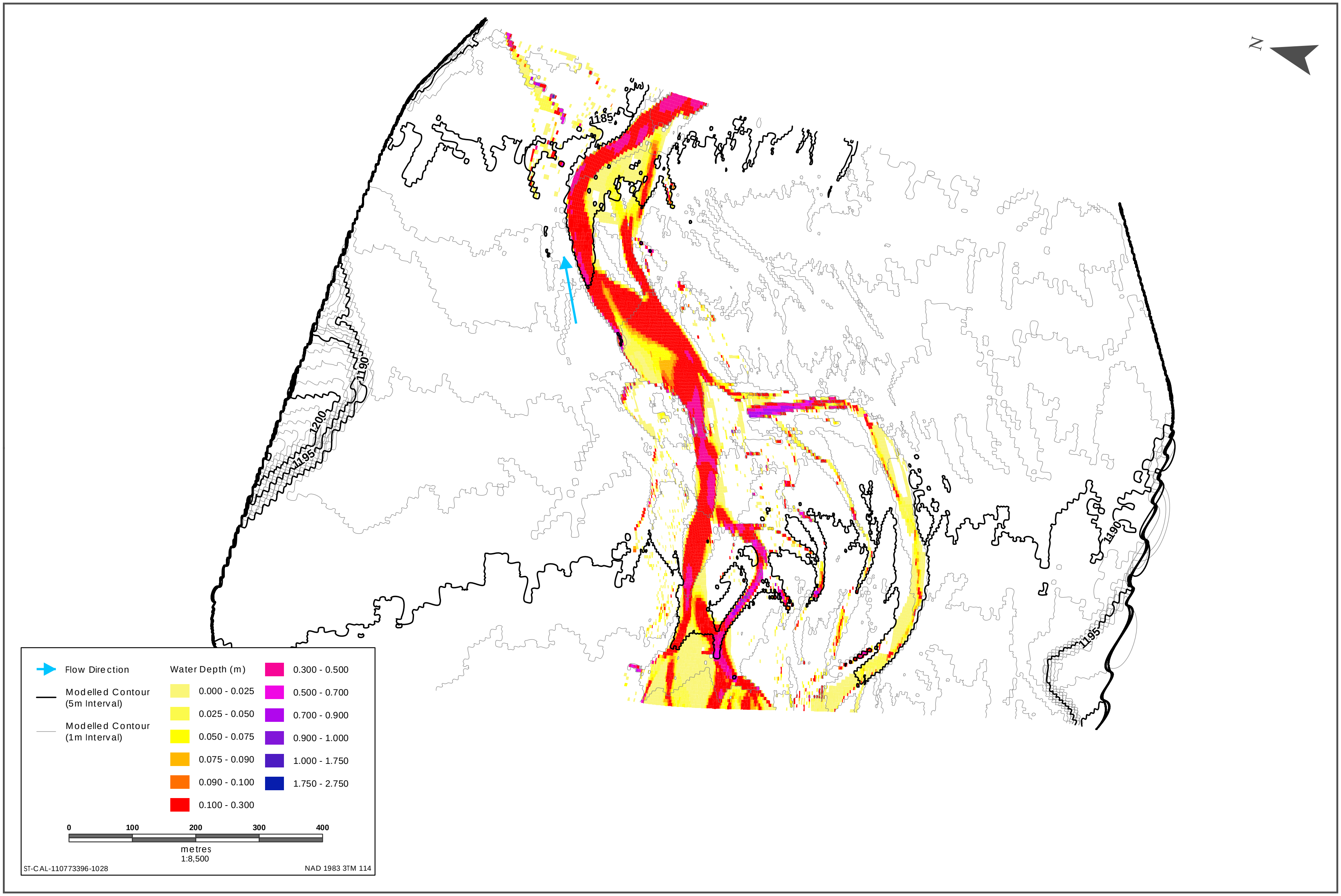


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m^3/s Discharge (1:10 Year Flood, Project Omitted)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 8

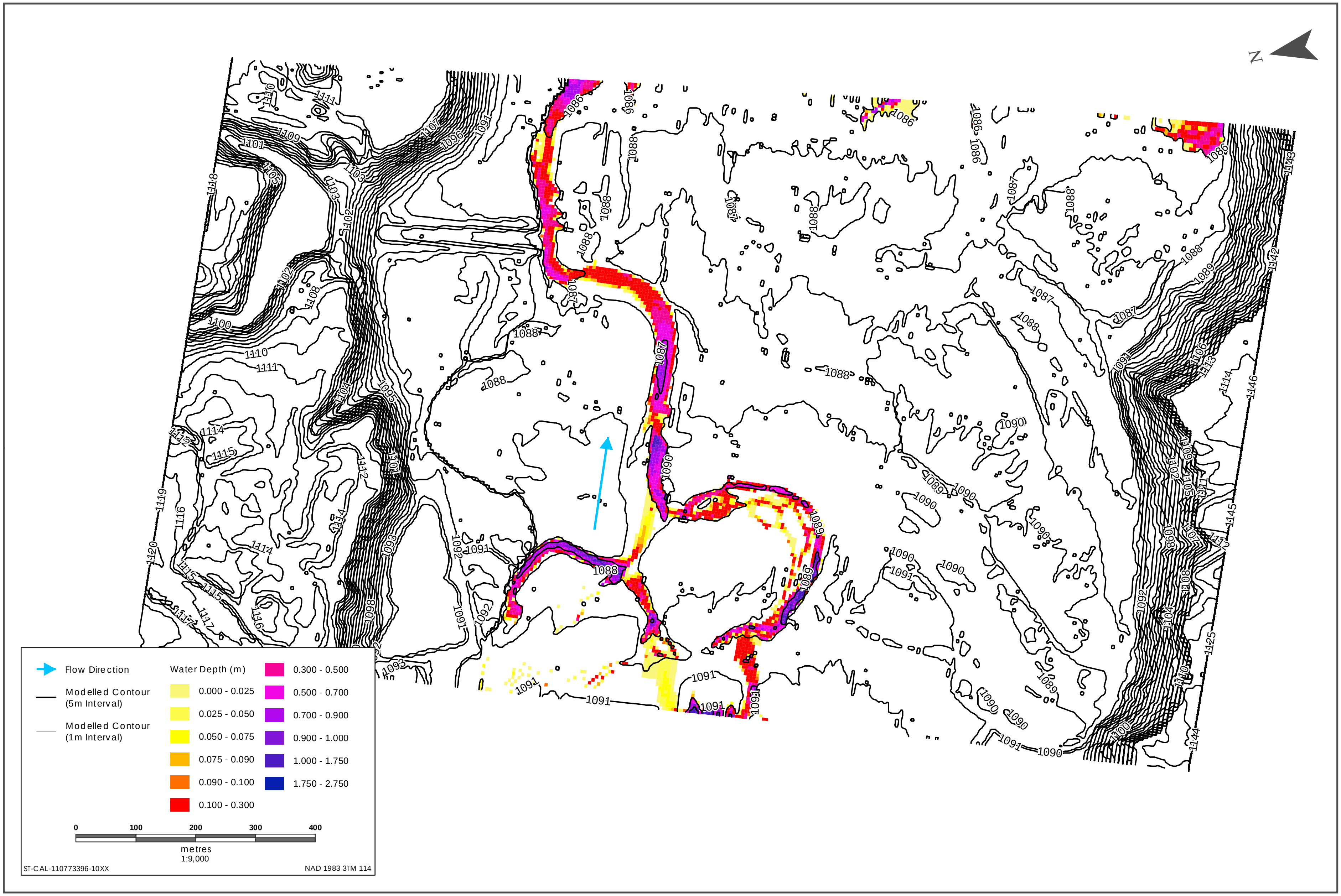


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:10 Year Flood, Project Included)

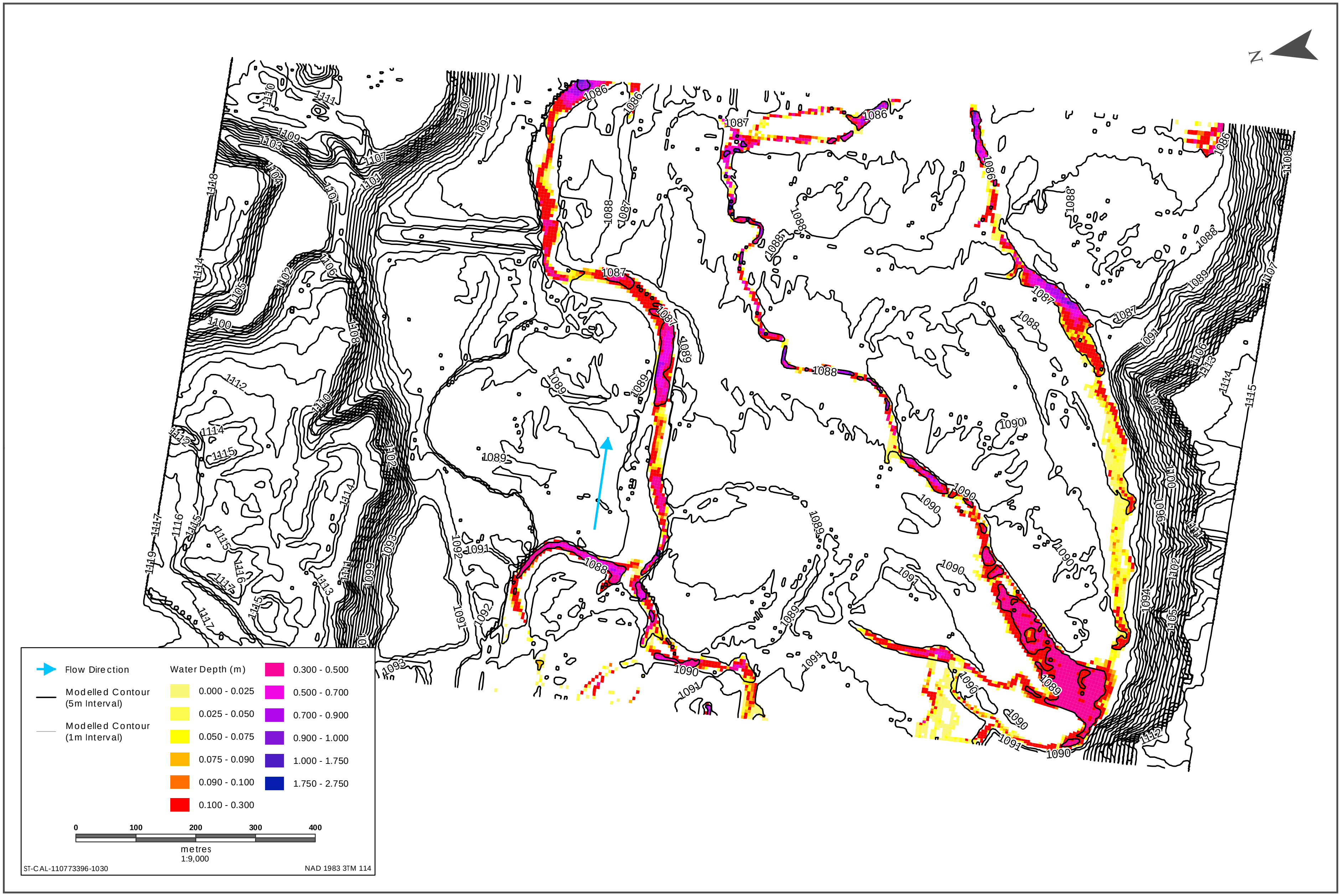
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 9



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:100 Year Flood, Project Omitted)



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m^3/s Discharge (1:100 Year Flood, Project Included)

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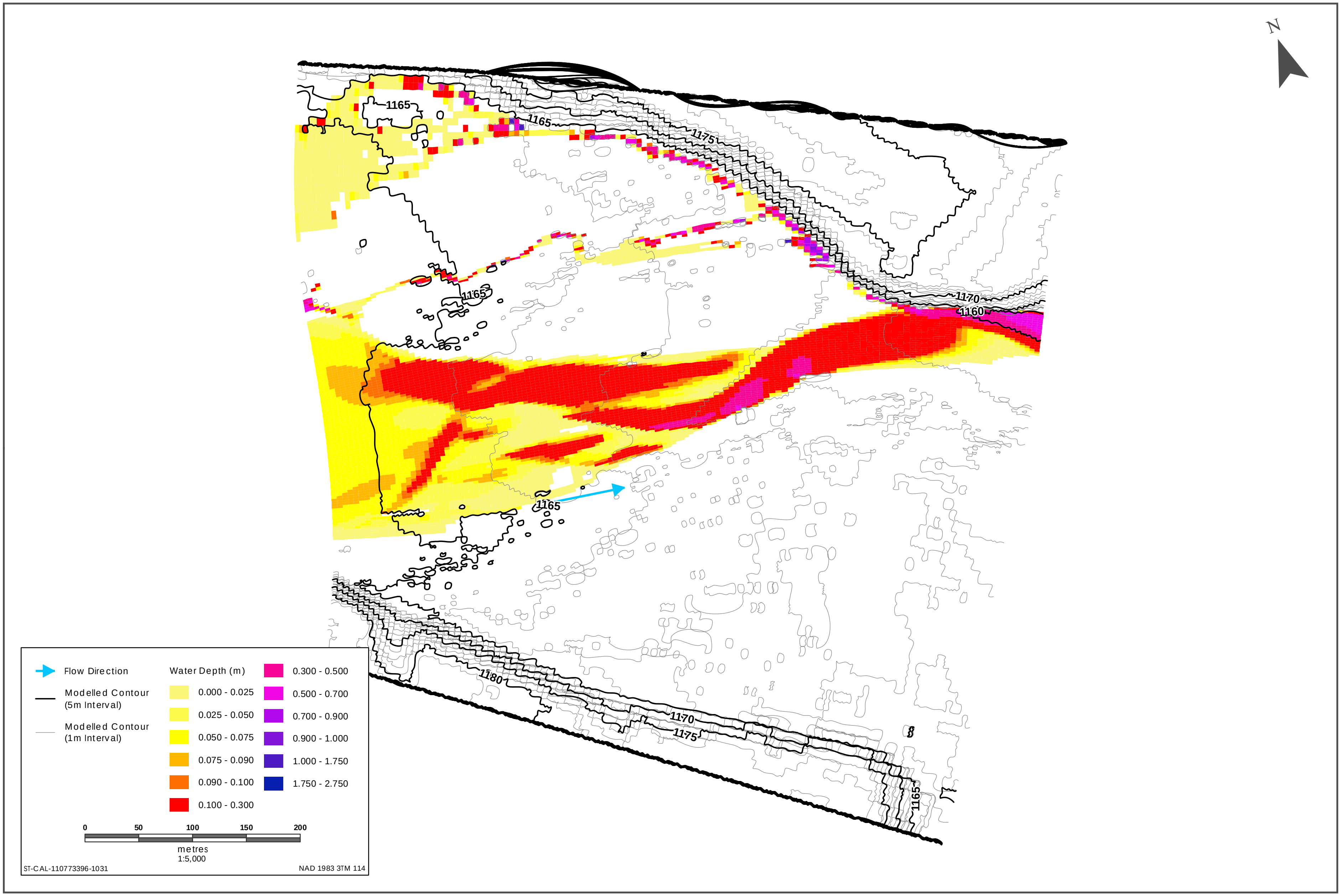
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 11



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m^3/s Discharge (1:100 Year Flood, Project Omitted)

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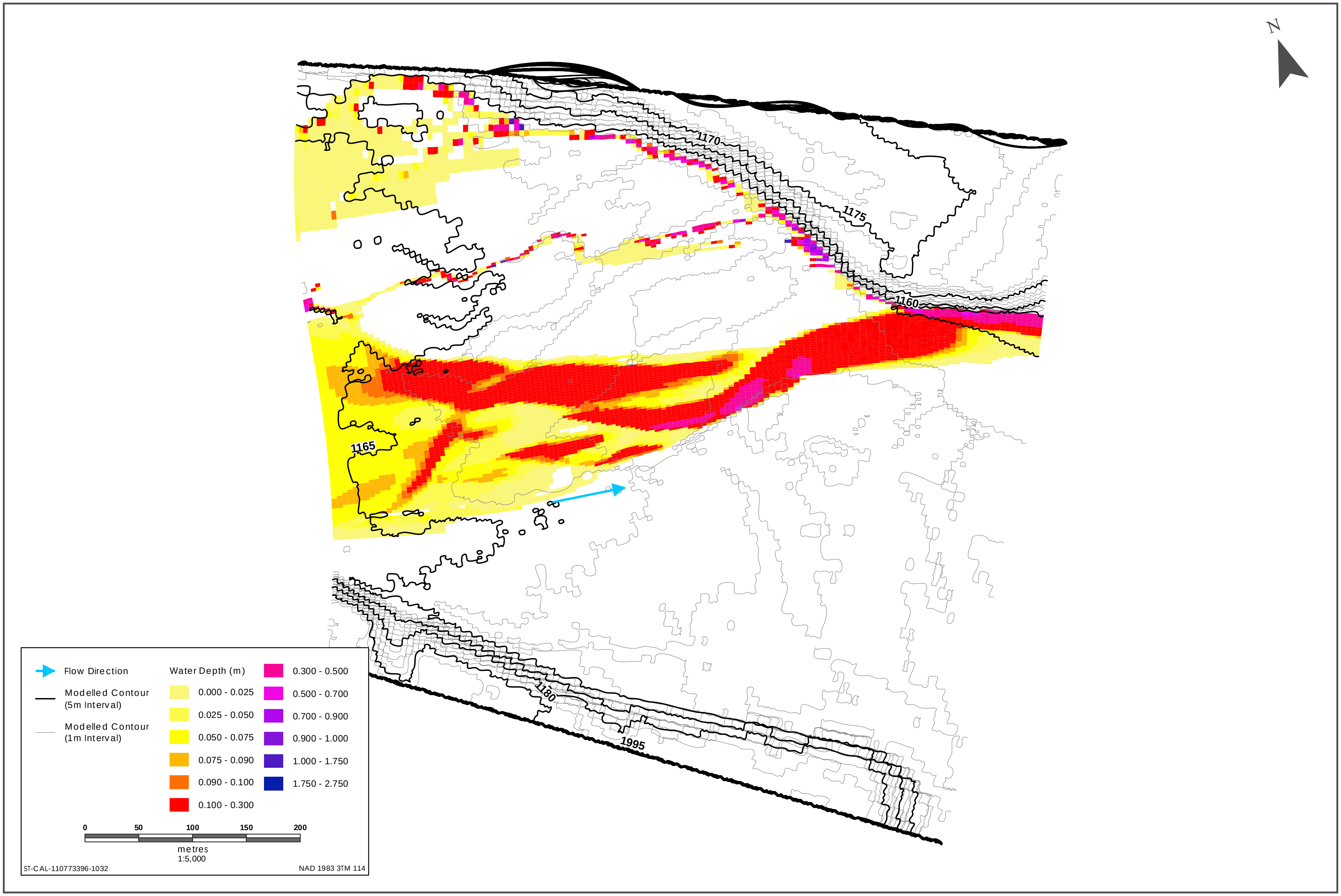
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 12



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m^3/s Discharge (1:100 Year Flood, Project Included)

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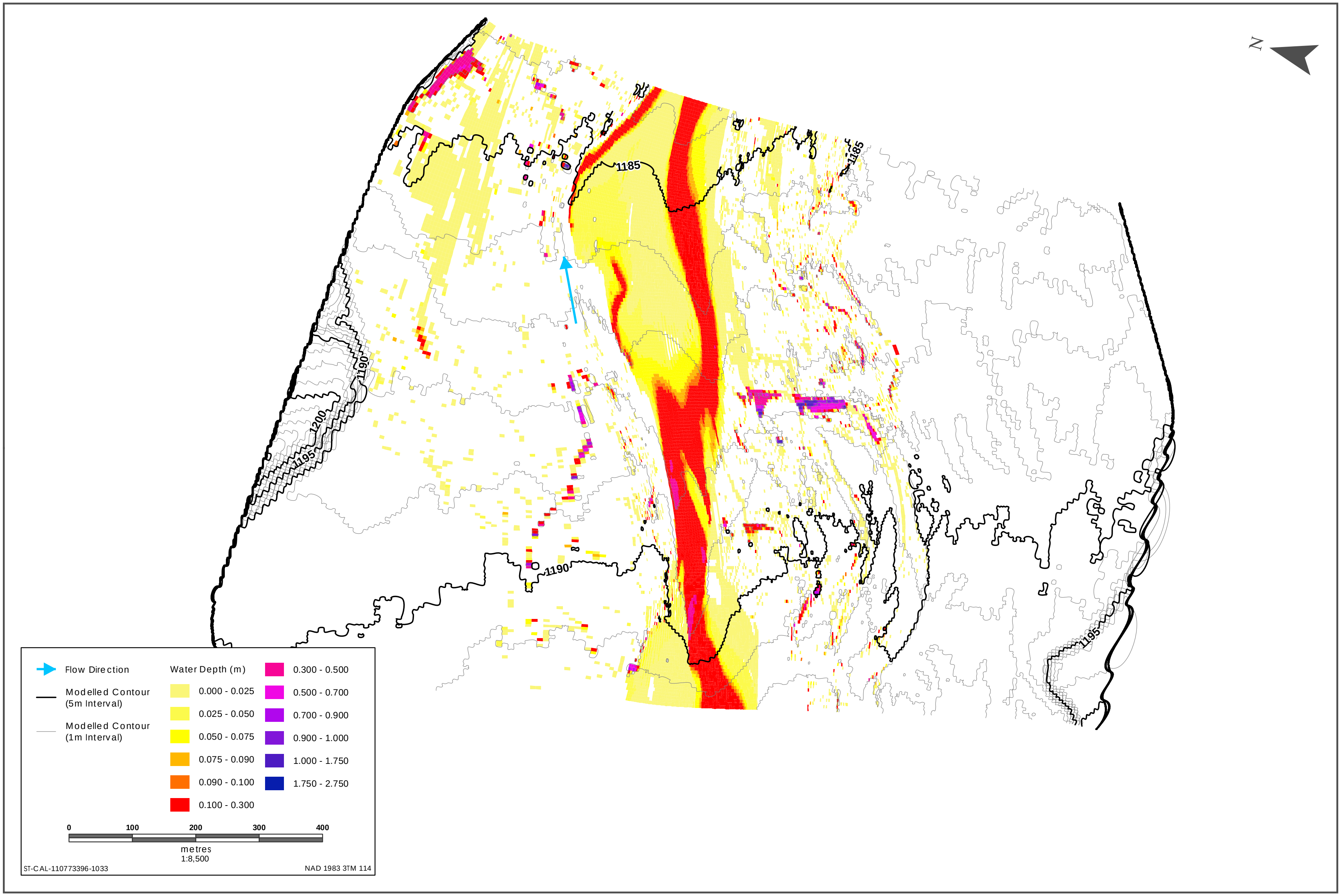
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 13

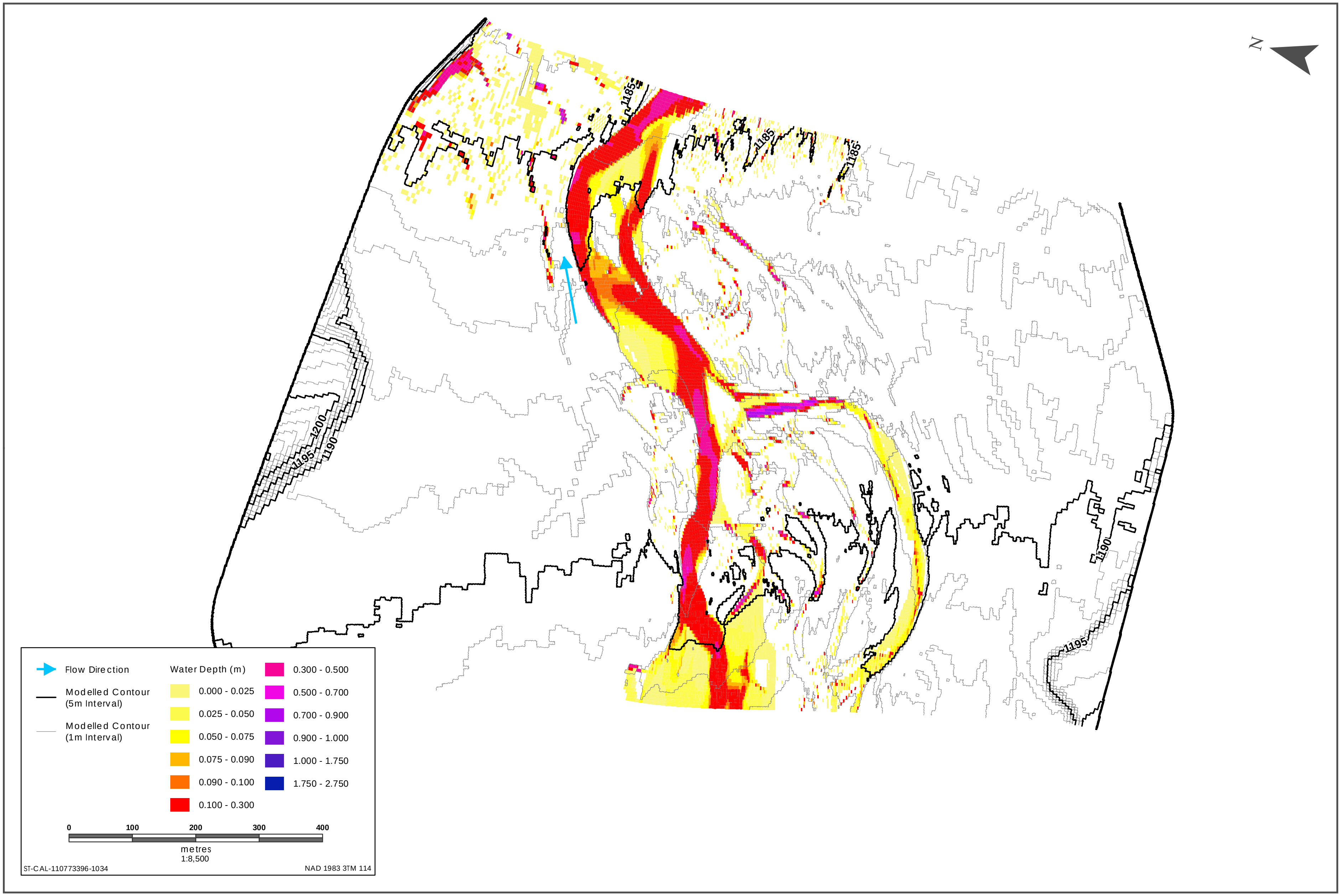


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:100 Year Flood, Project Omitted)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 14



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m³/s Discharge (1:100 Year Flood, Project Included)

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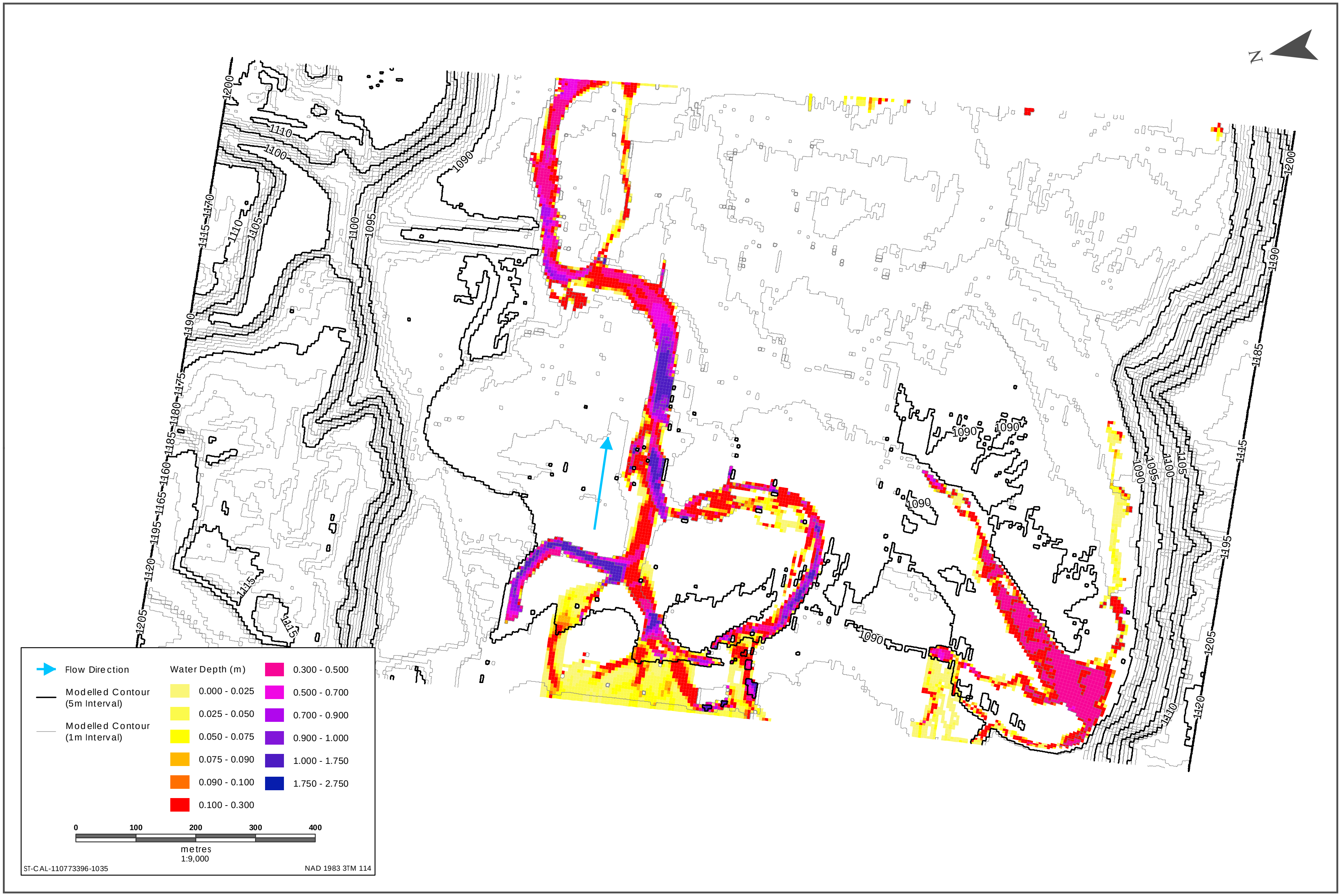
Attachment A - Figure 15



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m³/s Discharge (2013 Flood, Project Omitted)

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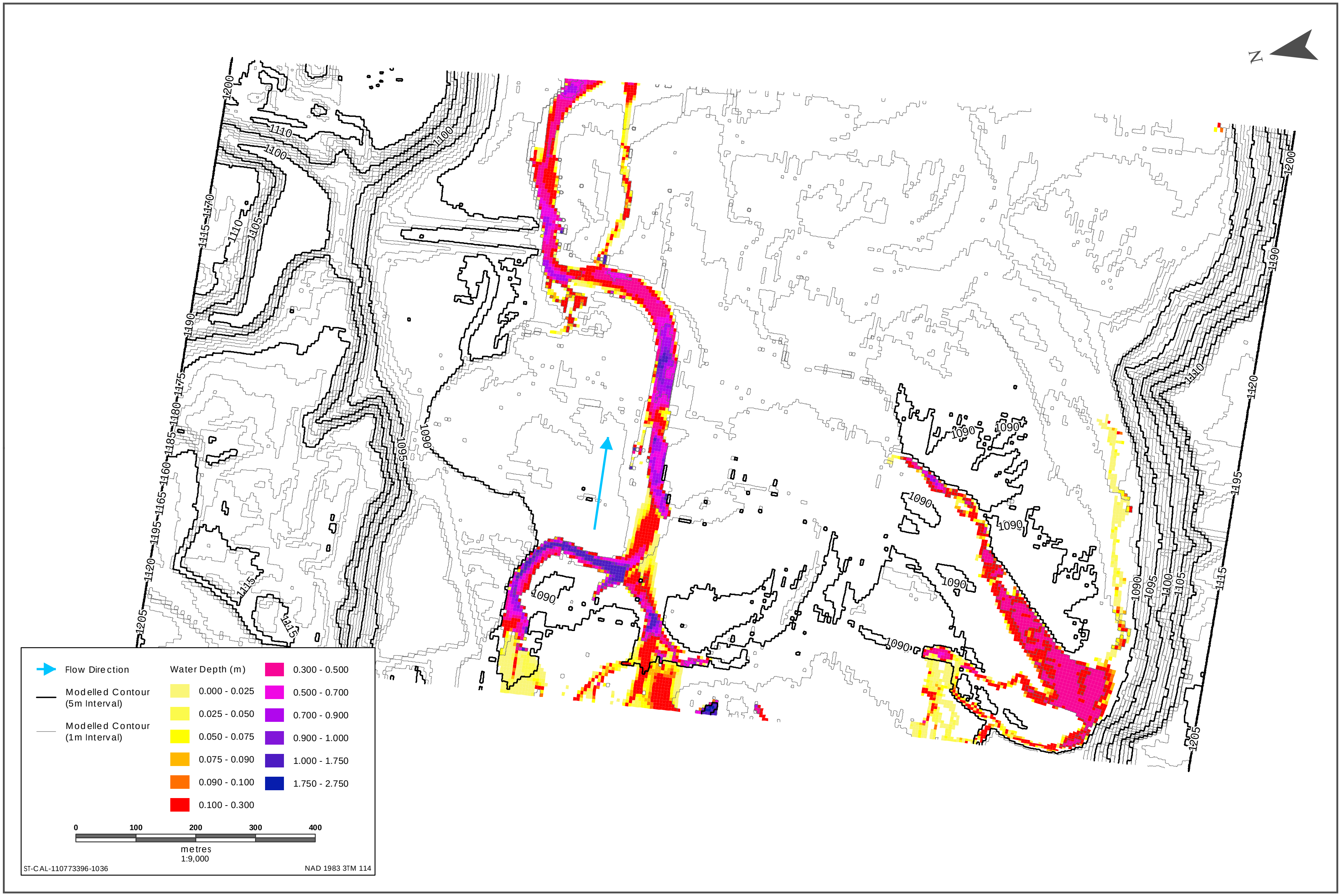
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 16



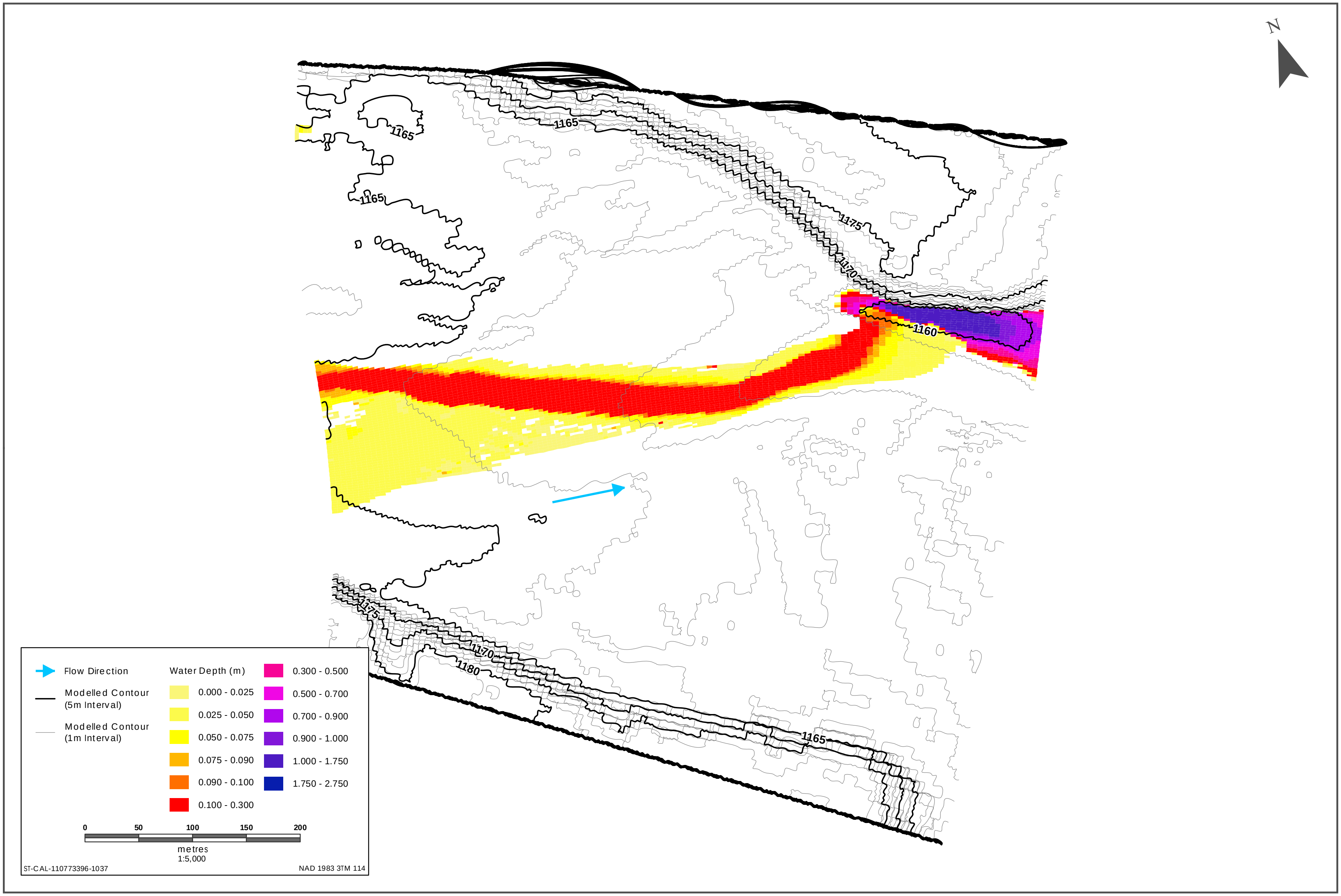
Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 1 Post-Flood Bathymetry at 7.4 m^3/s Discharge (2013 Flood, Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 17



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m³/s Discharge (2013 Flood, Project Omitted)

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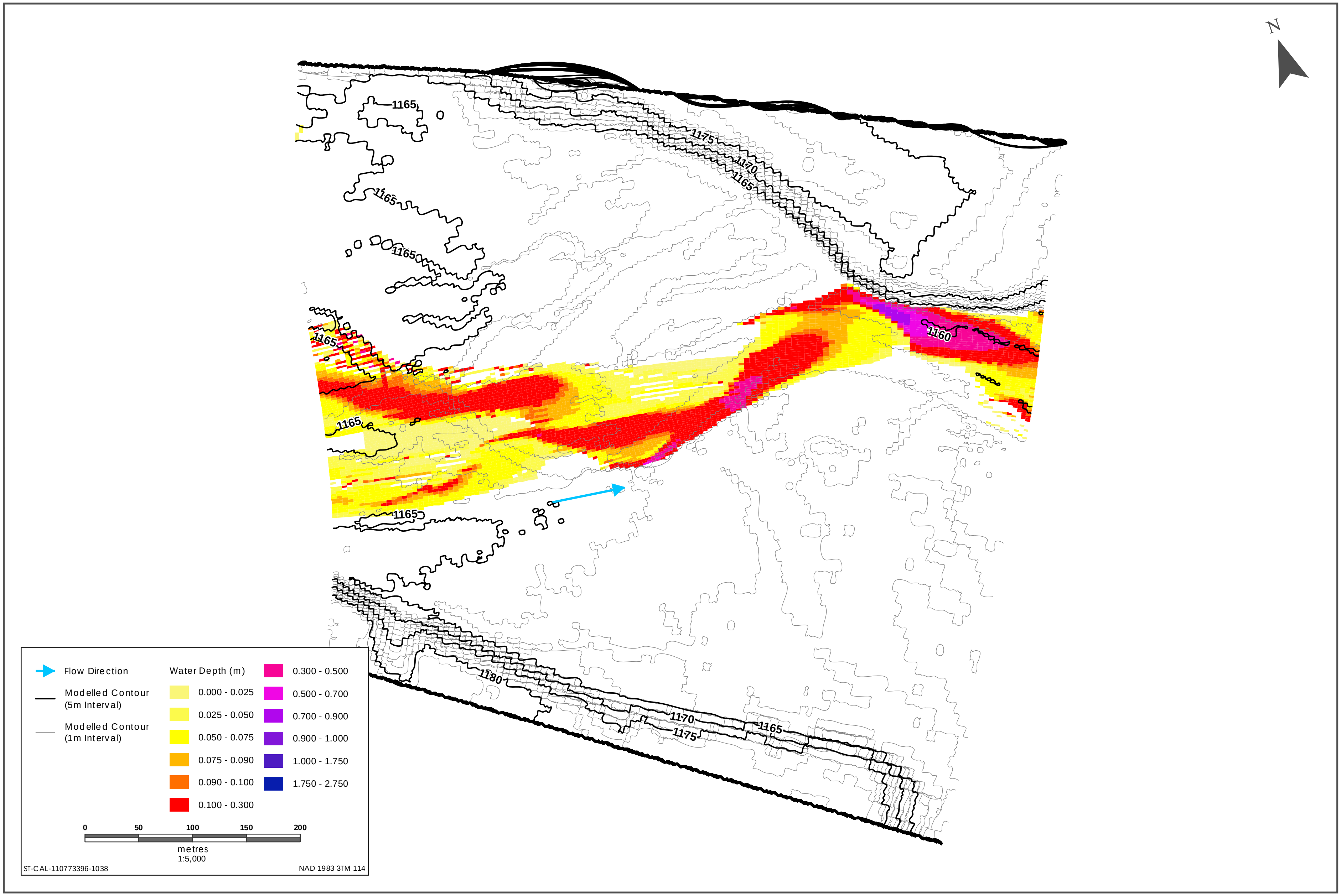
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

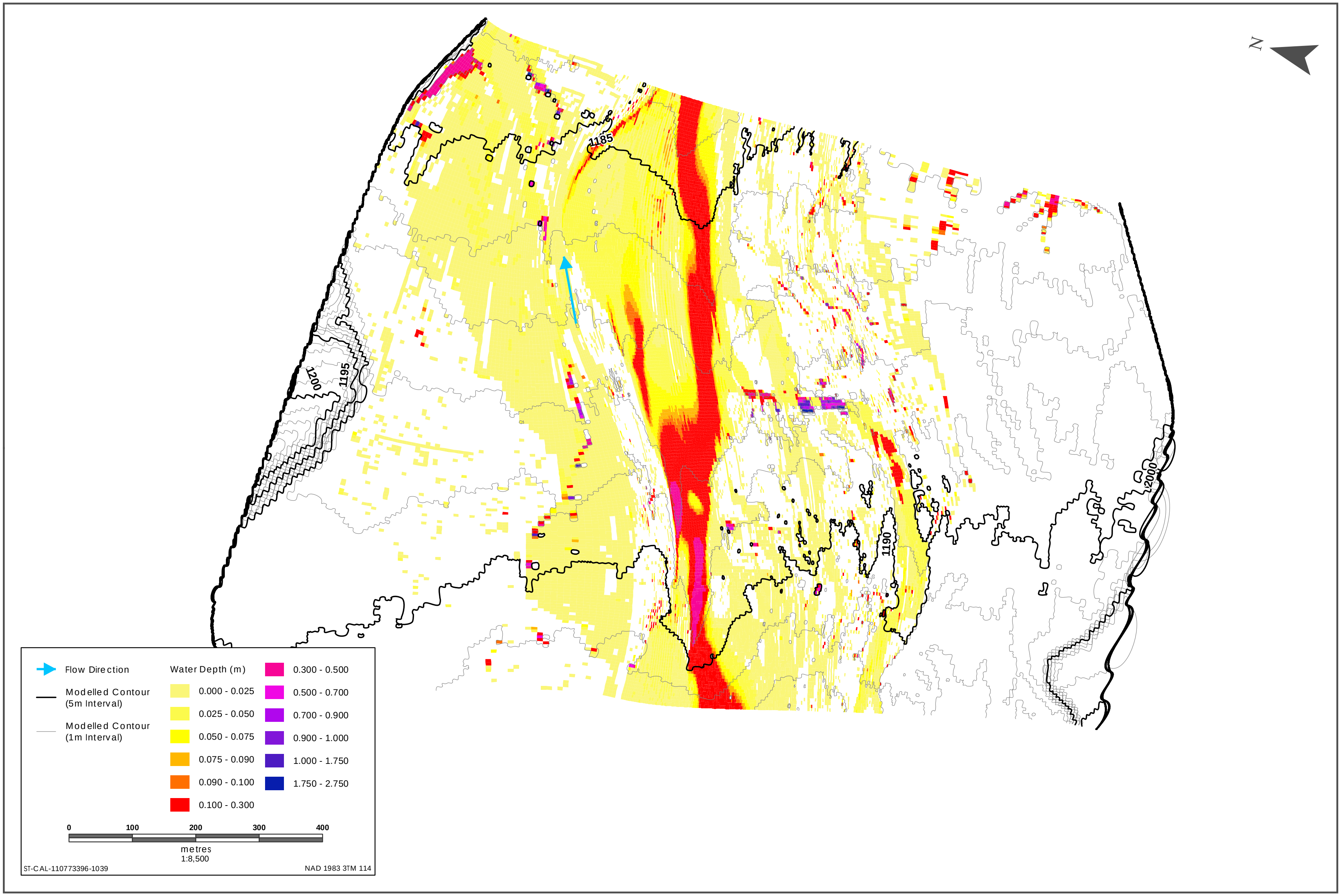
Attachment A - Figure 18



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 2 Post-Flood Bathymetry at 7.4 m³/s Discharge (2013 Flood, Project Included)

Attachment A - Figure 19

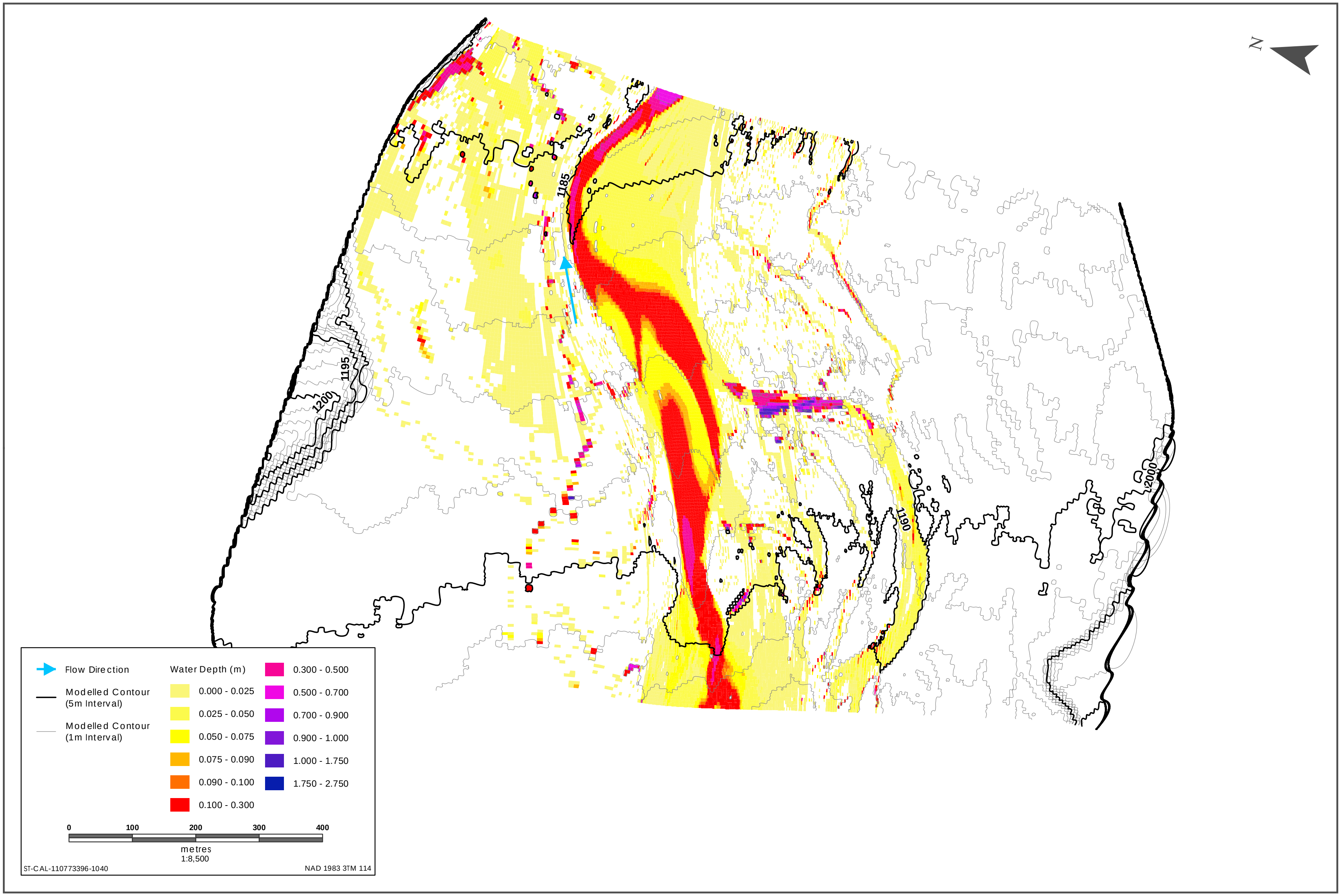


Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m³/s Discharge (2013 Flood, Project Omitted)

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 20



Sources: Base Data - Government of Canada. Thematic Data - Government of Alberta

Reach 3 Post-Flood Bathymetry at 7.4 m³/s Discharge (2013 Flood, Project Included)

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Attachment A - Figure 21

APPENDIX 27-1 BLOOD TRIBE/KÁÍNAI TRADITIONAL KNOWLEDGE, LAND, AND RESOURCE USE STUDY

This appendix was included in the April 8, 2020 filing. It has not been provided as part of this submission because of its large size. Please refer to the April 8, 2020 fling to view this appendix.

**ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2,
DATED NOVEMBER 18, 2019**

Appendix 27-1 Blood Tribe/Káínai Traditional Knowledge, Land, and Resource Use Study
June 2020

APPENDIX 27-2 INDIGENOUS GROUPS TECHNICAL REVIEW COMMENTS AND INFORMATION REQUESTS

This appendix was included in the April 8, 2020 filing. It has not been provided as part of this submission because of its large size. Please refer to the April 8, 2020 fling to view this appendix.

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 27-2 Indigenous Groups Technical Review Comments and Information Requests
June 2020

APPENDIX 27-3 ALBERTA TRANSPORTATION'S RESPONSES TO TECHNICAL REVIEW COMMENTS AND INFORMATION REQUESTS

This appendix was included in the April 8, 2020 filing. It has not been provided as part of this submission because of its large size. Please refer to the April 8, 2020 fling to view this appendix.

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2, DATED NOVEMBER 18, 2019

Appendix 27-3 Alberta Transportation's Responses to Technical Review Comments and Information Requests
June 2020

APPENDIX 31-1 DRAFT FISH RESCUE AND FISH HEALTH MONITORING AND MITIGATION PROGRAMS

**ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2,
DATED NOVEMBER 18, 2019**

Appendix 31-1 Draft Fish Rescue and Fish Health Monitoring and Mitigation Programs
June 2020

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Draft Fish Rescue and Fish Health Monitoring and Mitigation Programs

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

June 2020

Table of Contents

LIST OF TABLES

Abbreviations

AEP	Alberta Environment and Parks
DFO	Department of Fisheries and Oceans Canada
EIA	Environmental Impact Assessment
the Project	Springbank Off-stream Reservoir

1.0 INTRODUCTION

When floods occur in the Elbow River watershed, water could potentially be diverted from the Elbow River into the off-stream reservoir and, consequently, fish will be diverted into the reservoir. This Draft Fish Rescue and Fish Health Monitoring Plan has been developed to mitigate the potential effects of flood operation on fish. Entrainment of fish into the reservoir during flood operation may cause harm to fish as they are transported along the diversion channel and into the reservoir. There is potential for fish to be stranded during reservoir water drawdown and release, which could result in behavioural and physiological stress of fish (sublethal or lethal effects), physical trauma (sublethal or lethal), and predation. Construction of the reservoir will be limited to grading in select areas (for drainage, borrow, and energy dissipation at the low-level outlet), whereby the majority of the reservoir will rely on existing grades for the retention and release of diverted flood water. Disconnected pools may develop during flood operation that have the potential to strand fish, and that could lead to death by asphyxiation, exposure to elevated water temperatures, starvation and physiological stress, or increased predation. Fish mortality as result of entrainment is dependent on the number of fish entering the reservoir during flood operation and those returned to Elbow River during draining of the reservoir. Changes in downstream flows can also result in changes to natural conditions that strand fish in Elbow River or the low-level outlet. In-river stranding is the separation of fish from flowing water because of the decline in water level.

Mitigation for the potential fish mortality are in the EIA, Volume 3B, Section 8.2.2.2, summarized as follows:

- Water flows in the diversion channel will be gradually reduced and the reservoir drained to facilitate the movement of fish from the reservoir and back into Elbow River with the receding water.
- The low-level outlet will be designed and operated in a manner that allows fish egress out of the reservoir and downstream into the outlet channel and the unnamed creek.
- Drainage areas within the reservoir will be selectively graded to reduce stranding of fish during release of retained flood water from the reservoir.
- During draining of the reservoir, monitoring will be undertaken to identify isolated pools and the potential that fish may become stranded. If potential fish stranding is identified, further action will be taken to reduce the potential mortality of fish.

This Draft Fish Rescue and Fish Health Monitoring Plan expands on the commitments described in the EIA, along with a proposed approach for rescuing fish that are entrained in the reservoir, as well as monitoring of fish in Elbow River as water is drained. This plan will be finalized for review and approval by Fisheries and Oceans Canada (DFO) as part of the *Fisheries Act* authorization. The monitoring commitments herein are subject to change based on the outcome of consultation with DFO and engagement with Indigenous groups.

2.0 FISH RESCUE PROGRAM

This fish rescue program design is based on fish rescue programs conducted at several mines in northern Canada and General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011). Mine development often results in disturbance or destruction of fish habitat due to the dewatering of lakes and subsequent mine activities (Tyson et al. 2011). Fish rescues must be undertaken as the lakes are dewatered as part of DFO approvals under Section 35(2) of the *Fisheries Act*. Fish rescues, as part of lake dewatering, have been undertaken at mines throughout the Northwest Territories and Nunavut, including:

- BHP Billiton's Ekati diamond mine
- Diavik Diamond Mines
- Meadowbank Gold Project
- Gahcho Kue Mine
- Ekati Mine

The key components of a fish rescue program are:

- rescue of stranded fish
- temporary handling and holding of stranded fish
- redistribution of the rescued fish to a suitable release point in the river
- collection of biological data from rescued fish

2.1 METHODS TO RESCUE STRANDED FISH

Flood operation will limit the opportunity to rescue and monitor fish within the diversion channel upon activation of the Project; therefore, rescue and monitoring efforts are timed to coincide with reservoir water drawdown and release. The reservoir, diversion channel, and unnamed creek will be monitored, and fish rescues will be undertaken when water levels are appropriate for access. The following will be undertaken to rescue stranded fish:

- Preparations for crew and equipment deployment will be initiated as soon as water begins to be diverted from Elbow River into the diversion channel such that crews can be prepared to begin fish rescue efforts when reservoir drawdown commences at a later time.
- All equipment will be mobilized to a pre-designated staging area adjacent to the reservoir prior to any water being released back into Elbow River.
- Crew size will be based on previous experience conducting fish rescues of dewatered waterbodies. It is anticipated that up to 30 people will be required to cover the area of the reservoir as quickly as possible to rescue stranded fish.

- Fish capture methods may include the use of seine nets, standard Gee-style minnow traps, backpack electrofishing, tote electrofishing, or hand capture. Electrofishing efforts will follow the *Alberta Fisheries Management Division Electrofishing Policy Respecting Injuries to Fish* (GOA 2012).
- It is anticipated that some sections of the reservoir will have substantial sediment deposition and will be unwadeable. Additional effort is anticipated to access low areas where pooled water and stranded fish are present due to the amount of sedimentation that may be present in reservoir.
- Fish rescue will be considered complete when the reservoir has been drained and stranded fish have been captured and relocated into Elbow River.

2.2 TEMPORARY HANDLING AND HOLDING OF RESCUED FISH

The procedures for handling and holding of rescued fish are as follows:

- Rescued fish will be temporarily held in a bucket or tote with fresh river water and aerated with a battery-operated air pump.
- Handling of fish will be kept to a minimum to reduce stress.
- Retention time in the buckets or totes will be kept to a minimum before transferring to a large capacity, aerated live well. Designated personnel from the field crews will be responsible for transporting fish between the buckets and totes to the larger capacity holding systems to reduce stress to fish during transfer.
- Water in buckets and totes will be replaced as often as possible to maintain water temperature and dissolved oxygen concentrations suitable for rescued fish.
- Fish will be transferred from the temporary buckets or totes to a trailer mounted, large capacity (approximately 1,500 L) holding tank equipped with high capacity aerators. It is expected that one to two large-capacity tanks will be required for program.
- Water temperature and dissolved oxygen will be monitored regularly in the holding tank.
- Fish health and stress will be monitored in the holding tanks.
- Fish will be released into Elbow River when:
  - the large-capacity trailer mounted holding tank(s) has reached its capacity to hold fish
  - water temperature in the large-capacity trailer mounted holding tank(s) begins to rise
  - retention of fish in holding tank is resulting in stress to the fish
  - fishing efforts are deemed complete and multiple passes with electrofishing equipment and netting efforts result in no additional fish captures

2.3 RELEASE OF RESCUED FISH INTO THE ELBOW RIVER

The following steps will be undertaken to relocate and release rescued fish back into Elbow River:

- A suitable release location on the Elbow River will be identified in advance of operation of the reservoir.
- Criteria to determine a suitable release location will include:
  - adequate access for a truck towing a trailer will a large capacity holding tank
  - suitable water depth, flow and fish habitat are present and abundant
  - safe location for staff to work
- Fish in the large-capacity trailer mounted holding tank will be observed to evaluate their fitness prior to their release into the Elbow River.
- Visual observations of fish health and behaviour will be conducted and recorded immediately upon release into the river upstream of the diversion inlet (further monitoring efforts are proposed for the downstream reach, after the confluence of the unnamed creek with Elbow River, as discussed in Section 3).
- The water in the large-capacity trailer mounted holding tank will be flushed and replaced with fresh water from Elbow River before returning it to the reservoir to continue fish rescue efforts (if required). Specifically, a water pump with a fish exclusion screen will be used to refill the holding tank. The fish exclusion screen will meet the criteria outlined in the Interim Interim code of practice: end-of-pipe fish protection screens for small water intakes in freshwater (DFO 2020).

2.4 COLLECTION OF BIOLOGICAL DATA

In order to reduce stress and the potential for harm to rescued fish, it is recommended that fish handling be kept to a minimum. As such, rescued fish will be identified to species, life stage and observations of deformities, erosion, lesions or tumours recorded. Additional data, such as length and weight measurements will be undertaken only if requested to do so by Alberta Environment and Parks (AEP) or DFO.

If fish mortalities are observed, fish will be identified to species and life stage, measured for length and weight and observations of external condition conducted.

2.5 MONITORING BY INDIGENOUS GROUPS

Alberta Transportation is committed to Indigenous participation in the Project, including training, employment, and contracting opportunities. To this end, Alberta Transportation is preparing a draft Indigenous Participation Plan with the goal to create training, employment, monitoring, and contracting opportunities with interested Indigenous groups potentially affected by the Project. Indigenous environmental monitors may provide assistance with the fish rescue activities. Environmental monitors who are properly trained and experienced in safety protocols regarding working in and around water as well as environmental monitoring techniques can participate in the following activities:

- assist a qualified aquatic environmental specialist (QAES) in identifying locations in the reservoir where fish stranding may occur
- monitoring fish health and conditions during fish capture and rescue activities
- complete data recording

3.0 DOWNSTREAM FISH HEALTH MONITORING AND MITIGATION PROGRAM

Upon completion of fish rescues in the reservoir and release of rescued fish into Elbow River, fish health monitoring will be undertaken in the downstream reach of Elbow River (from the confluence of the unnamed creek with Elbow River to Glenmore Reservoir). Monitoring efforts downstream of the Project will also account for effects on fish that are exposed to water from the reservoir that has re-entered the Elbow River, which is likely to deteriorate in quality (i.e., increased water temperature, reduced dissolved oxygen, increased suspended sediment concentrations).

3.1 FISH HEALTH INDICATORS

Rather than relying on physiological indicators that are derived through laboratory analyses, the scope of the fish health monitoring program will use behavioural indicators, such as oxygen uptake (breathing rate), swim performance and avoidance behaviour. These are suitable indicators of fish health and stress that can be utilized in natural rivers and lakes. They do not require the capture of fish where undue stress could lead to a further deterioration of health.

Table 3-1 outlines the fish stress and health indicators, and corresponding ranking systems that will be utilized in the section of Elbow River downstream of the Project site to Glenmore Reservoir during release of water and fish from the reservoir.

Table 3-1 Fish Health Indicators and Ranking System

Rank	Health Indicator			Follow-Up Action by Monitoring Crew (if applicable)
	Swim Performance	Breathing Rate	Avoidance Behaviour	
0	• no deterioration • active and maintain expected swim speed and agility	• no deterioration • unaffected	• exhibits strong avoidance • maintains avoidance and not observed again	No action required; fish is unaffected by reservoir water release and/or fish rescue, and further capture and handling for monitoring purposes would result in undue stress.
1	• mild deterioration • appears mildly sluggish but regains swimming ability	• mild deterioration • generally unaffected and still able to function as expected	• exhibits moderate to strong avoidance	No action required; fish is generally only mildly affected and will recover. Capture and handling for monitoring purposes would result in undue stress.

Table 3-1 Fish Health Indicators and Ranking System

	Health Indicator			
Rank	**Swim Performance**	**Breathing Rate**	**Avoidance Behaviour**	**Follow-Up Action by Monitoring Crew (if applicable)**
2	• moderate deterioration • very sluggish, struggling to maintain body form in water • periods of time spent floating	• moderate deterioration • labored breathing affecting fish's ability to function as expected	• exhibits only moderate avoidance • struggles to gain body function and exhibits moderate avoidance behaviour	Fish will be captured and held in holding tank that contains fresh water that is well oxygenated to recover. When fish has recovered, it is to be released in a section of river with suitable habitat
3	• high deterioration • unable to maintain body form in water • floating, with no active swimming ability	• highly labored and low rate of breathing • no longer able to function in any capacity	• no longer capable of avoidance	Fish will be captured and held to recover in a holding tank that contains fresh water that is well oxygenated. When fish has recovered it is to be released in a section of river with suitable habitat. If an extended recovery time is required, fish will be relocated to large capacity holding tank to increase chance of recovery.
4	• mortality	• mortality	• mortality	Remove fish from river as per directions indicated in the AEP fish rescue license for the Project.

3.2 MONITORING OF FISH HEALTH AND MITIGATION

Monitoring of fish health in the downstream extent of the Elbow River will be carried out by two boat crews immediately following reservoir water drawdown and release, or at the soonest time that it is safe to enter the river upon reservoir water release. This section of the river is approximately 18 km in length and is divided into two reaches, and one boat crew will be assigned per reach. Reach 1 extends from the confluence point to 9 km downstream. Reach 2 extends for the next 9 km downstream to Glenmore Reservoir.

The following steps will be conducted by the boat crews to monitor for fish potentially impacted by the flood operations at the reservoir:

- Each boat crew will consist of a boat operator and a person to observe fish. It is expected that mortalities and fish that are experiencing stress will be visible at the surface; underwater cameras will also be employed, if possible.
- When fish are observed, each will be ranked according to criteria outlined in Table 3-1 and follow-up action will be taken to improve survival of fish that are exhibiting signs of behavioural stress.
- Fish that are Rank 0 or Rank 1 will not be captured because this could result in undue stress that could impact health. Each fish observed will be identified to species and life stage and the data recorded.
- Fish that are Rank 2 or Rank 3 will be captured and held in a well oxygenated live well on the boat until they have recovered. Each fish will be identified to species and life stage and observations of deformities, erosion, lesions or tumours recorded. Once they have recovered, they will then be released into Elbow River in a location with suitable water depth, velocity and habitat. Fish that do not recover will be removed as per directions indicated in the AEP fish rescue license for the Project.
- Any fish mortalities observed (Rank 4) will be retrieved from the river to record physical condition. They will be identified to species and life stage and measured for length and weight and observations of deformities, erosion, lesions or tumours recorded.
- The monitoring of fish health and mitigation will continue until water is no longer flowing from the reservoir into Elbow River.

Downstream Fish Health Monitoring and Mitigation Program
June 2020

4.0 CLEANING AND DECONTAMINATION

Whirling disease has been detected in many watersheds in southern Alberta. Therefore, equipment will be cleaned and disinfected to limit the spread of *Myxobolus cerebralis*, the parasite that causes the disease. The Government of Alberta has developed standard decontamination protocols for watercraft and equipment (GOA 2017; https://open.alberta.ca/publications/9781460134986). These will be implemented and adhered to prior to, and following, completion of the fish rescue and fish health monitoring and mitigation programs.

5.0 REFERENCES

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