APPENDIX D

Bibou Creek Stream Diversion

1.0 DESIGN BASIS, CRITERIA AND CONSIDERATIONS

1.1 Background of Design

In 2022, Golder Associates Ltd. prepared on behalf of Troilus Gold Ltd. (Troilus) an initial site-wide water management plan for their Troilus Project (Golder 2022). This water management plan included a design of the main diversion channel, shown in Figure 1. The channel was designed to contain the 100-year design flow with a minimum 0.3 m freeboard and included erosion protection that would be stable in events up to the 100-year design flow. The channel was approximately 10 km long with a 0.62 km long section that was to be constructed infill. The longitudinal slopes were between 0.1% and 6.7%. The PFS plan incorporated a dam at the Lac Amont outlet with an average height of four meters, which would increase the water level in Lac Amont by up to three meters and would allow the Main Diversion Channel to be moved out of the valley floor to reduce excavation and increase space for project infrastructure.

In 2023, WSP was retained by Troilus to advance the design of the surface water management plan to a feasibility level study (FS). Part of this work included updating and refining the design of the main diversion channel. In May 2023, an options analysis of the main diversion channel was completed to incorporate feedback from local communities and stakeholders to reduce the impact of the mine plan and diversion channel on the local waterbodies (WSP 2023a). WSP studied the following alternative options to the PFS concept:

1) Adjust the diversion channel alignment and design such that the diversion dam is not required (eliminate Lac Amont water level increase). Two sub-options were considered:
   - The J Waste Dump remains as a buttress to the Tailings Storage Facility (TSF) Dam such that the diversion channel is required during the operational period and at closure.
   - A corridor is left between the J Waste Dump and the TSF Dam, which is used at closure for a drainage channel. The diversion channel is dismantled as part of the reclamation period.
2) Remove the diversion channel around the open pits and the waste dumps from the Stormwater Management Plan. A corridor is left between the J Waste Dump and the TSF Dam. A channel (partially the original Bibou Creek, partially a constructed channel) conveys the Bibou Creek water to either the 87 Pit or the J Pit, from where it is pumped to Lac A. The mining sequence is adjusted so that one of the two pits can serve at any given time for water storage.

Following a discussion with Troilus, Option 1 was selected to be progressed to the FS-level design. During the design of the FS-level Surface Water Management Plan, the Main Diversion Channel was renamed the DC1 Bibou Creek Diversion (DC1).

The DC1 channel is approximately 9.7 km long. The channel follows a similar alignment to the PFS Main Diversion Channel but was adjusted to maintain the connection to Lac Amont without impacting the normal water surface elevation of the lake. Additional adjustments included:

- Incorporation of fish passage and fish habitat features into the channel design.
- Adjustment of the longitudinal slope of the channel to reduce the maximum required riprap size to 500 mm, to make use of available mine waste rock and reduce processing efforts.
- Incorporate the new X22 pit expansion on the west side of the project area adjacent to the 87 Pit footprint.

- Moved the diversion alignment away from the “Fishhook Lake” to the west of the project area to reduce potential impact to adjacent watersheds.
- Removal of the upstream Lac Amont dam and incorporation of a smaller flood protection berm to divert the 100-year flow from the Bibou Creek floodplain into the diversion.

1.2 Available Information and Data

The information outlined in Table 1 below describes the available external data used in the feasibility design of the stream diversion system.

Table 1: Available Data

Data	Source Date	Date Received	Prepared by	Source
AGP Mining Consultants Inc. (AGP) Mine Schedule V9 50ktpd	February 10, 2024	February 10, 2024	AGP	AGP Mining Consultants Inc.
Lac A Water Level Data		May 15, 2023		Troilus
État de référence du milieu récepteur. Étude sur le mouvement du poisson dans le ruisseau Sans Nom – Version préliminaire.		May 17, 2023	Wachiih	Troilus
220507-MFFP-LiDAR-1m	2019	June 27, 2023	Government of Quebec	Government of Quebec
Characterisation habitat des poisons	January 21, 2019	August 1, 2023	Wachiih	Troilus
Lake A and B Bathymetry Final Report	January 2019	August 2, 2023	Wachiih	Troilus
Hydrology – Reference Study – Troilus Mining Project	March 22, 2024	March 22, 2024	Wachiih	Troilus

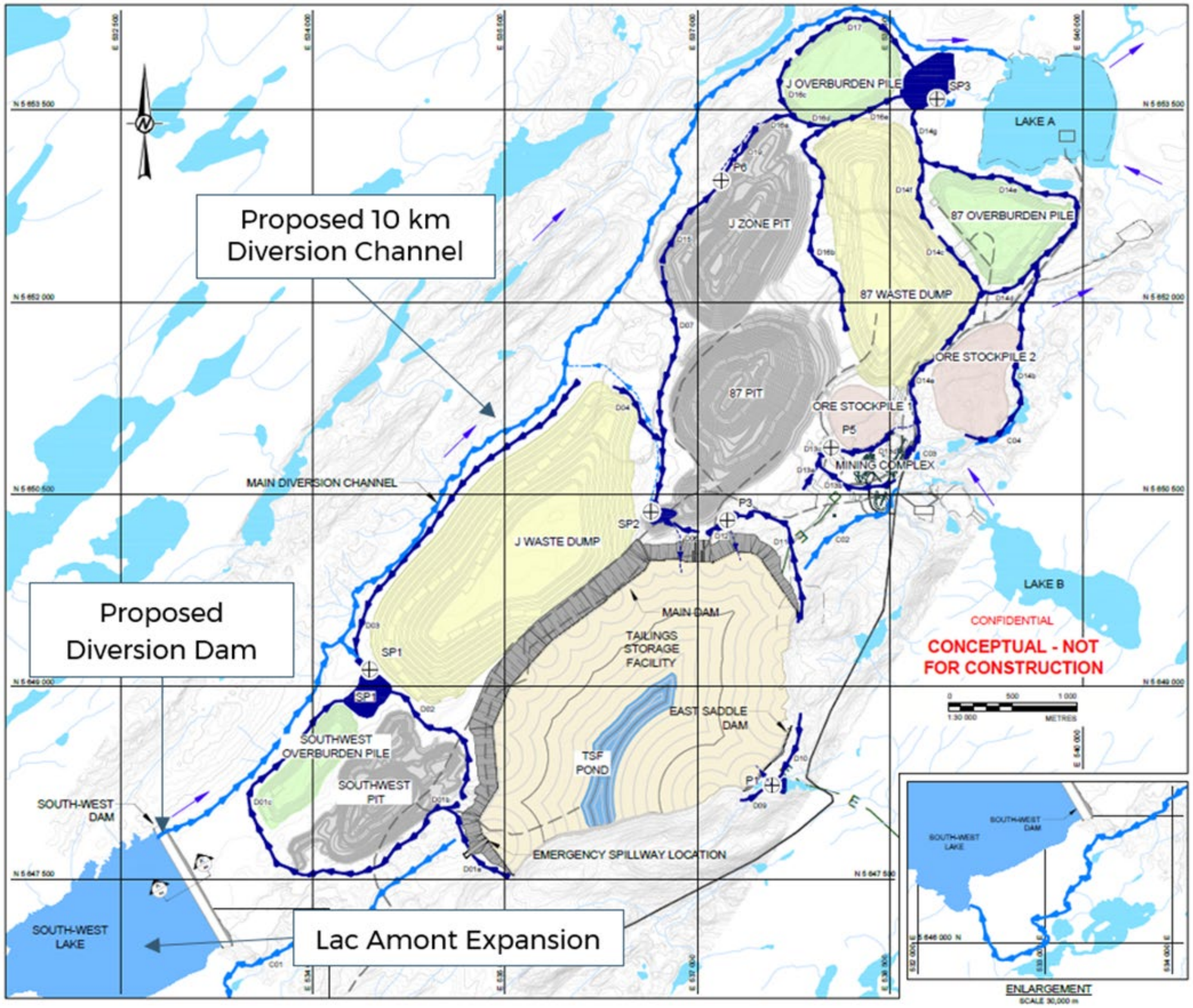


Figure 1: Early Concept (Before the Feasibility Study) Site Wide Water Management Plan - Ultimate Project Development

1.3 Design Criteria and Considerations

The feasibility design of the diversion channel refines the design outlined in the pre-feasibility study. For the feasibility study further hydrological, geotechnical, hydraulic, and environmental assessments/analyses were conducted. Special consideration was also given to maintaining fish habitat and passage through the channel. Table 2 below outlines the design criteria and considerations used in the design of the stream diversion system.

Table 2: Design Criteria

Item Description	Design Basis, Criteria and Considerations	Information Sources
Design Life	Operational portion of channel: ▪ During the life of Mine. Less than 30 years. Closure portion of channel: ▪ Long-term sustainability	Proposed Water Management Plan
Coordinate System	NAD_1983_UTM_Zone_18N	
Topographical Data	1.0 m LiDAR	Quebec (2019)
Hydrologic		
Determination of Design Flood Discharges	Calculated with HEC-HMS (Hydrologic Engineering Center and Hydrologic Modeling System) (US Army Corps of Engineers [USACE] 2021)	Industry Standard
Geotechnical		
Side Slopes	In Bedrock: 1H:1V In Till: 2.5H:1V	Assumed
Aquatic		
Fish Passage	Fish Passage must be provided between the 7Q10 low flow and 14Q2 high flow conditions	Recommended
Hydraulic		
Design Flow Event for Flow Conveyance	Contain the 100-year flood event based on historical climate selected	Directive 019 (MELCCFP, 2022)
Freeboard	Minimum 0.3 m above the 100-year water depth, to be provided with access road construction adjacent to the channel, where practical.	Recommended; industry practice.
Design Flood Event for Erosion Protection	Design for the non-erodible 100-year flood event	Directive 019 (MELCCFP, 2022)
Minimum Channel Bottom Width	Minimum channel bottom width of 2 m (not including low flow channels)	For constructability, with consideration of equipment expected to be used.
Channel Materials		
Erosion Protection Material Selection	Maximum riprap size of 500 mm	Sourcing from Run-of-Mine blast rock
Bedding Material Requirements	Filter layers – sandy gravel, cobble, as required by erosion protection material size	

Fish Passage Design Criteria

The channel is designed to provide fish passage for conditions between the 7Q10 low flow and 14Q2 high flow conditions:

- 7Q10 refers to the annual minimum 7-day average flow rate with a 10-year occurrence interval (May to October).
- 14Q2 refers to the annual maximum 14-day average flow rate with a 2-year occurrence interval.

As described in Section 5.1, the Walleye and the Burbot were selected as the design species. Walleye are the main species that will make use of the channel during spring freshet. The 14Q2 high flow event was selected as the representative spring freshet event. Flow velocities during this period were assessed against the Walleye's maximum swimming ability over a 25 m distance against a 1 m/s current. The lower swimming capacity of the burbot was considered by including frequent shelter places in the design; the maximum flow velocities limits for Burbot were not imposed as design constraints for the entire 7Q10 – 14Q2 flow interval.

Table 3 below outlines the maximum distances Burbot and Walleye can travel, given the flow velocity.

Table 3: Maximum Distance Over Which Burbot and Walleye can Travel without Shelter Given the Flow Velocity During High Flow Events (Katopodis, 2016)

Swim Distance	Maximum Flow Velocity for Burbot (m/s)	Maximum Flow Velocity for Walleye (m/s)
3	1	2.2
25	-	1.0
100 - 300	0.1	0.4

To maintain passage during the representative low flow 7Q10 event, the channel was designed to have a minimum water depth of 0.1 to 0.2 m.

Other Design Criteria

Other design considerations are listed below.

- Reduce use of erosion protection materials.
- Reduce excavation volumes.
- Minimize impact on existing infrastructure, where practical.

2.0 HYDROLOGICAL ASSESSMENT

HEC-HMS (Hydrologic Engineering Center and Hydrologic Modeling System) (USACE 2021) was used to simulate peak design flows for the DC1 diversion channel. The model's data inputs include meteorological and hydrological data, drainage areas, Curve Number (CN) values, and lag times to determine peak design flows.

2.1 Hydrologic Inputs

Climate design inputs (extreme, short-term rain statistics) are described in Appendix C. WSP used the 100-Year, 24-Hour extreme rainfall event as a design event for ditches and channels; the Soil Conservation Service (SCS) Type 2 distribution was used.

2.2 Drainage Areas and CN Values

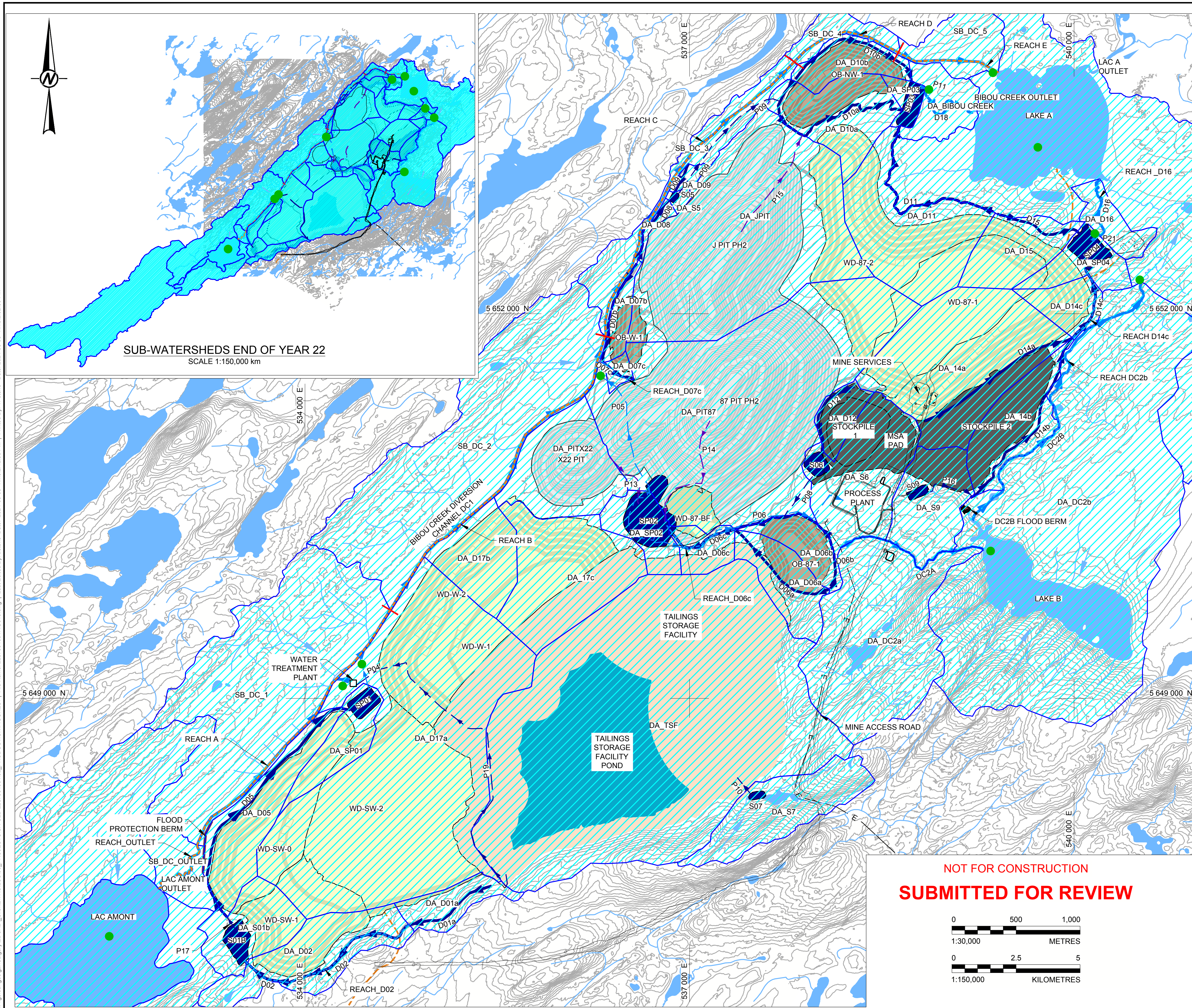
The drainage areas were delineated using a Digital Terrain Model (DEM) and topographic contours derived from provincial 2019 LiDAR with 1m resolution (Quebec 2019) and mine plan information, including pit and dump boundaries and surface contours from AGP. Existing surface drainage features were incorporated. Streamflow paths were delineated based on the drainage areas and existing and future mine plan topography. Drainage areas and streamflow paths are shown in Figure 2.

SCS CN and SCS Unit Hydrograph methods (US Department of Agriculture [USDA], 1986) were estimated for the HEC-HMS model. The SCS-CN method is an empirical technique used to estimate rainfall-runoff volume in small watersheds, with CN being an empirically derived parameter calculating direct runoff from a rainfall event. CN values range from 100 (for water bodies) to approximately 30 for permeable soils with high infiltration rates. The value depends on soil type, condition, and the land use and land cover (LULC) of an area.

In 2021, WSP completed terrain mapping of the project area (WSP 2021). This terrain mapping was cross-referenced with the mine plan to develop an estimate of the land type distribution for each drainage area contributing to the DC1 diversion channel. The proposed land type and Curve Number (CN) value were determined using the terrain map's land type and future mine plan for the area, as tabulated in Table 4.

Table 4: Hydrological Design Parameters – Selected SCS CN Values

Land Type for HEC-HMS Model	Terrain Map Analogue	CN Value
Overburden dumps, built areas		91
Cleared area of the mine site	Anthropocene	86
Waste dump (rock)		72
Natural area, wooded	Morainal (Till)	60
Natural Area, vegetated	Organic	71
Tailings Beach		94
Mine Pit Area		93
Pond area (including wetland)	Waterbody	100



NOT FOR CONSTRUCTION

SUBMITTED FOR REVIEW

0 500 1,000
1:30,000 METRES

0 2.5 5
1:150,000 KILOMETRES

WATER MANAGEMENT

- TOPOGRAPHIC CONTOUR (5 m INTERVAL)
- DIVERSION CHANNEL (NON-CONTACT WATER)
- CONTACT WATER DITCH
- DRAINAGE THROUGH WASTE ROCK
- CLEAN WATER PIPELINE (PUMPING)
- CONTACT WATER PIPELINE (PUMPING)
- PIT DEWATERING
- FLOW DIRECTION
- NATURAL WATERCOURSES
- NATURAL LAKES
- TSF POND
- SEDIMENTATION POND (CONTACT WATER)
- SUMPS / PUMP STATION (CONTACT WATER)
- MONITORING POINT / WATER EFFLUENT TO ENVIRONMENT

MINE INFRASTRUCTURE

- WATER CONTAINMENT BERM
- OVERBURDEN PILE
- WASTE DUMP
- MINE PIT
- TAILINGS STORAGE FACILITY
- ORE STOCKPILE
- PROCESS PLANT
- RELOCATED ELECTRICITY TRANSMISSION LINE
- EXISTING ROADS (2023)
- FUTURE ROAD
- WATERSHED AREAS
- DIVERSION REACHES FLOW PATH
- DITCH REACHES FLOW PATH

REFERENCE(S)

1. DIGITAL TERRAIN MODEL (PRODUCTS DERIVED FROM LIDAR - 1 m RESOLUTION), MFFP, © GOUVERNEMENT DU QUÉBEC.
2. MINE POLYGONS AND SURFACES FROM AGP MINING FEBRUARY 28, 2024.
3. FUTURE PROCESS PLANT AND MINE ACCESS ROAD LAYOUT FROM LYCOPODIUM NOVEMBER 29, 2023.
4. FUTURE ELECTRICITY TRANSMISSION LINE FROM LYCOPODIUM, FEBRUARY 22, 2024.
5. EXISTING ROADS FROM TROILUS GOLD, MAY 25, 2022.

NOTE(S)

1. THE FIGURE IS A SCHEMATIC REPRESENTATION OF THE END-OF-MINE-LIFE SURFACE WATER MANAGEMENT PLAN.
2. THE THICKNESS OF THE CHANNELS AND DITCHES LINES ARE NOT AN ACCURATE REPRESENTATION OF THE ACTUAL FOOTPRINT OF THESE STRUCTURES.
3. THE FIGURES SHOW ONLY WATER PIPELINES WHICH ARE PART OF WSP'S SITE-WIDE WATER MANAGEMENT PLANT SCOPE; ALSO IN-PIT WATER PIPELINES ARE PRESENTED SCHEMATICALLY.
4. COORDINATE SYSTEM: UTM NAD 83, ZONE 18.

CLIENT

TROILUS

PROJECT

TROILUS GOLD PROJECT - SITE-WIDE WATER MANAGEMENT PLAN - FEASIBILITY STUDY

TITLE

SURFACE WATER MANAGEMENT PLAN
SUB-WATERSHEDS END OF YEAR 22

CONSULTANT

wsp

YYYY-MM-DD	2024-05-03
DESIGNED	JF
PREPARED	TF
REVIEWED	VR
APPROVED	VR

PROJECT NO.	CONTROL	REV.	FIGURE
2257554004		A	02

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

2.3 Lag Times

SCS unit hydrograph method was applied to simulate the design flows in HEC-HMS. This method requires Lag time and curve number (CN) as input. The lag time was determined from the delineated streamflow flow paths and was calculated using the curve number of the watershed, slope, and area of the basin flow paths as input and time of concentration (T_c) for each sub-basin.

The lag time and the total time of concentration (T_c) are calculated using the time of Concentration and Travel time equations (USDA 1986). The total time of concentration (T_c) is the sum of Travel time (T_t) values for the various consecutive flow segments in a flow path (sheet flow, shallow concentrated flow, and channel flow).

The travel time (T_t) is calculated for each individual flow path and their flow segments based on the sheet flow, shallow concentrated flow, and open channel flow.

- Sheet flow over plane surfaces usually occurs near the ridgeline that defines the watershed boundary. Sheet flow typically occurs for no more than 100 feet (30 meters) before transitioning to shallow concentrated flow. The travel time (T_t) is computed based on the Manning's kinematic solution.
- Shallow concentrated flow collects in swales, small rills, and gullies. The shallow concentrated flow velocity (V) is calculated as a function of terrain slope and roughness.
- Open channel flow occurs when the shallow concentrated flow meets the proposed designed diversion channel or the contact ditches. Natural channels are identified from aerial imagery or site topography. Manning's equation is used to estimate average flow velocity.

2.4 Summary Table

Table 5 summarizes the HEC-HMS inputs for each hydraulic reach of the DC1 diversion channel, including drainage area, CN values, and calculated lag times.

Table 5: HEC-HMS Input Parameters

HEC-HMS ID	Description	Sub-Basin Drainage Area (km^2)	CN Value	% Impervious	Lag Time (min)
SB_01	Drainage area upstream of Lac Amont, including upstream lakes	10.4	71	20%	350
SB_02	Drainage area around Lac Amont	4.7	71		49
Lac Amont	Waterbody	1.2	100	100%	Not applicable
SB_DC_Outlet	Drainage area between Lac Amont and the start of the diversion	0.26	71	0	21
SB_DC_01	Diversion, Sta 0+000 to 2+406	1.9	71	0	40
SB_DC_02	Diversion, Sta 2+406 to 5+219	2.0	71	0	43
SB_DC_03	Diversion, Sta 5+219 to 7+912	0.43	71	0	37
SB_DC_04	Diversion, Sta 7+912 to 8+834	0.16	71	0	14
SB_DC_05	Diversion, Sta 8+834 to 9+657	0.31	71	0	38

Channel reaches, which serve as collectors for upstream segments, also had separate lag times calculated for the length of the channel to estimate the flow concentration time from upstream drainage areas. These lag times are shown in Table 6.

Table 6: Reach Lag Times

Structure ID	Lag Time (min)
Reach_Outlet	36.6
Reach A	42.6
Reach B	52.6
Reach C	49.0
Reach D	6.1
Reach E	5.6

2.5 HEC-HMS Results

HEC-HMS outputs for the 100-year summer event are shown in Table 7.

Table 7: HEC-HMS Outputs

Hydrologic Element	Description	Total Contributing Drainage Area (km2)	Peak 100-Year Discharge (m3/s)
SB_01	Lakes upstream of Lac Amont	10.4	18.3
SB_02	Lac Amont runoff area	4.68	30.4
Lac Amont	Lac Amont Waterbody	1.19	49,0
UpstreamLake	Total flow out of Lac Amont	16.3	3.6
Reach-Outlet	Flow conveyed from upstream areas toward diversion	16.3	3.6
SB_DC_Outlet	Flow from local drainage area around Lac Amont Outlet	0.26	2.9
DC_Outlet	Total runoff through Lake A Outlet toward diversion	16.5	3.7
Reach-A	Flow conveyed from upstream areas	16.5	3.7
SB_DC_1	Flow from local drainage area	1.94	14.5
DC_A	Total flow through DC1, Sta 0+000 to 2+403	18.5	17.4
Reach-B	Flow conveyed from upstream areas	18.5	17.4
SB_DC_2	Flow from local drainage area	2.00	14.2
DC_B	Total flow through DC1, Sta 2+403 to 5+218	20.5	25.1
Reach-C	Flow conveyed from upstream areas	20.5	24.9
SB_DC_03	Flow from local drainage area	0.42	3.3
DC_C	Total flow through DC1, Sta 5+218 to 7+913	20.9	25.6

Table 7: HEC-HMS Outputs

Hydrologic Element	Description	Total Contributing Drainage Area (km2)	Peak 100-Year Discharge (m3/s)
Reach-D	Flow conveyed from upstream areas	20.9	25.5
SB_DC_04	Flow from local drainage area	0.16	2.2
DC_D	Total flow through DC1, Sta 7+913 to 8+833	21.1	25.7
Reach-E	Flow conveyed from upstream areas	21.1	25.7
SB_DC_05	Flow from local drainage area	0.31	2.4
DC_E	Total flow through DC1, Sta 8+833 to 9+654	21.4	26.2

2.6 Significant Flow Statistics for Fish Passage Assessment

Based on the regional hydrology assessment conducted for this project (see Section 2.2 in Appendix C of the main report), the 7Q10 low flow, average annual flow, and 14Q2 high flow rates were calculated for the DC1 channel. These flows are summarized in Table 8.

Table 8: Flow Rates Utilized in DC1 Design

Flow Event	Upstream (Sta 0+000 to 2+403) Flow Rate (m^3/s)	Downstream (Sta 2+403 to 9+654) Flow Rate (m^3/s)
7Q10 Low Flow	0.03	0.04
Average Annual Flow	0.56	0.70
14Q2 High Flow	2.5	2.8

3.0 GEOTECHNICAL ASSESSMENT

3.1 Overview of Ground Conditions

Geotechnical conditions were assessed along the length of the DC1 diversion channel. Boreholes (BH) were selected based on proximity and representative topography to characterize the in-situ material. Conditions are summarized in Table 9. The station numbers in Table 9 are shown in Drawing C200 in Appendix J, and in below. Borehole data is from WSP (2022b) and WSP (2023b).

For locations where boreholes were scheduled at the time of design but had not been completed, values for bedrock depths and peat thicknesses were inferred based on surficial geology and other boreholes. These assumptions should be confirmed during detailed design.

Table 9: Geotechnical Condition by Reach

Segment	Station	Borehole	Distance from Diversion (m)	Bedrock Depth (m)	Summary of Sub-Surficial Material	Peat Thickness (m)
1	0+000 to 0+100	BH-23-14-TP	67	10 (inferred)		1.2 (inferred)
2	0+100 to 0+700	MW-21-10	95	5	Gravely silty sand, presence of cobbles and boulders	0.8
3	0+700 to 1+380	BH-23-27	2	10 (inferred)		1 (inferred)
4	1+380 to 1+820	BH-23-27	2	10 (inferred)		1 (inferred)
5	1+820 to 2+120	BH-23-29-TP	1	8 (inferred)		1 (inferred)
6	2+120 to 2+740	BH-23-32	10	7 (inferred)		1.2 (inferred)
7	2+740 to 3+370	GZ-21-005	167	7.13		1.2 (inferred)
8	3+370 to 3+700	GZ-21-003	13	7.37		1.2 (inferred)
8	3+700 to 4+500	BH-23-36	65	2.82	Fine to coarse sand - silty, traces of gravel	0.76
8	4+500 to 5+250	BH-23-40	40	6.45	Sand (fine to coarse), traces of gravel, cobbles and boulders near bottom	0.61
9	5+250 to 6+170	BH-23-41	24	3.19	Fine to coarse sand, to sandy gravel, to cobbles and boulders near bottom	0.61
10	6+170 to 6+670	BH-23-42	0	2	Shallow bedrock under organics	1
11	6+670 to 7+600	BH-23-71	5	3.3	Sand (fine to coarse), trace of gravel	0.6
12	7+600 to 7+990	BH-23-72	5	10.7	Sand (medium to coarse), to silty sand, to sand (fine to coarse) to medium-coarse sand, traces of gravel throughout	0.61

Table 9: Geotechnical Condition by Reach

Segment	Station	Borehole	Distance from Diversion (m)	Bedrock Depth (m)	Summary of Sub-Surficial Material	Peat Thickness (m)
13	7+990 to 8+510	BH-23-73	10	7.79	Sand (medium), trace of gravel, cobbles and boulder near bottom	0.61
14	8+510 to 8+870	BH-23-46	220	2.45	Silty sand to sand and gravel to coarse sand	0.76
15	8+870 to 9+300	BH-23-22	40	1.44	Fine sand with trace of gravel	0.46
16	9+300 to 9+654	BH-23-74-TP	20	10 (inferred to be deep based on proximity to Lac A)		1.5 (inferred based on proximity to Lac A)

Notes: “inferred” = For locations where boreholes were scheduled at the time of design, but had not been completed, values for bedrock depths and peat thicknesses were inferred based on surficial geology and other boreholes. These assumptions should be confirmed during detailed design.

3.2 Design Considerations and Geotechnical Uncertainty

Side-slopes in bedrock were set at 1H:1V. Side slopes in till were set at 2.5H:1V, except for some areas where they were adjusted to 2H:1V to improve conditions for fish passage.

While the assumptions for channel side slopes, including removal of peat excavation in till and bedrock and construction of embankments, were reviewed by a geotechnical engineer, a slope stability analysis along the length of the diversion channel was not conducted. It is recommended that for the next design phase, a side slope analysis of each channel segment be conducted to assess channel stability and optimize channel geometry where appropriate.

4.0 HYDRAULIC ASSESSMENT

4.1 Channel Alignment

The channel alignment of DC1 was refined from the pre-feasibility study using updated hydrological and geotechnical assessments. The updated alignment is 9.7 km long, and is separated into sixteen segments with longitudinal slopes ranging from 0.01% to 1.7%. The 1.70% slope represents an average slope through the segment, for hydraulic modelling of flood flows. This is described in detail below.

The upstream portion of the channel (the first 5.3 km) will remain after the mine closure, whereas the downstream portion of the diversion channel (4.4 km) will only be operational during the life of the mine. The entire channel is designed to provide fish passage. The upstream closure portion of the channel is designed to provide sustainable fish habitat as well as fish passage, and limit disturbance during the operational life of the diversion as well as through the transition to the closure phase.

4.2 Channel Hydraulic Design

Hydraulic design analysis of the channel was performed based on the design criteria and considerations outlined in Table 2. The hydraulic analysis was performed to assess the required channel depth, channel side slopes, and erosion protection to contain the design event without erosion. A one-dimensional hydraulic model was developed for the diversion using HEC-RAS (USACE 2021). The 2-year, 10-year, and 100-year flood events were simulated through the channel for design of flood flow conveyance and erosion protection requirements. The 7Q10 low flow, 14Q2 high flow, and average annual flows were simulated in the 1D HEC-RAS model to assess the channel against fish passage requirements.

The Manning's roughness values varied between segments and within cross-sections. Manning's roughness values between 0.03 and 0.20 were selected for calculating the design flow depths and the design flow velocities (USACE 2019). A roughness of 0.03 represents a moderately clean, straight channel, while a roughness of 0.20 represents a channel with variable slopes, pools and large embedded boulders.

The 1D HEC-RAS model boundary conditions were based on existing conditions on the upstream and downstream ends of the channel, and are included in Table 10.

Table 10: Model Boundary Conditions.

Boundary Condition	Type	Value	Consideration
Upstream	Normal Depth	0.3%	Slope of the upstream Bibou Creek Channel
Downstream	Normal Depth	0.01%	Gradient of the ground adjacent to Lac A

The simulated design flood water surface profiles are shown in Figure 3. The calculated depth-averaged design flood flow velocities along the entire channel alignment are shown in Figure 4.

Each of the sixteen channel segments uses one of ten typical cross-sections, and incorporates additional details to provide fish passage under high and low-flow conditions. The typical cross-sections are included in the design drawings (Appendix J) and also in Figure 5 through Figure 14. The fish passage design details are also included in the design drawings, and are described in detail in Section 5.0.

- Cross-section 1 is shown in Figure 5, and applies to channel segments 1 and 4. It is designed to convey flow down a moderately steep channel slope to follow existing topography. The low-flow portion of the cross-section is designed as a small meandering channel.
- Cross-section 2 is shown in Figure 6, and applies to channel segments 2, 3, and 5 through 7. It is designed to convey flow on a shallow sloped channel. The low-flow portion of the cross-section is designed as a small meandering channel.
- Cross section 3 is shown in Figure 7, and applies to channel segment 8. It is designed to convey flow on a very shallow sloped channel. The low-flow portion of the cross-section is designed as a small meandering channel.
- Cross-section 4 is shown in Figure 8, and applies to channel segments 9 and 11. It is designed to convey flow on a shallow sloped channel. The channel is excavated in bedrock with steep side slopes. The low-flow portion of the cross-section is designed with a series of low weirs to provide backwatered areas for fish passage and rest.

- Cross-section 5 is shown in Figure 9, and applies to channel segment 10. It is designed to convey flow on a very shallow sloped channel. The channel is constructed in fill to convey flow through a topographical low area. The low-flow portion of the cross-section is designed with a series of low weirs to provide backwatered areas for fish passage and rest.
- Cross-section 6 is shown in Figure 10, and applies to channel segment 12. It is designed to convey flow on a shallow sloped channel. The channel is excavated in bedrock with steep side slopes up to the top of bedrock, and shallower side slopes in till. The low-flow portion of the cross-section is designed with a series of low weirs to provide backwatered areas for fish passage and rest.
- Cross-section 7 is shown in Figure 11, and applies to channel segment 13. It is designed to convey flow down an average 1.70% slope to follow existing topography. The channel is constructed as a series of rock ramps and pools to provide fish passage during high- and low-flow events.
- Cross-section 8 is shown in Figure 12, and applies to channel segment 14. It is designed to convey flow on a shallow sloped channel. The low-flow portion of the cross-section is designed with a series of low weirs to provide backwatered areas for fish passage and rest.
- Cross-section 9 is shown in Figure 13, and applies to channel segment 15. It is designed to convey flow down an average 1.70% slope to follow existing topography. The channel is constructed as a series of rock ramps and pools to provide fish passage during high- and low-flow events.
- Cross-section 10 is shown in Figure 14, and applies to channel segment 16. It conveys flow into the downstream Lac A.

Table 11 outlines the channel characteristics and parameters which were modelled in HEC-RAS and references the typical cross-sections and fish passage design details described above. Table 11 also includes embankment heights for local sections of the channel where the design freeboard is either provided for through construction of access roads adjacent to the diversion or where the channel ins constructed entirely in fill to reduce excavation.

Table 12 summarizes the modelling results for the 2-year, 10-year and 100-year flood events and the erosion protection and filter layer requirements. Selected cross-sections from the HEC-RAS model showing the 2-year, 10-year, and 100-year water levels are shown in Attachment A.

The 7Q10, average annual flow, and 14Q2 flow events were modelled for fish passage. The results of the hydraulic modeling of these events are described in Section 5.0. The design details incorporated to meet fish passage requirements are also described in detail in Section 5.0. and are described in low flow design type for each segment is included in Table 11.

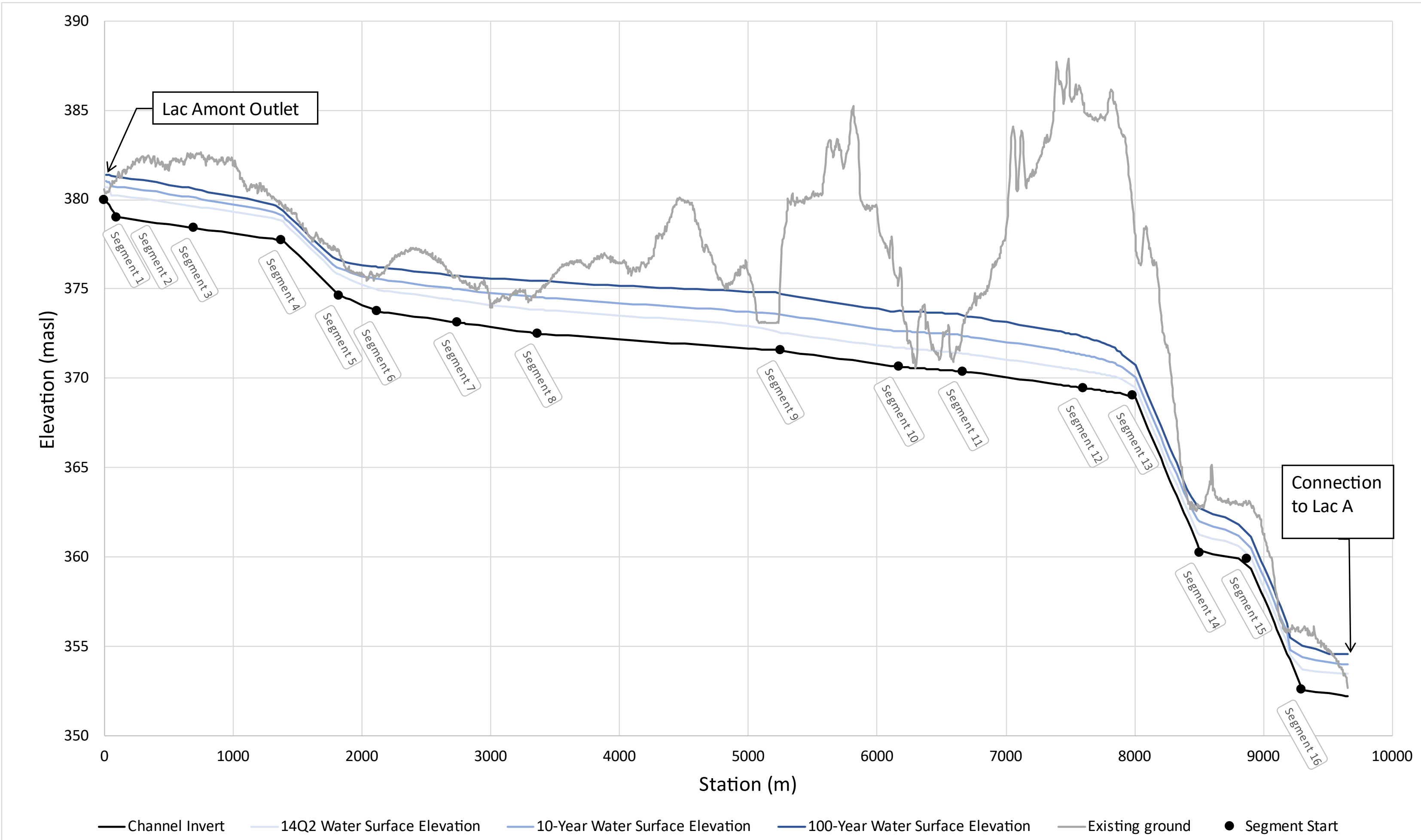


Figure 3: DC1 Diversion Channel Water Surface Profiles

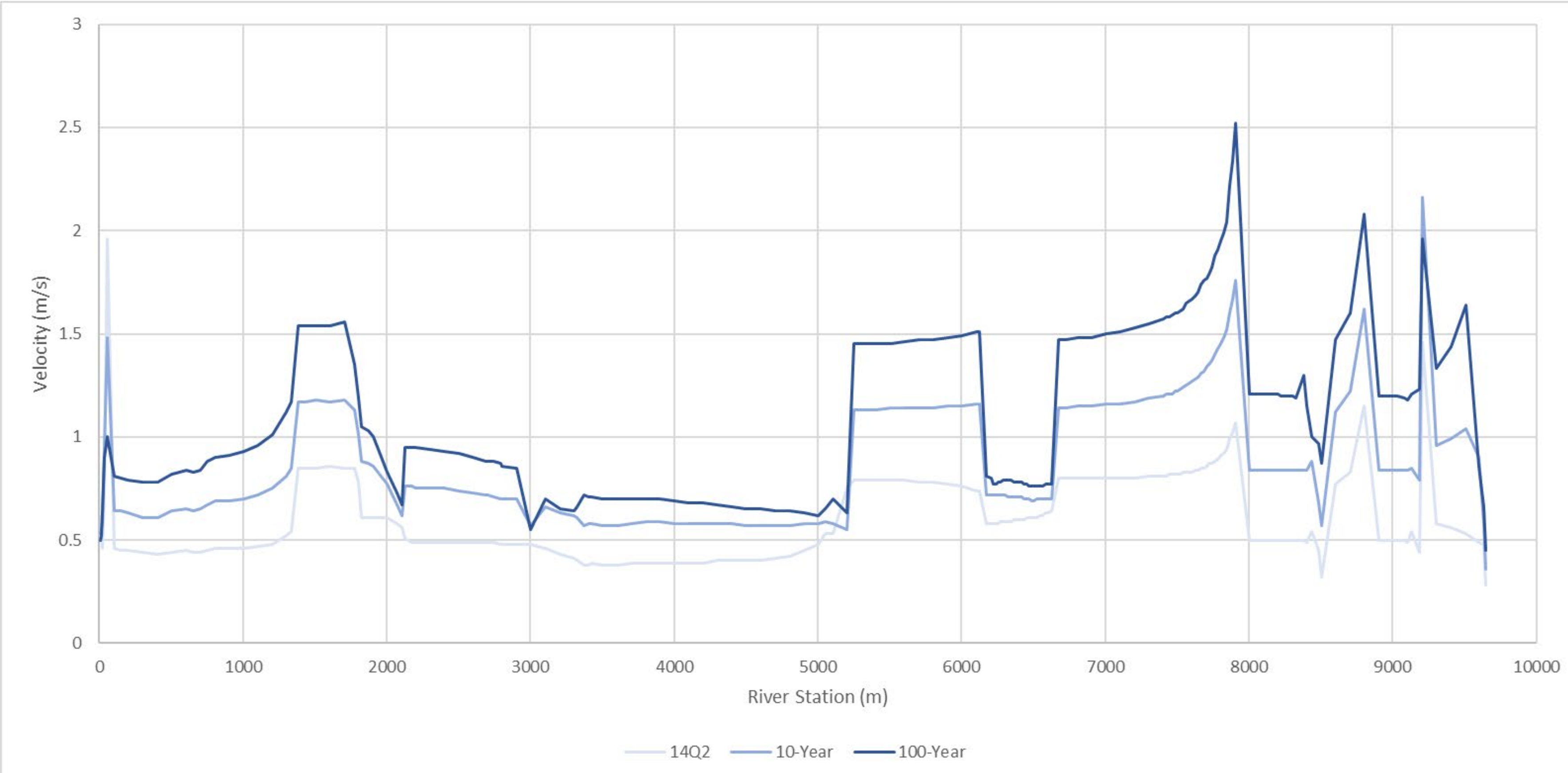


Figure 4: DC-1 Diversion Channel Velocity Profiles

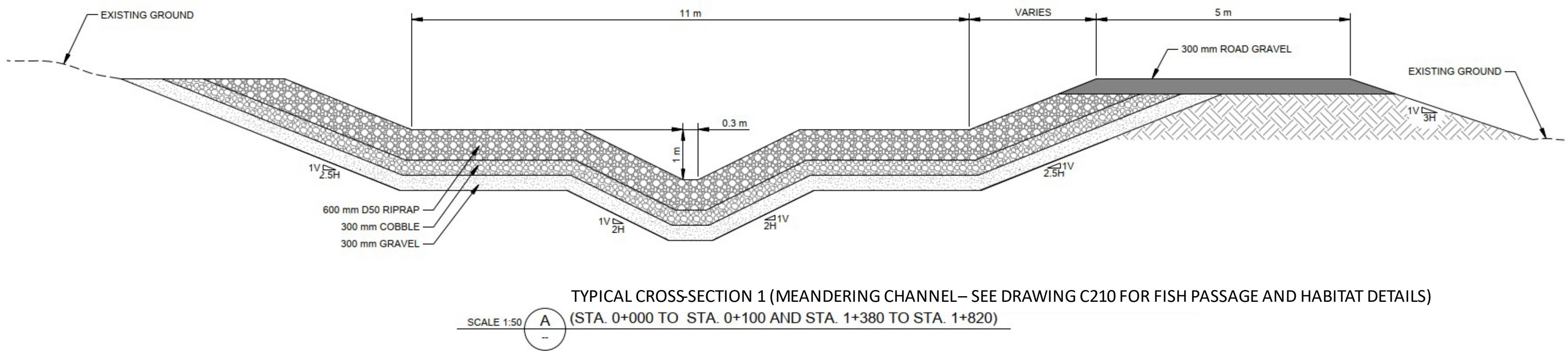


Figure 5: Typical Section 1

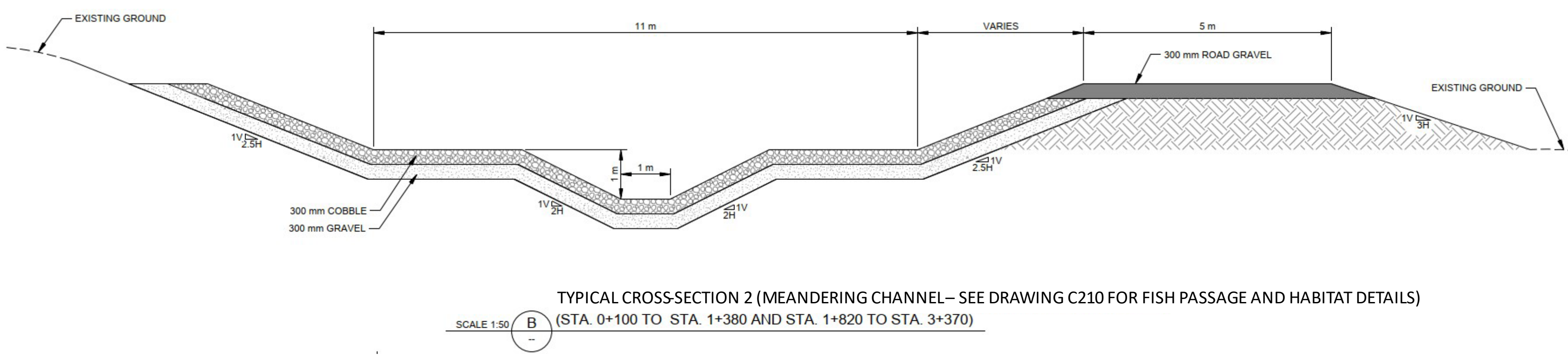


Figure 6: Typical Section 2

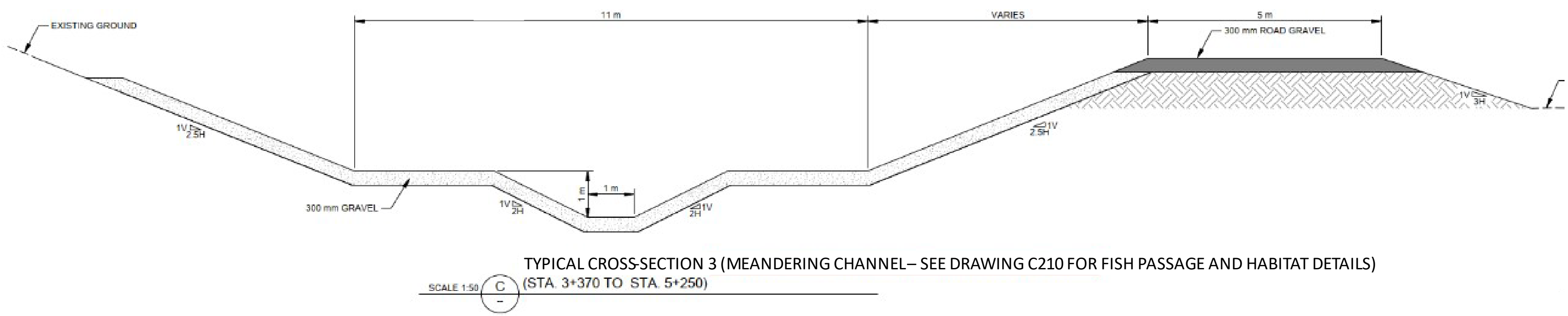


Figure 7: Typical Section 3

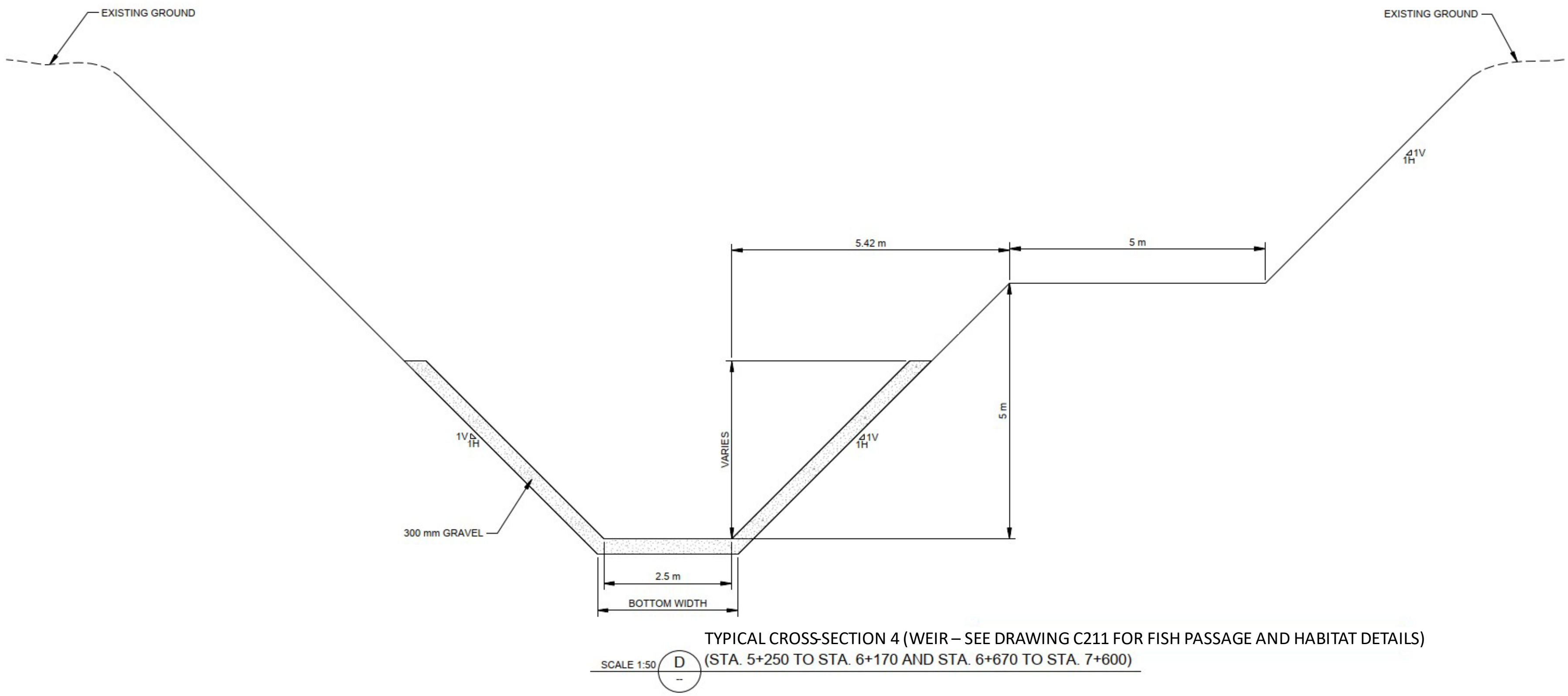


Figure 8: Typical Section 4

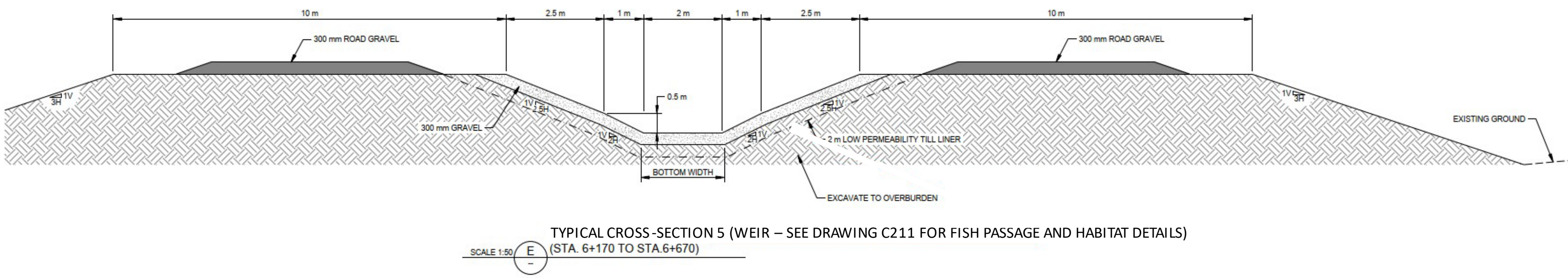


Figure 9: Typical Section 5

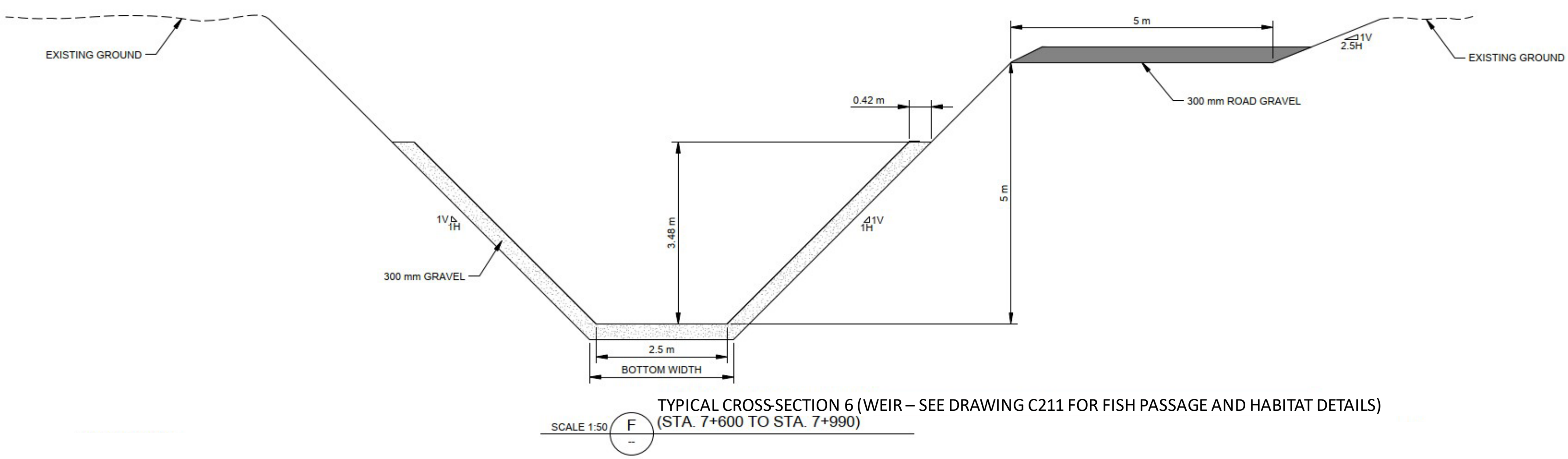


Figure 10: Typical Section 6

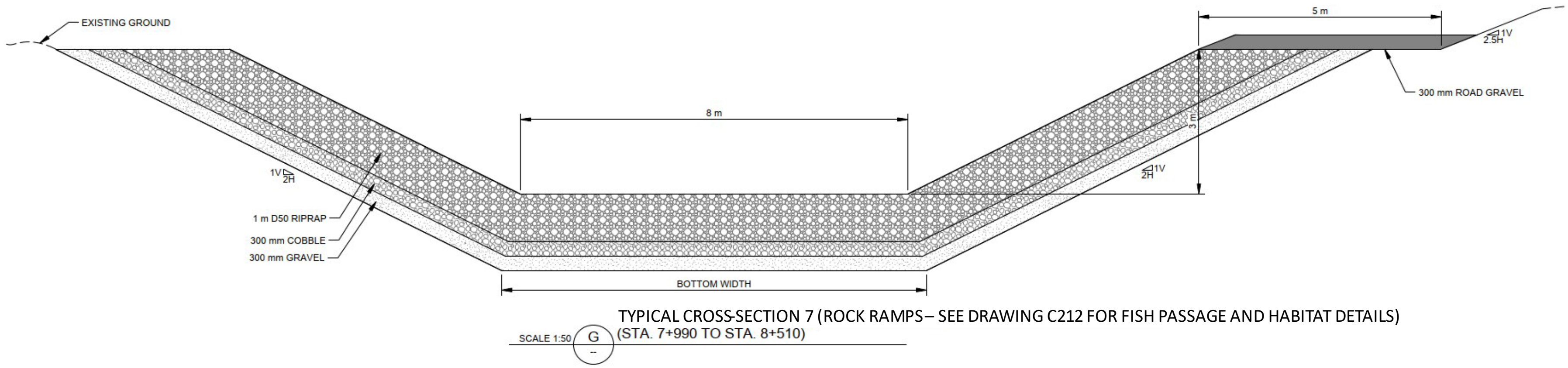


Figure 11: Typical Section 7

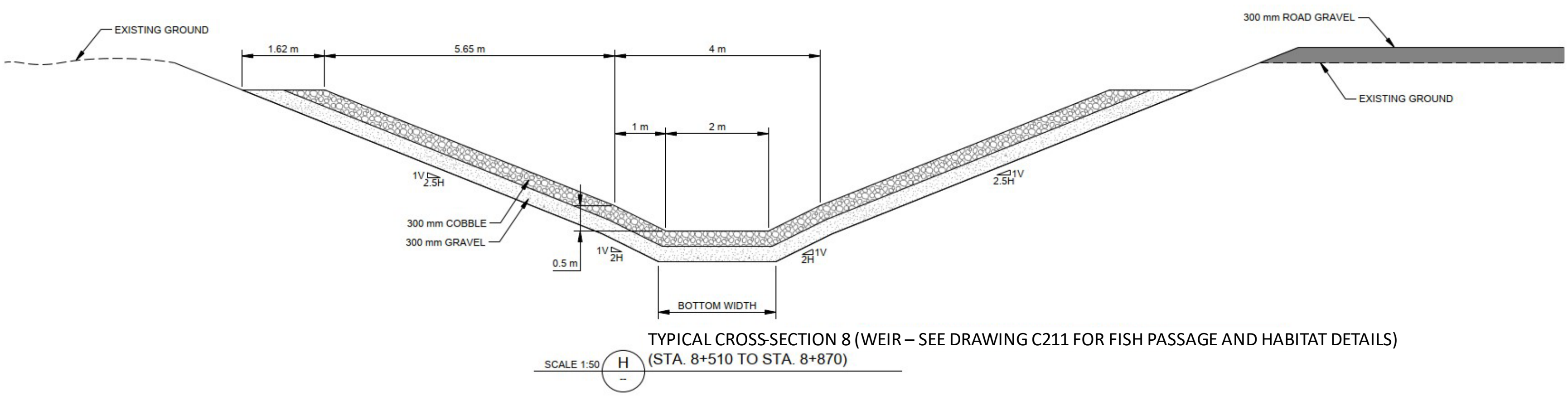


Figure 12: Typical Section 8

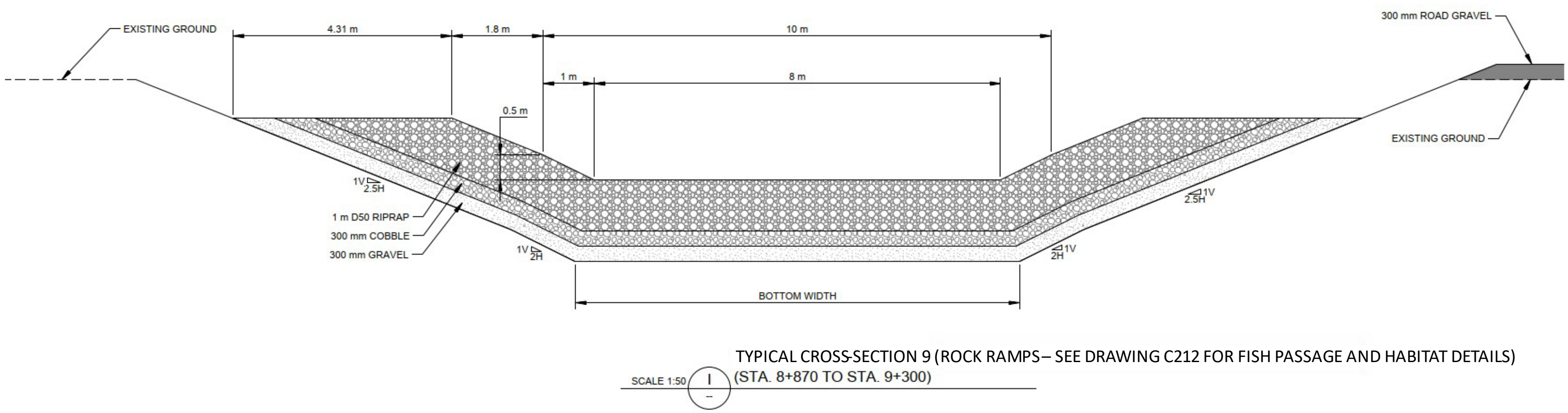


Figure 13: Typical Section 9

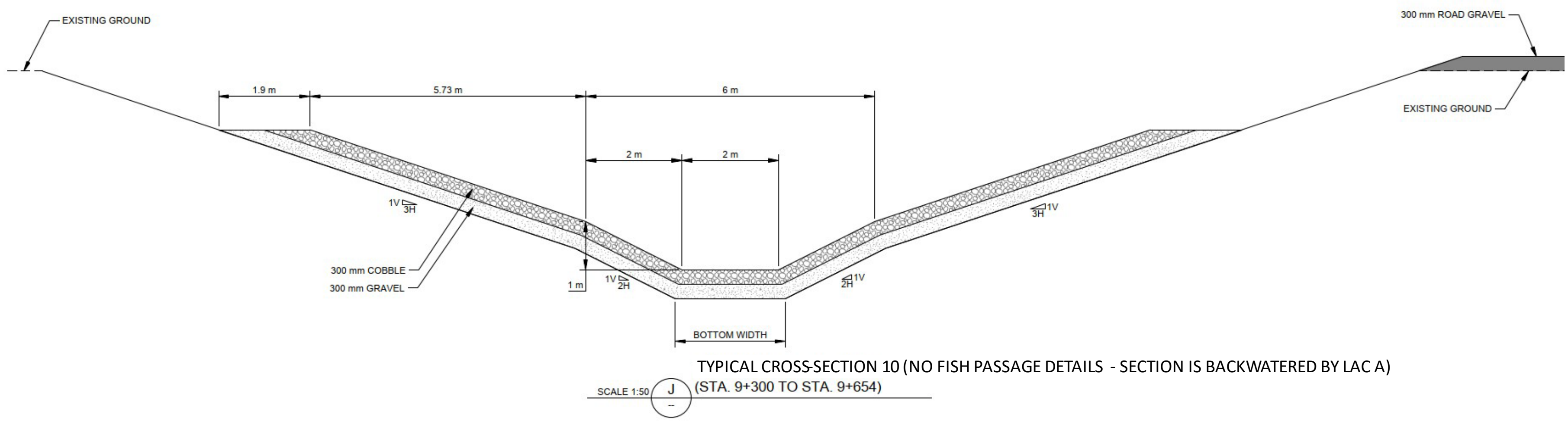


Figure 14: Typical Section 10

Table 11: DC1 Geometry

Segment							Low Flow Channel			Main Channel			Embankment (c)		
Segment Number	Station		Typical Cross-Section # (a)	Fish Passage Detail (b)	Length	Slope	Width	Depth	Side Slope	Width (including Bench)	Side Slope	Bench Width	Height above Channel Invert	Top Width	Side Slope
	From	*To*			*m*	*%*	*m*	*m*	*H:1V*	*m*	*H:1V*	*m*	*m*	*m*	*H:1V*
1	0+000	0+100	1	Meandering channel	100	1.00%	0.3	1	2	11	2.5	-	Right Side: 2.12 m -	5	3
2	0+100	0+700	2	Meandering channel	600	0.10%	1	1	2	11	2.5	-	Right Side: 2.57 m -	5	3
3	0+700	1+380	2	Meandering channel	680	0.10%	1	1	2	11	2.5	-	Right Side: 2.22 m -	5	3
4	1+380	1+820	1	Meandering channel	440	0.70%	0.4	1	2	11	2.5	-	- -	5	3
5	1+820	2+120	2	Meandering channel	300	0.30%	0.5	1	2	11	2.5	-	Right Side: 2.79 m -	5	3
6	2+120	2+740	2	Meandering channel	620	0.10%	1	1	2	11	2.5	-	Right Side: 2.90 m -	5	3
7	2+740	3+370	2	Meandering channel	630	0.10%	1	1	2	11	2.5	-	Right Side: 3.23 m -	5	3
8	3+370	5+250	3	Meandering channel	1880	0.05%	1	1	2	11	2.5	-	Right Side: 3.45 m -	5	3
9	5+250	6+170	4	Weir	920	0.10%	2.5	5	1	17.5	1	5	- -	-	-
10	6+170	6+670	5	Weir	500	0.05%	2	0.5	2	4	2.5	-	Right Side: 3.49 m Left Side: 3.49 m	10	3
11	6+670	7+600	4	Weir	930	0.10%	2.5	5	1	17.5	1	5	- -	-	-
12	7+600	7+990	6	Weir	390	0.10%	2.5	5	1	17.5	2.5	5	- -	-	-
13	7+990	8+510	7	Rock Ramp	520	1.70% (d)	8	3	2	25	2.5	5	Right Side: 2.46 m Left Side: 2.67 m	5	3
14	8+510	8+870	8	Weir	360	0.10%	2	0.5	2	4	2.5	-	- -	-	-
15	8+870	9+300	9	Rock Ramp	430	1.70% (d)	8	0.5	2	10	2.5	-	Right Side: 2.08 m -	5	3
16	9+300	9+654	10	Backwatered from Lac A	354	0.10%	2	1	2	6	3	-	- -	-	-

Notes:

(a) Typical cross-sections describe the channel geometry designed for flood flow conveyance, including widths, depths, and side slopes,

(b) Fish passage details describe the additional features not shown in the typical cross-sections which are provided for fish passage and conveyance. These details are fully described in Section 5.0.

(c) Embankments are for freeboard above existing ground (typically through construction of access roads parallel to the channel, and for flow containment in sections where the channel is constructed in fill.

(d) The 1.70% slope represents an average slope through the segment, for hydraulic modelling of flood flows. The compound slope in these segments, which incorporates additional details for fish passage, is represented by the detailed schematic of the rock ramps shown in Drawing C212 and in Section 5.2.3. Actual hydraulic parameters on the rock ramps will be different than those shown here.

Table 10: DC1 HES-RAS Results and Erosion Protection

Segment					Erosion Protection				Channel Hydraulics			
Segment Number	Station		Length	Slope	Total Thickness	Erosion Protection Size (D50) (b)	Filter Layers	Erosion Protection Height above Invert	Return Period	Design Discharge	Maximum Water Depth above Invert	Average Velocity
	From	*To*	*m*	*%*	*m*	*mm*	*Filter 1 / Filter 2*	*m*	*Years*	*m3/s*	*m*	*m/s*
1	0+000	0+100	100	1.00%	1.20	300	Cobble Gravel	2.12	2	2.73	0.96	0.87
									10	7.93	1.28	0.82
									100	17.44	1.82	0.71
2	0+100	0+700	600	0.10%	0.60	100	Gravel -	2.61	2	2.73	1.27	0.46
									10	7.93	1.75	0.63
									100	17.44	2.31	0.81
3	0+700	1+380	680	0.10%	0.60	100	Gravel -	2.51	2	2.73	1.25	0.49
									10	7.93	1.70	0.73
									100	17.44	2.21	0.97
4	1+380	1+820	440	0.70%	1.20	300	Cobble Gravel	2.20	2	2.73	1.10	0.85
									10	7.93	1.44	1.15
									100	17.44	1.90	1.48
5	1+820	2+120	300	0.30%	0.60	100	Gravel -	2.77	2	2.73	1.22	0.60
									10	7.93	1.78	0.78
									100	17.44	2.47	0.89
6	2+120	2+740	620	0.10%	0.60	100	Gravel -	2.91	2	3.14	1.27	0.51
									10	10.51	1.86	0.74
									100	25.07	2.61	0.92
7	2+740	3+370	630	0.10%	0.60	100	Gravel -	3.24	2	3.14	1.35	0.48
									10	10.51	2.02	0.65
									100	25.07	2.94	0.73
8	3+370	5+250	1880	0.05%	0.30	50	- -	3.53	2	2.98	1.38	0.44
									10	10.19	2.06	0.58
									100	25.64	3.23	0.68
9	5+250	6+170	920	0.10%	0.30	50	- -	3.43	2	2.98	1.08	0.80
									10	10.19	2.00	1.15
									100	25.64	3.13	1.49

Table 10: DC1 HES-RAS Results and Erosion Protection

Segment					Erosion Protection				Channel Hydraulics			
Segment Number	Station		Length	Slope	Total Thickness	Erosion Protection Size (D50) (b)	Filter Layers	Erosion Protection Height above Invert	Return Period	Design Discharge	Maximum Water Depth above Invert	Average Velocity
10	6+170	6+670	500	0.05%	0.30	50	- -	4.27	2	2.98	1.95	0.62
									10	10.19	2.85	0.72
									100	25.64	3.97	0.80
11	6+670	7+600	930	0.10%	0.30	50	- -	3.40	2	2.98	1.04	0.82
									10	10.19	1.99	1.17
									100	25.64	3.10	1.54
12	7+600	7+990	390	0.10%	0.30	50	- -	3.10	2	3.01	1.00	0.95
									10	10.24	1.83	1.47
									100	25.68	2.80	2.02
13	7+990	8+510	520	1.70% (a)	1.60	50	Cobble Gravel	2.66	2	3.01	0.93	0.50
									10	10.24	1.62	0.81
									100	25.68	2.36	1.14
14	8+510	8+870	360	0.10%	0.60	100	Gravel -	2.56	2	3.06	0.95	0.94
									10	10.42	1.58	1.32
									100	26.21	2.26	1.72
15	8+870	9+300	430	1.70% (a)	1.60	50	Cobble Gravel	2.08	2	3.06	0.70	0.62
									10	10.42	1.21	0.98
									100	26.21	1.78	1.29
16	9+300	9+654	354	0.10%	0.60	100	Gravel -	2.80	2	3.06	1.31	0.51
									10	10.42	1.81	0.81
									100	26.21	2.50	1.06

Notes

(a) The 1.70% slope represents an average slope through the segment, for hydraulic modelling of flood flows. The compound slope in these segments, which incorporates additional details for fish passage, is represented by the detailed schematic of the rock ramps shown in Drawing C212 and in Section 5.2.3. Actual hydraulic parameters on the rock ramps will be different than those shown here.

(b) After the installation of the riprap layer, the channel surface can be smoothed out with a small quantity of gravel that is more favorable for fish passage and aquatic life. Additional specific measures to accommodate fish passage and aquatic life are included in Section 5.0

4.3 Erosion Protection Design

As described in the design criteria, the channel was designed to be non-erodible up to the 100-year flood event. Using the flow velocities and water depths determined from the hydraulic model, riprap nominal diameter (D_{50}) was calculated using the following two methods:

1. U.S. Army Corps of Engineers Riprap Design (USACE 1994)
2. Simon's Method (Simon 1977)

The maximum calculated riprap D_{50} for each channel segment was rounded up to 50 mm, 100 mm, 300 mm or 500 mm. In segments where riprap was not required, the channel was lined with a layer of cobble followed by a layer of gravel. In segments where riprap was required, filter layers of cobble and gravel are also included. Table 12 below outlines the riprap and filter layer requirements for each segment of the channel.

Table 12: Riprap and Filter Layer Design

Segment	USACE (D_{50}) (mm)	Simons (D_{50}) (mm)	Layer 1 (Riprap) [(b)]		Layer 2 (Cobble)		Layer 3 (Gravel)	
			Size (D_{50}) (mm)	Thickness (mm)	Size (D_{50}) (mm)	Thickness (mm)	Size (D_{50}) (mm)	Thickness (mm)
1	128	227	300	600	100	300	50	300
2	24	28			100	300	50	300
3	24	28			100	300	50	300
4	92	168	300	600	100	300	50	300
5	77	79			100	300	50	300
6	39	32			100	300	50	300
7	35	32			100	300	50	300
8	24	19			50	300	50	300
9	25	26			50	300	50	300
10	40	24			50	300	50	300
11	25	26			50	300	50	300
12	25	27			50	300	50	300
13 [(a)]	251	366	500	1000	100	300	50	300
14	69	42			100	300	50	300
15 [(a)]	300	359	500	1000	100	300	50	300
16	45	44			100	300	50	300

Notes:

(b) Erosion protection on these segments are based on a 1.70% slope, which represents an average slope through the segment, for hydraulic modelling of flood flows. The compound slope in these segments, which incorporates additional details for fish passage, is represented by the detailed schematic of the rock ramps shown in Drawing C212 and in Section 5.2.3. Actual hydraulic parameters and erosion protection requirements on the rock ramps may vary from those shown here.

(b) After the installation of the riprap layer, the channel surface can be smoothed out with a small quantity of gravel that is more favorable for fish passage and aquatic life. Additional specific measures to accommodate fish passage and aquatic life are included in Section 5.0.

5.0 FISH PASSAGE AND FISH HABITAT

As described in the design criteria in Section 1.3, the proposed DC1 diversion channel will replace Bibou Creek diverting flow from the Bibou Creek watershed around the Troilus Project area. The diversion channel is required to provide fish passage between Lac Amont and Lac A. Following the initial hydraulic design to size the channel for flood flow conveyance and erosion protection, additional details were incorporated into the channel to provide fish passage through the channel.

This section describes the approach followed to accommodate fish passage requirements. It summarises the fish passage design considerations as well as the modelling results for the 7Q10 high flow, the 14Q2 low flow, and the average annual flow design events, which were selected as the design events to assess fish passage.

5.1 Description of Bibou Creek

The existing Bibou Creek connects Lac Amont with Lac A. A portion of the existing creek is a historical diversion channel, which routes flow around the TSF, 87 Pit and J Pit. Bibou Creek is 1 to 4 m wide and has a water depth ranging between 0.3 m and 1.2 m. A fish survey of Bibou Creek conducted in 2021 (Wachiih 2021) Creek found the following fish species in the creek and adjacent lakes:

- Mottled Sculpin
- Cisco
- Walleye
- Northern Pike
- Burbot
- Minnow
- Longnose Dace
- Brook Trout
- Lake Whitefish
- Toru Perch

Of the fish found in the existing Bibou Creek, the Burbot was identified as the fish with the lowest swimming capabilities, and Walleye was identified as the fish most likely to use the channel during spring freshet. As such, the diversion channel was designed to allow for fish passage of Walleye; consideration was given for the Burbot's lower swimming abilities.

5.2 Fish Passage Design Concepts

Additional design details are incorporated into each of the ten typical cross-sections to incorporate fish passage requirements. There are three fish passage design types which are applied to the typical cross-sections, as summarized in Table 11. These types are described in detail below.

- Type 1 – Meandering Channel – Applicable for typical cross-sections 1, 2 and 3 (Figure 5, Figure 6, Figure 7).
- Type 2 – Flat Segments with Small Weirs – Applicable for typical cross-sections 4, 5, 6 and 8 (Figure 8,Figure 9, Figure 10, Figure 12).
- Type 3 – Rock Ramps – Applicable for typical cross-sections 7 and 9 (Figure 11, Figure 13).

5.2.1 Design Type 1 - Meandering Channel

Design Type 1 (Meandering Channel) is incorporated into segments 1 through 8 of the diversion channel. This design concept consists of a sinuous main channel lined with wooden logs and boulders located within a wider flood flow channel. The sinuosity of the channel is maintained at 1.05 throughout all eight segments. The main channel varies in width and roughness. Boulders are placed in strategic locations to create areas of shelter for fish, as well as slow down the overall velocity within the channel. Wooden logs are placed approximately every 20 m; this increases overall water depth during periods of low flow.

The HEC-RAS model described in Section 4.0 incorporated the low flow channel sinuosity by increasing the roughness of the low flow channel in the model to 0.06. Separate calculations were conducted for the 7Q10 flow event to include sinuosity, and the results are outlined in Table 13 below. The HEC-RAS model outputs, as described in Section 4.2, were used for the annual average, 14Q2 and 100-year flow events. Figure 15 through Figure 18 show the typical plan, profile and section of this design type.

Table 13: Design Type 1 - Channel Parameters and Modelling Results

	Diversion Segment							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length (m)	600	680	600	680	300	620	630	1880
Slope %	1.0	0.1	0.1	0.7	0.3	0.1	0.1	0.05
Main Channel								
Main Channel Sinuosity	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Main Channel Width (m)	0.4	1.0	1.0	0.4	0.5	1.0	1.0	1.0
Main Channel Depth (m)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Main Channel Side Slopes (H:1V)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Channel Roughness, n	0.06	0.045	0.045	0.06	0.06	0.045	0.045	0.045
Flood Flow Channel								
Flood Flow Channel Width (m)	11	11	11	11	11	11	11	11
Flood Flow Channel Depth (m)	2.12	2.61	2.51	2.20	2.77	2.91	3.24	3.53
Flood Flow Channel Side Slopes (H:1V)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Channel Roughness, n	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Modelling Results								
7Q10 depth (m)	0.15	0.14	0.14	0.15	0.17	0.16	0.16	0.19
7Q10 velocity (m/s)	0.33	0.16	0.16	0.29	0.21	0.19	0.19	0.15
Annual Average Depth (m)	0.49	0.65	0.65	0.58	0.67	0.69	0.72	0.77
Annual Average Velocity (m/s)	0.77	0.37	0.37	0.62	0.46	0.43	0.40	0.37
14Q2 depth (m)	0.8	1.23	1.20	1.05	1.15	1.23	1.26	1.30
14Q2 Velocity (m/s)	0.86	0.45	0.48	0.84	0.60	0.49	0.46	0.43
100 Year Depth (m)	1.60	2.26	2.07	1.72	2.19	2.54	2.76	3.06
100 Year Velocity (m/s)	0.71	0.81	0.97	1.48	0.89	0.92	0.74	0.68

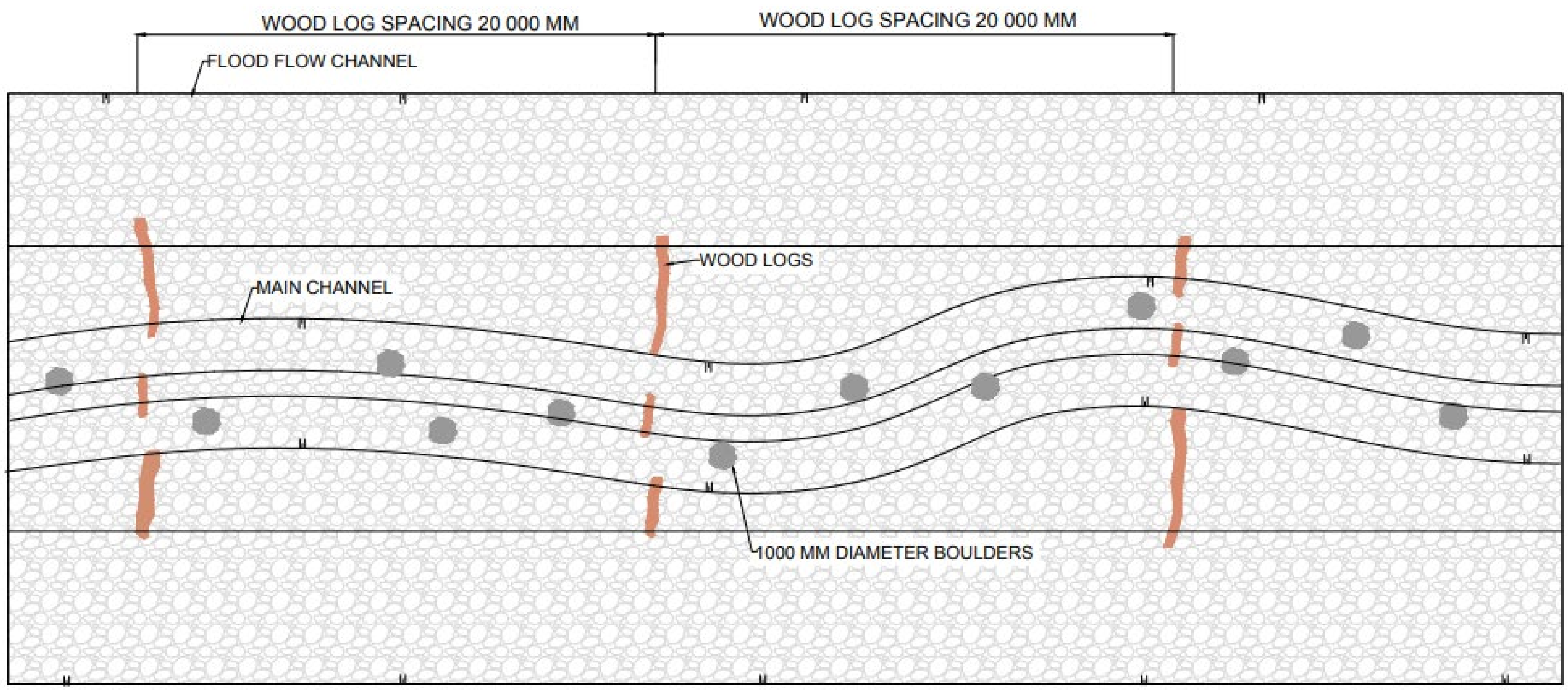


Figure 15: Design Type 1 – Plan View

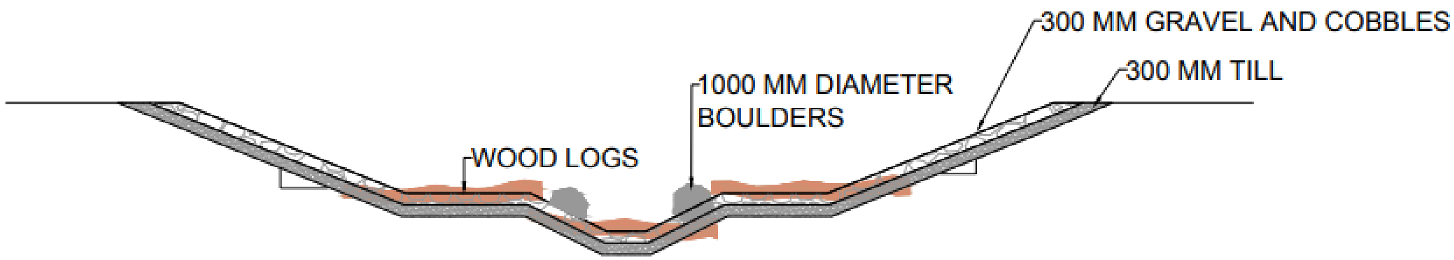


Figure 16: Design Type 1 - Cross Section

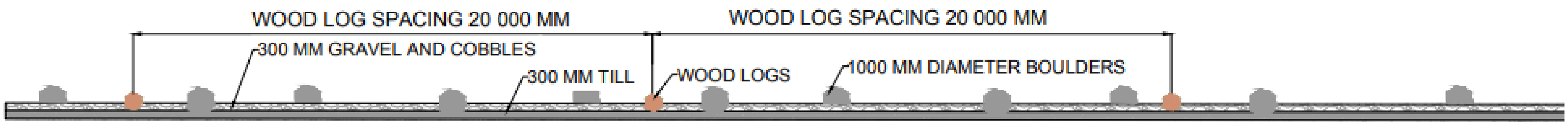


Figure 17: Design Type 1 - Main Channel Profile

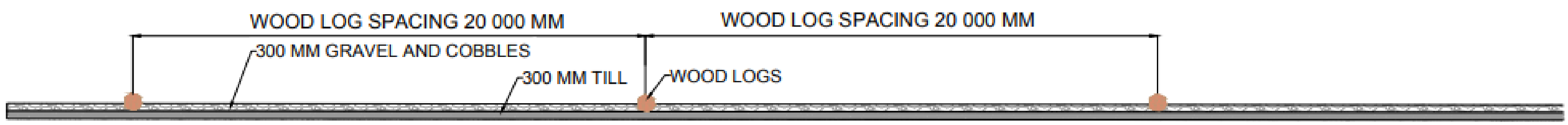


Figure 18: Design Type 1 - Flood Flow Channel Profile

5.2.2 Design Type 2 – Flat Segments with Small Weirs

Design Type 2 is incorporated into segments 9 through 12 and segments 14 and 16 of the diversion channel. The general concept of design type 2 is that it is implemented in the operational portion of the channel, where the slope of the channel is shallow. The channel is lined with gravel and cobble, and a check weir is placed every 100 m to create a backwater effect and increase the water depth during periods of low flow.

The check weir is composed of a 10% slope upstream of the crest, a 5 m long crest and a 1% slope downstream of the crest. The weir crests are made of riprap, where the voids are filled with smaller material, such as bedding gravel, to prevent flow through the weir. As mentioned previously, a HEC-RAS model was developed to determine the flow velocity and water depth for the various segments and design types. The modelling results of Design Type 2 and the channel characteristics are summarized in Table 14. Figure 19 through Figure 22 show the arrangement of this design type in plan view, profile view, and section view.

Table 14: Design Type 2 - Channel Characteristics and Modelling Results

	Segment					
	9	10	11	12	14	16
Length (m)	920	500	930	390	360	354
Slope %	0.1	0.05	0.1	0.1	0.1	0.1
Manning n	0.03	0.03	0.03	0.03	0.03	0.03
Main Channel						
Main Channel Width (m)	2.5	2	2.5	2.5	2	2
Main Channel Depth (m)	3.43	4.27	3.40	3.10	2.56	2.80
Main Channel Side Slopes (H:1V)	1	1	1	1	3	2.5
Modelling Results						
7Q10 depth (m)	0.19	0.20	0.19	0.19	0.19	0.14
7Q10 Velocity (m/s)	0.09	0.11	0.09	0.09	0.09	0.14
Average Annual Depth (m)	0.50	0.56	0.50	0.50	0.42	0.79
Average Annual Velocity (m/s)	0.48	0.44	0.48	0.48	0.61	0.26
14Q2 Depth (m)	0.91	1.09	0.91	0.91	0.82	1.21
14Q2 Velocity (m/s)	0.90	0.60	0.90	0.90	0.92	0.49
100 Year Depth (m)	2.63	3.22	2.63	2.63	2.1	2.35
100 Year Velocity (m/s)	1.92	0.78	1.92	1.92	1.72	1.06

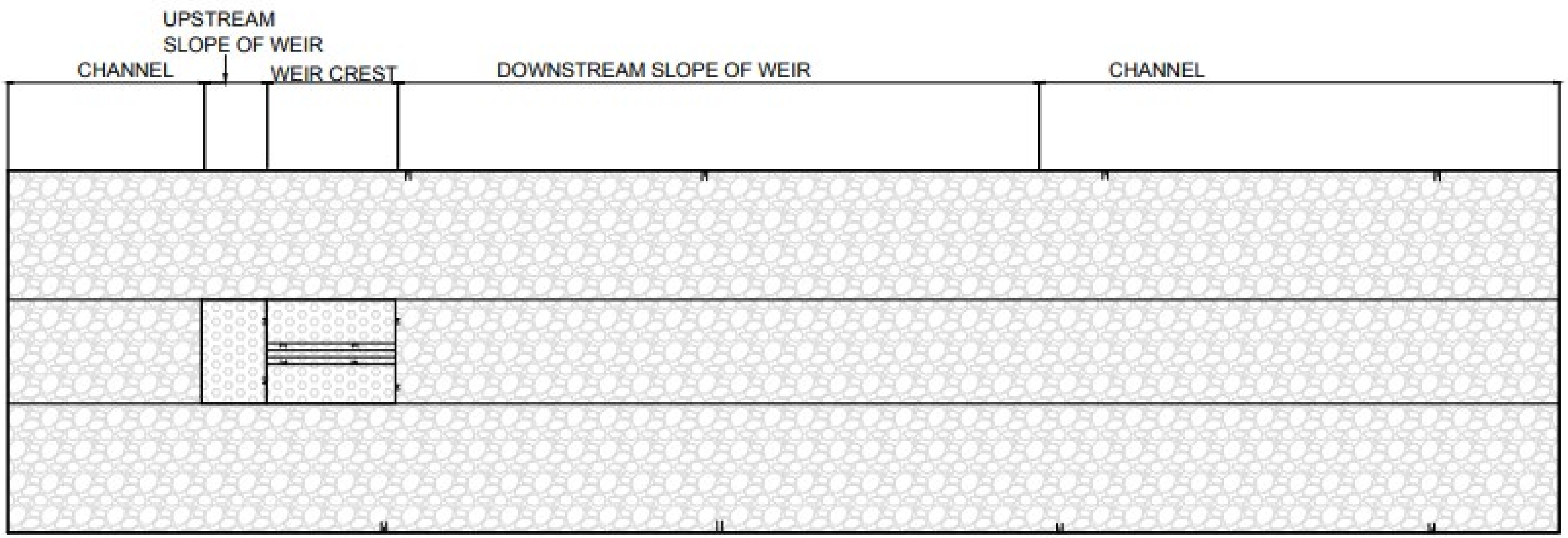


Figure 19: Design Type 2 - Plan View

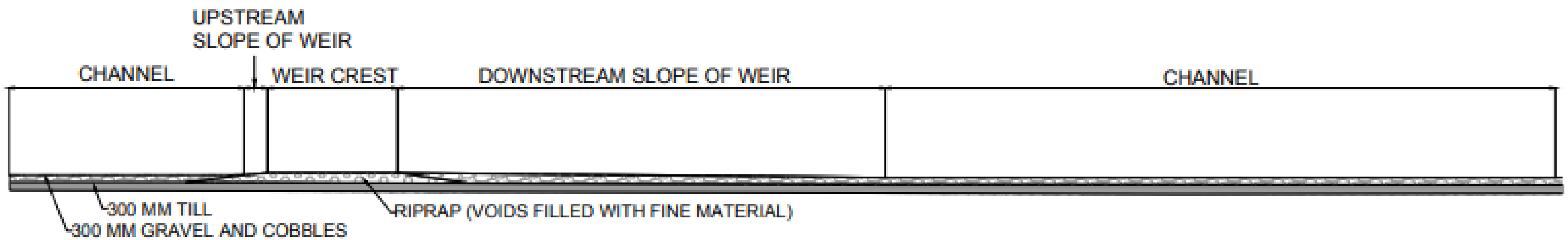


Figure 20: Design Type 2 - Profile

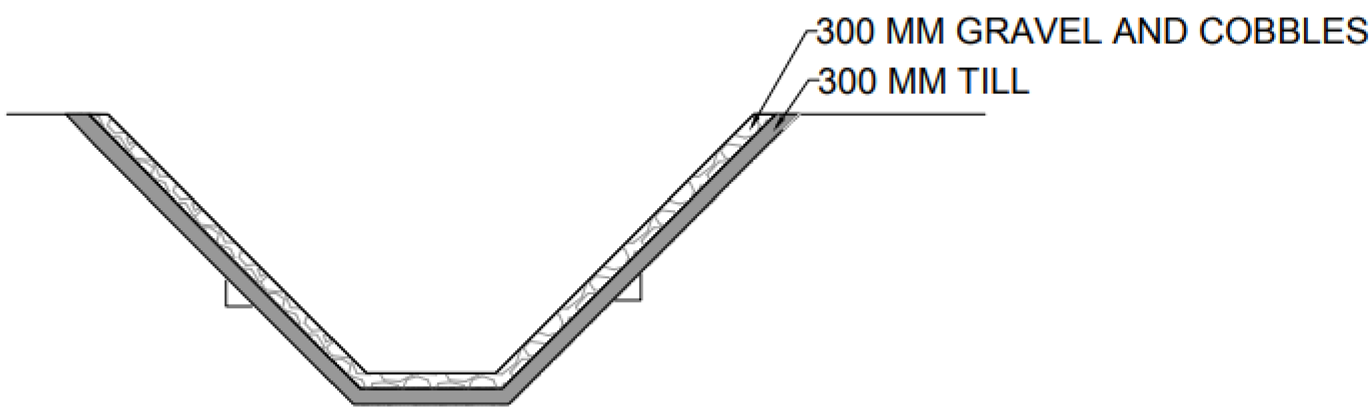


Figure 21: Design Type 2 - Channel Cross Section

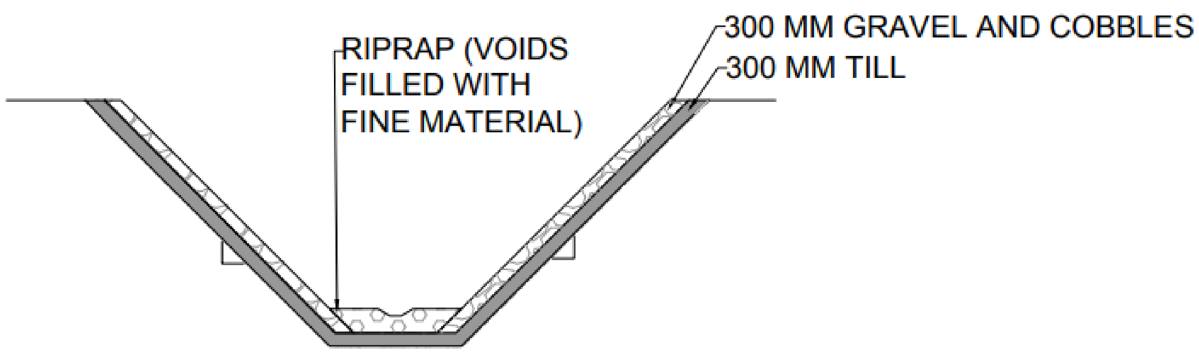


Figure 22: Design Type 2 - Check Weir Crest Cross Section

5.2.3 Design Type 3 – Steep Channel with Rock Ramps

Design Type 3 is incorporated into the steep operational channel segments 13 and 15. It is composed of a series of rock ramps with a 3.5 % slope and flat pools which result in an average slope of 1.7%. The length of the rock ramp section is 24 m, and the pool length is 11 m. Rock ramps are analogues of natural fishways which provide fish passage and aquatic habitat through the simulation of a natural stream environment. Rocks and boulders are placed in strategic locations to decrease velocity and increase flow depth. The placement of the rocks and boulders mimics a natural steep stream and allows fish to move from one pool to another.

A low flow channel is located within the main channel in the rock ramp sections. The low flow channel is narrow and shallow and is designed to contain the 7Q10 low flow. Flow higher than the 7Q10 would spill into the main channel. The low flow channel is lined with a geomembrane to reduce seepage losses into underling rock and sand, so that flow depth is maintained in the channel during low flow conditions. The low flow channel has a sinuosity of 1.05 to further decrease velocity and increase flow depth during low flow conditions.

The main channel is lined with gravel and cobbles, and boulders are placed in strategic locations to ensure enough areas of fish shelter are available in the rock ramp sections. The spacing of boulders was calculated using the methodology outlined in the Journal of Hydraulic Engineering (Baki, 2016). Using this methodology, the following spacing is required for the rock ramp sections:

- Longitudinal spacing of 3.0 m
- Transverse spacing of 2.5 m

This design type was modelled separately from the 1-D HEC-RAS model described in Section 4.2. The original HEC-RAS model did not include the riffle and pool sequencing an instead assumed a long steep segment. A separate 1-D HEC-RAS model was developed to model the riffle and pool sequencing. The 1-D HEC-RAS model was used to inform on the 14Q2, average annual, and 100-year flood event. Further calculations were required for the 7Q10 flow event as the low flow channel was not included in the 1D HEC-RAS model. The low flow channel and 7Q10 event was modelled separately using Manning's equation. The results of these 1-D model and 7Q10 low flow calculations along with channel parameters can be found below in Table 15. Figure 24 through Figure 28 below show the arrangement of this design type.

Table 15: Design Type 3 - Channel Characteristics and Modelling Outputs

	Segment	
	13	15
Length (m)	520	430
Compound Slope %	1.7	1.7
Rock Ramp Slope %	3.5	3.5
Manning n	0.05	0.05
Low Flow Channel		
Low Flow Channel Sinuosity	1.05	1.05
Low Flow Channel Width (m)	0.3	0.3
Low Flow Channel Depth (m)	0.2	0.2

Table 15: Design Type 3 - Channel Characteristics and Modelling Outputs

	Segment	
	13	15
Low Flow Channel Side Slopes (H:1V)	0.5	0.5
Main Channel		
Main Channel Width (m)	6	6
Main Channel Depth (m)	2.66	2.08
Main Channel Side Slopes (H:1V)	3	3
Modelling Results on Rock Ramp Sections		
7Q10 Depth (m)	0.15	0.15
7Q10 Velocity (m/s)	0.64	0.64
Annual Average Depth (m)	0.29	0.29
Annual Average Velocity (m/s)	0.30	0.30
14Q2 Depth (m)	0.64	0.64
14Q2 Velocity (m/s)	0.77	0.77
100 Year Depth (m)	1.70	1.70
100 Year Velocity (m/s)	2.39	2.39

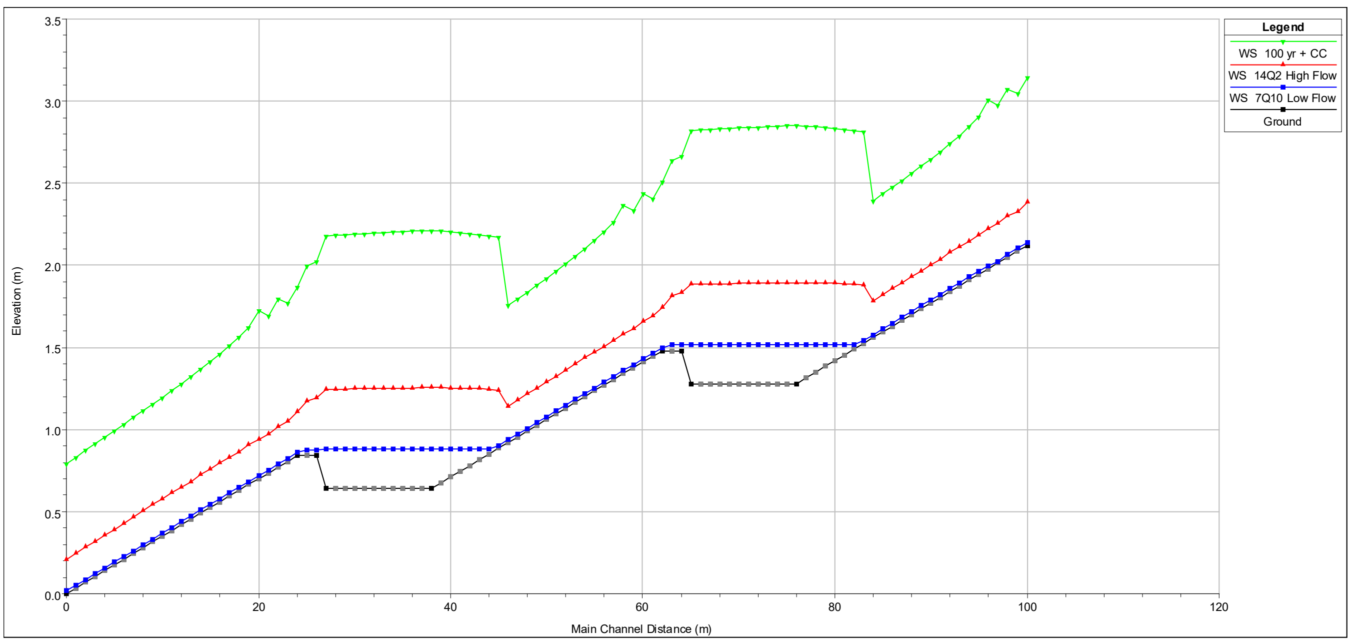


Figure 23: Riffle and Pool 1D HEC-RAS Model Water Surface Profiles

Riprap Sizing

In Section 4.3, the required riprap sizing was calculated for the whole stream diversion. Design Type 3 – Steep Channel and Rock Ramps was not fully incorporated into the hydraulic model. The required riprap calculated for segments 13 and 15 in Section 4.3 and shown in Table 12 was based on an average slope of 1.7%, as an approximation of conditions during high flow events. instead of the rock ramp and pool sequence. Based on that calculation, a D50 of 500 mm is required for high flows.

Upon further design of these segments, additional calculations were conducted to determine the required riprap in the Design Type 3 segments. Based on the expected energy at the bottom of the rock ramp sections, erosion protection is required along the steep segments of this design type to increase the roughness of the channel as well as provide the necessary energy dissipation. Using the USACE method for calculating riprap, a D50 of 350 mm is required along these rock ramp sections and should extend 5 m upstream and downstream into the pools. The individual boulders that provide the macro-roughness to the rock ramps would have a typical diameter of approximately 1,000 mm.

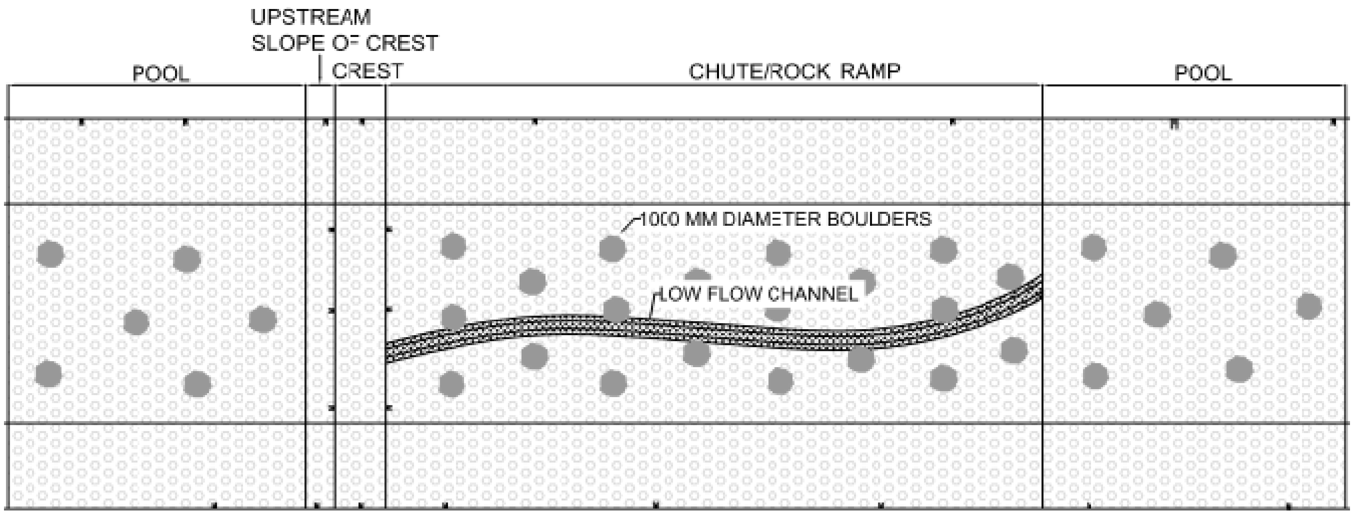


Figure 24: Deign Type 3 - Plan View

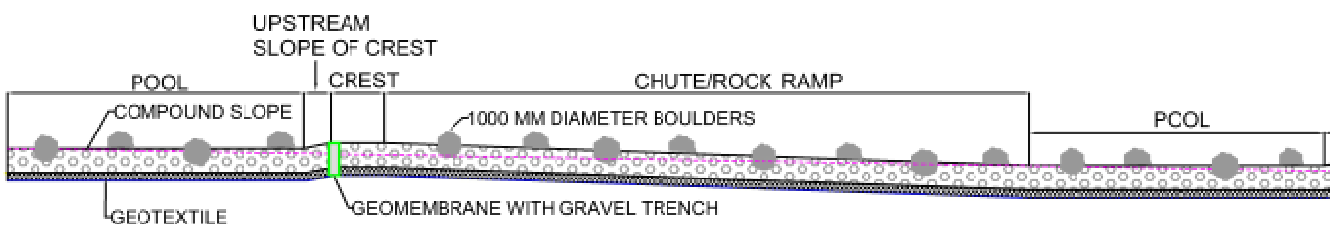


Figure 25: Design Type 3 - Profile of Main Channel

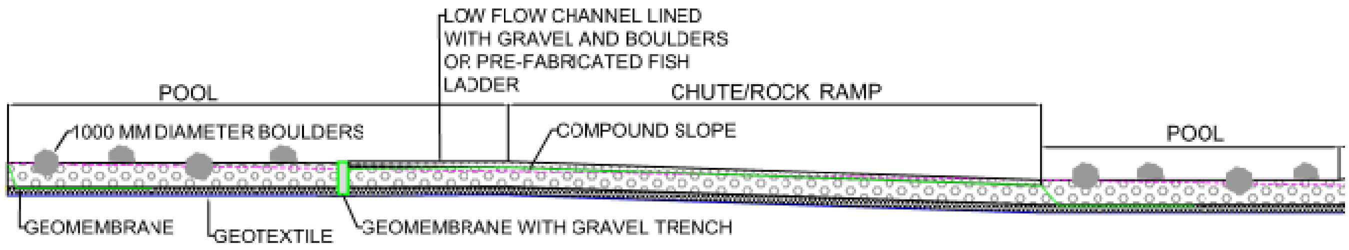


Figure 26: Design Type 3 - Profile of Low Flow Channel

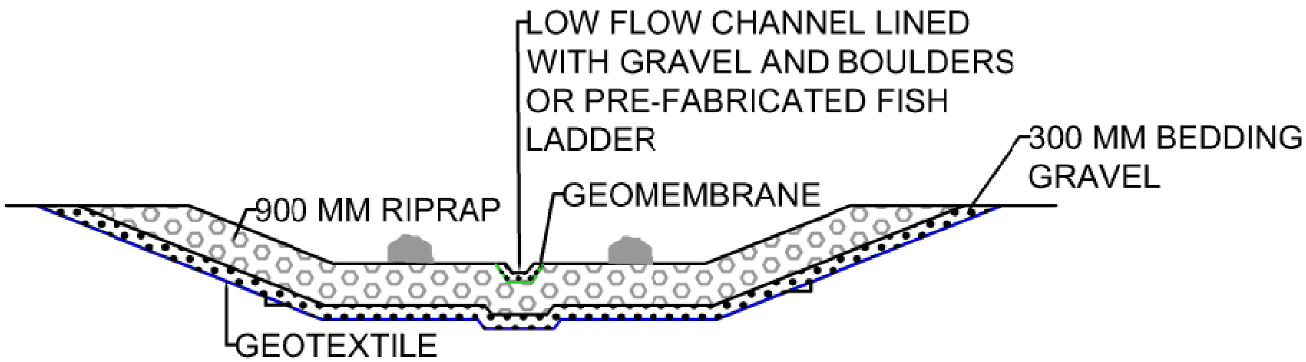


Figure 27: Design Type 3 - Cross Section of Rock Ramp

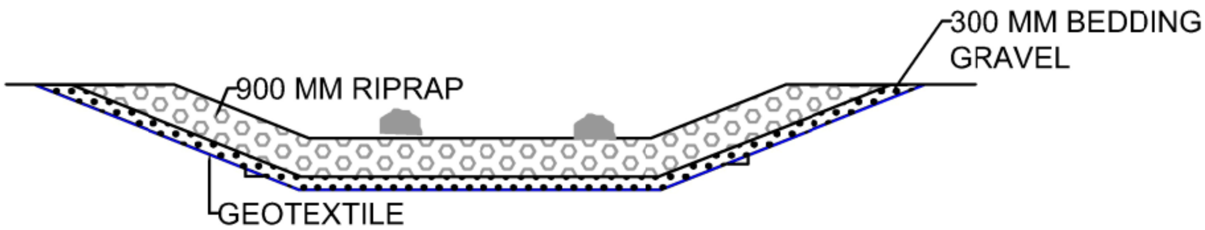


Figure 28: Design Type 3 - Cross Section of Pool

6.0 FLOOD PROTECTION BERM

The southwest Flood Protection Berm, which diverts runoff from the Bibou Creek floodplain into the DC1 Diversion Channel, is approximately 400 m long and has a maximum height above ground elevation of 2.4 m at the existing Bibou Creek thalweg. The proposed berm cross-sections are shown in the FS design drawings in Appendix J.

The conceptual design for the Flood Protection Berm is based on surficial terrain mapping and limited test pit data (Table 16). Additional data within and adjacent to the proposed footprint should be collected, and the design should be updated as required.

Table 16: Geotechnical Data for the Flood Protection Berm

Borehole	Location on Berm Alignment	Peat Thickness	Underlying Material
TM-23-14	Near Bibou Creek Thalweg near Sta 0+300 on the berm	1.4	Sand, fine to medium, wet. Augered to 2.6 m
MW-23-24	150m south of the south end of the berm	0.61	Sande, fine to coarse, to 6.73 m depth at bedrock.

The berm crest has an elevation of 382.3 masl. The lowest point along the berm's toe is at 379.9 masl, within the existing Bibou Creek channel. The freeboard accommodates the 100-year flood, which would lead to a 2.06 m maximum water depth relative to the invert of the DC1 diversion channel. The berm design includes over-excavation through approximately 1.4 m of peat to a fine to medium-grained sand layer and a 1.2 m deep cutoff key of compacted till, excavated into the underlying sand layer to intercept. The berm is built with a compacted till core with a top width of seven meters. Erosion protection is provided with a minimum of 0.6 m of waste rock over a filter layer of 0.3 m of sandy gravel.

The berm is covered with waste rock, including on the downstream 10H:1V face, to safely pass the overflow up to the Probable Maximum Flood (PMF). Overflow will be directed to the area within the southwest pit footprint and adjacent waste rock dumps.

The berm has a 10 m top width, 3H:1V side slope on the upstream side near the diversion, and 10H:1V side slopes on the downstream side. Flow in excess of the 100-year flood would overtop the berm. WSP verified that the overtopping depth would reach a maximum flow depth of approximately 0.25 m during the probable maximum flood (71.3 m^3/s). Velocities and depths were estimated using the DC1 HEC-RAS model with a levee to represent the berm. The required erosion protection riprap on the berm crest, upstream, and downstream faces is shown in Table 17. Riprap calculations were based on Simons (1977) for flow against the upstream face and USACE (1994) for flow over the crest and on the downstream face.

Table 17: Erosion Protection on the Flood Berm

Location	Slope	Minimum Rock Size (mm)	Minimum Rock Thickness (m)	Filter Layers
Upstream Face	3H:1V	108	1.0	0.3 m sandy gravel
Crest	0.3%	10	0.6	None
Downstream Face	1H:1V	175	1.0	0.3 m sandy gravel

7.0 WATERCOURSE INTERCEPTIONS AND TIE-INS (SMALL TRIBUTARIES)

The next engineering phase will need to include design details at locations where the diversion channel intercepts an existing watercourse. Table 18 below lists all the locations of small tributaries for which further consideration is required.

Table 18: Watercourse Interception Locations

Tie-In	DC1 Station
1	1+640
2	1+780
3	2+100
4	3+000
5	3+390
6	4+070
7	6+300
8	6+600

8.0 CIVIL DESIGN

Two surfaces were developed in Civil 3D, representing both the finished grade (top of erosion protection) and the excavation surface. Transitions between channel geometries were designed using approximated widths of the design water surface elevation for the 100-year return period upstream and downstream of the transition to change the width of water over a distance of five times the difference of the top widths (Smith 1995). A minimum transition distance of 20 m was deemed appropriate.

9.0 MAINTENANCE AND OPERATIONS

The upstream 5.3 km of the channel, which would remain in place at closure, was designed to require less maintenance and monitoring. However, regular inspections should be conducted to ensure lining materials have not been displaced after large flood events. The closure concept of the diversion channel is described in the main report.

The downstream 4.4 km of the channel, which would be decommissioned at closure, will require monitoring and maintenance after periods of high flow to replace boulders and rocks which may have been displaced. Weirs may require reshaping, and meandering portions of the low flow channels on the rock ramp sections should be regularly inspected to ensure ongoing fish passage connectivity through these sections of the channel.

The section of the channel built in fill between Sta 6+170 to 6+6670 should be monitored regularly for seepage from the channel, especially with respect to the integrity of the berm and low-permeability lining.

10.0 OPPORTUNITIES

- The suggested riffle and pool design type is expected to be labour-intensive to construct, as boulders must be placed at specified intervals. A potential opportunity to reduce this risk would be to implement pre-fabricated fish ladders in place of the low flow channel. Further engineering should be conducted to determine if this is a feasible option.
- At locations where the channel was excavated in bedrock, side slopes of 1H:1V were assumed. During detailed design, a side slope stability review should be conducted to assess if the bedrock side slopes can be reduced to 0.5H:1V or steeper. This could reduce the excavation volume and disturbance footprint, especially in Segment 9, Segment 11 and Segment 12, where the channel excavation is up to 17 m deep.
- In the first five kilometres of the channel, fish passage is provided for through a gently meandering low flow channel, logs, and boulders. Pools spaced along the channel will provide additional shelter and habitat and aid in channel naturalization.

11.0 RISKS

- Seepage out of the channel was not accounted for in sections where the channel is excavated in till. During detailed design, further hydrogeological assessment will be required to assess the seepage rate out of the channel and provide low-permeability layers where appropriate to ensure that the flow depth for fish passage is maintained during low-flow periods.
- Geotechnical assumptions in some locations were based on limited or unavailable data. Borehole data should be reviewed during detailed design, and additional data should be collected and integrated, where possible, to confirm or update assumptions. This may result in increased construction costs.
- The construction of the DC1 Main Diversion Channel is likely to be labour intensive and slower than expected, based on the bulk construction quantities alone. This is due to the detail nature of adding fish habitat features through-out the channel’s length. Also, the requirement that more than half of the channel’s length would remain in place at the site’s restauration adds stringency and a high level of required rigour to the construction. These elements could lead to a high cost of construction for the diversion channel.

12.0 REFERENCES

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