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Coats Marsh Weir Replacement Elevation Study Final Report

Prepared by:

Northwest Hydraulic Consultants Ltd.
405-495 Dunsmuir Street
Nanaimo, BC V9R 6B9
Tel: (250) 754-6425
www.nhcweb.com

NHC Project Contact:
Nathan Valsangkar, M.Sc., P.Eng.

Prepared for:

Regional District of Nanaimo
6300 Hammond Bay Road
Nanaimo BC V9T 6N2

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Report prepared by:

PROFESSIONAL
PROVINCE OF
N. A. VALSANGKAR
53447
BRITISH COLUMBIA
ENGINEER

2023-04-12

Nathan Valsangkar, M.Sc., P.Eng.
Hydrotechnical Engineer
Project Manager

Evan Arbuckle, EIT
Hydrotechnical Engineer

Report reviewed by:

Graham Hill, P.Eng.
Principal
Senior Review

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- Jordan Vander Klok Parks Planner, RDN
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- Nathan Valsangkar Project Manager, NHC
- Evan Arbuckle Hydrotechnical Engineer, NHC
- Graham Hill Principal, NHC

NHC partnered with EDI, who provided subconsultant environmental services:

- Randy Morris Environmental Planner/Biologist, EDI
- Rachelle Robitaille Biologist, EDI

EXECUTIVE SUMMARY

The Regional District of Nanaimo (RDN) retained Northwest Hydraulic Consultants Ltd. (NHC) in partnership with Environmental Dynamics Inc. (EDI) to prepare a study evaluating replacement options for the Coats Marsh weir, located on Gabriola Island, BC. This 90% report summarizes study findings and incorporates changes made after feedback with RDN following the 70% report. Feedback received from RDN on this 90% report will be reviewed before issuing a final report.

Coats Marsh is naturally occurring but has been modified over time by human activities. The marsh was historically drained for agriculture by ditching and blasting of the natural outlet, but the marsh was reflooded by construction of the existing concrete weir some time in the late 1960s to 1980s. The weir does not have a water licence but is currently regulated as a dam under the *Water Sustainability Act* and the BC Dam Safety Regulation (B.C. Reg. 40/2016).

The existing weir has several deficiencies relative to current dam safety standards, and beavers have constructed a beaver dam upstream of the weir. RDN has been using a siphoning system since 2021 to reduce water levels behind the beaver dam; however, the long-term goal for Coats Marsh is to phase out this siphoning system and restore the marsh to a state where water levels require little to no active management by RDN. Given the need to address the weir structure's deteriorating condition, the objective of this study was to determine the engineering and environmental implications of modifications considering the following five elevation scenarios:

1. A replacement dam at an elevation that precludes the need to build a new embankment structure along the west side of the weir pool (elevation 96.1 m)
2. A replacement dam at the same elevation as the existing weir overflow flashboard (elevation 96.4 m)
3. A replacement dam at an intermediate elevation between the existing weir overflow and the top of the site's beaver dam. This has been set as the top elevation of the existing weir concrete (elevation 97.0 m)
4. A replacement dam at the same elevation as the beaver dam (elevation 97.7 m)
5. Removal of the existing weir and decommissioning of the dam structure

NHC and EDI carried out desktop and field assessments to characterize the site; evaluated the hydrologic, regulatory, and environmental implications of the five scenarios; and prepared preliminary engineering designs and cost estimates for dam replacement. The following summarizes the study's key findings and recommendations.

Regulatory Context

- The existing weir and berm, and any future dam replacement, are regulated under the provincial *Water Sustainability Act* and the BC Dam Safety Regulation. The land is co-owned by The Nature Trust of BC and was received in part through the federal Ecological Gifts Program, administered by Environment and Climate Change Canada (ECCC). Other legislation applicable to the project includes the provincial Wildlife Act and the federal Fisheries, Migratory Birds, and Species at Risk acts. Future dam replacement or decommissioning will require permits and approvals, including provincial Dam Safety Regulation approvals; a wildlife permit and DFO Request for Review for beaver dam removal; amphibian and fish salvage permits; and review and approval by ECCC under the Ecological Gifts Program. Consultation with regulators may identify other project requirements beyond those listed.

Site Characterization

- There were several deficiencies identified with the existing weir and berm, including inadequate spillway width and freeboard; spillway obstructions; concrete cracking; abutment seepage; berm geometry issues (inadequate crest width and freeboard, and overly steep side slopes); poor berm foundation conditions, lack of fill compaction during the berm's construction, and evidence of seepage along the toe of the berm; and trees growing on the berm slopes.
- The beaver dam upstream of the weir appeared to be actively maintained by beavers, with no overflow channels or breaches identified. However, the beaver dam impounds water above the existing weir and berm. This arrangement is contrary to current dam safety practices for a regulated structure, **regardless of the real or presumed stability of the beaver dam**. NHC recommends beaver dam removal under all scenarios.
- The marsh is a complex of wetland classes currently dominated by shallow water (aquatic), where permanent inundation occurs. The shallow water area transitions into a marsh, where emergent vegetation and seasonal drying occurs. Beyond the marsh area a forested swamp is presented. The forested swamp has been classified as a Western Red Cedar – Indian Plum ecological community.
- The wildlife community within the marsh is predominantly birds and amphibians. It is notable that the northern red-legged frog is a federally listed species of concern and a provincially blue-listed species. To date, no fish have been detected within Coats Marsh, though this does not definitely confirm their absence. Both Cutthroat Trout and Rainbow Trout were observed at Hoggan Lake in 1972. Mammal presence around the marsh includes beavers and deer.

Consequence Classification Review

- NHC provided a dam consequence classification review in accordance with provincial guidelines, including an inventory of downstream assets and a qualitative assessment of potential consequences in the event of a dam breach. We recommend a preliminary classification of **High Consequence** for the existing weir due to potential for loss of life at a cabin located on private property at 1040 Coats Drive.
- A High Consequence dam has much greater safety requirements than a Significant dam, including a larger spillway, requirements for weekly site surveillance, and a legislated Dam Safety Review every ten years. The existing structure could be reduced to Significant with appropriate mitigation. The most technically straightforward approach is for RDN to form an agreement with the land owner to carry out one of the following actions: 1) removing or relocating the cabin to another area of the property, or 2) removing the unlicensed stacked rock weir adjacent to the cabin, thereby greatly increasing the channel capacity and reducing flood levels at the cabin. If neither of these options is tenable, alternative actions are presented in the main report for consideration by RDN. Future dam replacement options can likely be reduced to Significant if downstream rockfill is incorporated into the design.

Review of Dam Elevation Scenarios

- NHC and EDI assessed the hydrologic and environmental implications of the dam elevation scenarios, with key findings presented in this report. Note that all findings for a given scenario are relative to current conditions in the wetland with the beaver dam in place; these conditions have only existed at the site for approximately the last 15 years.
- Scenario 1 provides the lowest reservoir volume, surface area, and water depth of the dam replacement scenarios. This scenario would also experience the greatest relative loss of wetted area and depth during summer drawdown, particularly with future climate change, except for Scenario 5, which is a complete removal of the existing weir without replacement. Implementing Scenario 1 would reduce the average marsh elevation compared to present conditions, exposing lands along the edges of presently wetted areas and allowing them to revegetate with shrubs and trees. This would likely provide a substantial new forage source for beavers, potentially increasing long-term beaver management requirements at the new dam. Due to the shrinkage of the surface area and perimeter edges, marsh habitat and emergent vegetation would be reduced and yield less habitat area for amphibian and waterfowl species. However, the construction-related environmental effects of Scenario 1, such as site access clearing and ground disturbance within the marsh, are the lowest of the five scenarios. This is primarily because berm removal and reconstruction, as required for Scenarios 1 through 4, have a large footprint but are not required for Scenario 1.
- Scenario 2 will decrease the area of shallow water and will increase the marsh ecological community area, potentially re-introducing more swamp ecological community area. Similar to Scenario 1, this lower-depth scenario is anticipated to have reduced habitat value for amphibians compared to current conditions due to a reduction in marsh fringe breeding habitat and increased water temperatures. This scenario also has a high possibility of creating a “drier” edge area, thereby allowing the potential re-establishment of shrubs and trees along the periphery of Coats Marsh.
- Scenario 3 would reduce water levels upstream of the existing beaver dam, but shallow open water habitat would remain. With slightly less water depth than Scenario 4, this scenario would yield a similar or larger amount of marsh-like habitat due to shallow transitional conditions along the edges. Scenario 3 should not create any significant changes affecting wildlife habitat, such as amphibians. Foraging and nesting habitat for birds may improve due to greater encroachment of woody vegetation along the wetland edge.
- Scenario 4 provides the greatest reservoir volume, surface area, and water depth of the dam replacement scenarios, and would likely be the most resilient to climate change. This scenario would raise water levels at the dam structure higher than they have ever been since anthropogenic interventions have been implemented. This scenario is identified as the most beneficial overall for maintaining the present species diversity, particularly for waterfowl and amphibians. However, Scenario 4 would have the greatest construction-related impacts for site access and berm removal/reconstruction within the marsh.
- Scenario 5, decommissioning of the existing weir and removing the beaver dam, would result in near complete drainage of Coats Marsh. Ephemeral streams would continue to flow toward the historical drainage ditch that runs linearly to the outlet. Dry season wetted area would be minimal, and there would be a significant reduction in amphibian habitat compared to present

conditions. If regulators allow the beaver dam to remain, the general condition of the marsh will be similar to current conditions, though with limited to no wetted area in the "weir pool" between the beaver dam and the present weir location. Marsh conditions would evolve over time in response to beaver activity and associated water levels.

Conceptual Engineering Design

- NHC prepared conceptual engineering designs for replacement dams for Scenarios 1 through 4. All scenarios include similar design components, with the main difference being the final elevation and extents of the new embankments and spillway structure. This list summarizes the recommended design components; constructability considerations are described in the main body of the report.
  - Removal of the beaver dam.
  - Structural upgrades to the existing weir, involving constructing a new concrete overflow spillway on the downstream side of the existing weir. Rock excavation (i.e., blasting or hammer breaking) will be required to accommodate the spillway, which is 4 m to 6 m wide depending on the final consequence classification for the dam.
  - Construction of a low-level outlet pipe through the concrete structure, including installation of an upstream control gate.
  - Installation of a debris boom, new pedestrian footbridge, a staff gauge, and dam safety signage at the concrete structure.
  - Scenarios 2, 3, and 4 would require removal of the existing berm and construction of a new zoned dam embankment. The maximum bottom width of the new embankment was estimated as approximately 15 m, 18 m, and 22 m, for Scenarios 2 to 4, respectively. For these scenarios, it is unlikely that DSO would allow raising the existing berm due to the lack of foundation preparation and fill compaction during its original construction. For Scenario 1, berm reconstruction is not required.
- For Scenario 5, we anticipate the following design components will be required for decommissioning:
  - Removal of the beaver dam.
  - Removal of the concrete weir structure, and potentially removal of the existing berm.
  - Restoration of the former drainage channel/stream within the marsh to a natural state.
  - Erosion control measures to limit the amount of exposed marsh sediment that mobilizes downstream. Restoration planting in disturbed areas.
  - Consultation with provincial regulators regarding potential habitat compensation for lost wetland area.
  - Further study of potentially affected fish populations downstream of the existing weir to determine whether decommissioning would cause adverse effects.
  - Performance monitoring and adaptive management following decommissioning, typically for a period of 1 to 3 years following construction.

- The above decommissioning components were developed based on provincial guidelines and NHC's experience with previous decommissioning projects. However, recent discussions with the regulator indicate that it may be permissible to decommission the weir structure while leaving the beaver dam in place (D. Johnson, pers. comm.) The advantages of this approach are that the environmental values of the marsh would be largely retained, and that costs associated with restoring/stabilizing the exposed stream channel and marsh bottom would be greatly reduced. However, we note the following disadvantages of this approach for RDN's consideration:
    - NHC is not prepared to certify, warranty, or otherwise "sign off" on the stability of a beaver dam. We note that by removing the weir, the stability of the beaver dam is likely to decrease. This is because the ponded depth in the weir pool would be eliminated, roughly doubling the total water level differential supported by the beaver dam. The beaver dam's stability may decrease over time if forage material around the marsh continues to decrease and the beavers become less active.
    - The regulator would likely require that the residual hazards/risks associated with the beaver dam be documented in the decommissioning plan. Under the *Water Sustainability Act*, RDN would retain the liability associated with keeping the beaver dam in place. If there are residual life safety risks, it is likely that mitigation would be included in the decommissioning plan.
- Class 4 (preliminary) cost estimates were prepared for the five scenarios, including construction and professional services. A contingency allowance of 20% has been included in the cost estimates; however, actual costs may vary from those estimated by -30% to +50% based on the current level of design definition. RDN should consider carrying additional contingency within their implementation budget if it is tied to upcoming capital plans. The cost estimates, including 20% contingency, are:
    - Scenario 1: $390,000
    - Scenario 2: $590,000
    - Scenario 3: $740,000
    - Scenario 4: $1,080,000
    - Scenario 5: $410,000 (including beaver dam removal and upstream restoration/stabilization)

Recommendations for Short-Term Actions

- RDN should inform the DSO that the proposed classification for the existing dam is High Consequence.
- RDN should initiate discussions with the land owner at 1040 Coats Drive regarding options for reducing flood hazards to the existing downstream cabin.
- A provincial water licence application is required to authorize surface water storage. We understand that RDN submitted a water license application on November 24, 2022 (J. Vander Klok, pers. comm.).
- RDN must meet requirements under Part 2 and Part 3 of the Dam Safety Regulation. A High consequence dam requires weekly site surveillance. All Significant and High consequence dams

require an operations, surveillance, and maintenance manual and a dam emergency plan RDN could prepare the plans using templates available from the province or opt to have them prepared by a qualified engineer.

- RDN should remove trees from the existing berm by cutting as close to the ground as possible. Root wads should be left in place.
- Depending on their risk tolerance, RDN could consider removing the beaver dam this summer (2023) if beaver dam removal is a component of their preferred dam elevation scenario. Apart from environmental considerations, the main drawback to removing the beaver dam is that it couldn't be used as part of a cofferdam/site isolation system during construction of a future weir replacement or decommissioning.
- RDN could consider installing a temporary log boom upstream of the weir to mitigate spillway blockage in the event of beaver dam failure or other debris entrainment.

Recommendations for Detailed Design and Future Implementation

- An options assessment matrix is presented in this report to comprehensively explore the trade-offs involved in selecting a replacement dam elevation. In general, a lower dam would be the least expensive option and have the lowest construction footprint and disruption, but a higher dam may be able to retain more of the characteristics of the present ecosystem and provide greater storage to mitigate against potentially higher summer evaporation losses due to climate change. Dam decommissioning and beaver dam removal (Scenario 5) would relieve RDN of its monitoring and maintenance requirements under the Dam Safety Regulation, as well as its liability in the event of a dam failure; however, this option would result in the greatest adverse environmental effects for the marsh by substantially draining wetted areas. It is possible that the dam could be decommissioned without removing the beaver dam, but this will require further planning, consultation with the regulator, and the RDN's acceptance of increased risk. Following RDN's selection of a preferred scenario, detailed design will be required to advance to conceptual design to construction.
- For all scenarios, future implementation will involve a series of supplemental investigations, detailed design, and permitting prior to construction. For permitting, all scenarios will require preparation of a construction environmental management plan, DSO authorization, review by from Fisheries and Oceans Canada, provincial wildlife permits, and engagement with the province to determine any specific requirements for blue- and SARA-listed species. For detailed design, all scenarios will require design drawings and plan submissions in accordance with DSO requirements. The following scenario-specific investigations and plans will be required:
    - For Scenarios 1 through 4:
        - Preparation of Issued for Tender design drawings, a Dam Development Report, draft OMS and DEP documents, and engineering field review plans in accordance with provincial requirements.
        - Geotechnical drilling or test pit investigation will be required to confirm subgrade conditions. Additional survey may be warranted to map bedrock elevations.
    - For Scenario 5:

- Public engagement, referrals with other government agencies, and First Nations consultation. The DSO leads both First Nations consultation and government agency referrals, but public engagement is the responsibility of the dam owner. The scope of public engagement can vary, but typically involves public notices (e.g., mail-outs, signage, newspaper), a community meeting or individual meetings with stakeholders, and a formal comment period with associated documentation.
- An overview-level social impact assessment may be required, including aesthetic concerns; potential for archeological sites; recreational objectives; First Nations considerations; and any other known community values.
- Preparation of a performance monitoring and adaptive management plan, typically for 1 to 3 years following decommissioning.
- If decommissioning includes beaver dam removal:
  - Detailed bathymetric survey of the marsh to confirm ground elevations and the dimensions of the existing drainage ditch/stream.
  - Sediment sampling around the pond may be required to support site revegetation and sediment control plans. Hydrologic and geomorphic assessment to determine the effects of decommissioning on flood flow attenuation and downstream channel stability may be required.
  - Additional environmental assessments (desktop-based and field-based). The scope of environmental assessment will depend in large part on engagement with regulators, particularly around the blue- and SARA-listed red legged frogs.
- If decommissioning includes leaving the beaver dam in place:
  - An analysis of residual hazards and potential consequences, and the development of mitigation recommendations.

- The seasonal timing of construction should be considered. From a flood risk perspective, it is preferable to complete the work during the summer low-flow period. However, fire restrictions on Gabriola can be significant during dry conditions and authorities may not allow construction work to proceed during the summer (J. Vander Klok, pers. comm.). We recommend that RDN initiate early discussions with the fire department to evaluate any seasonal constraints. Any planned work activities should also avoid the breeding periods for birds and amphibians and be carried out during the least-risk window for cutthroat trout. Considering environmental constraints, the overall least-risk construction period is late-August to October 31. Note that the October 31 limit is driven by the least-risk timing window for cutthroat trout. This requirement could be removed if downstream sampling is conducted and confirms that there are no trout present in the stream or Hoggan Lake. Construction could also start earlier in the summer if the contractor uses cofferdams or other approaches to maintain the upstream marsh level during the last few months of the amphibian breeding period.

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ABBREVIATIONS

Acronym / Abbreviation	Definition
CDA	Canadian Dam Association
DEP	Dam Emergency Plan
DSO	Dam Safety Office of BC
EDI	Environmental Dynamics Inc.
EGBC	Engineers and Geoscientists BC
HDPE	High density polyethylene
IDF	Inflow Design Flood
IDF Curve	Intensity-Duration-Frequency Curve
LLO	Low-level outlet
MOTI	BC Ministry of Transportation and Infrastructure
NHC	Northwest Hydraulic Consultants Ltd.
OMS	Operations, Maintenance, and Surveillance
RDN	Regional District of Nanaimo
TNT	The Nature Trust of BC
WSA	Water Sustainability Act

SYMBOLS AND UNITS OF MEASURE

Symbol / Unit of Measure	Definition
m^3/s	Cubic metres per second
ha	Hectares
kW	Kilowatts

1 INTRODUCTION

1.1 Foreword

The Regional District of Nanaimo (RDN) retained Northwest Hydraulic Consultants Ltd. (NHC) to prepare a study evaluating replacement options for the Coats Marsh weir. NHC is responsible for the engineering and hydrological aspects of the project and retained Environmental Dynamics Inc. (EDI) as a subconsultant to provide expertise for environmental aspects. This 90% report summarizes study findings and incorporates changes made after feedback with RDN following the 70% report. Feedback received from RDN on this 90% report will be reviewed before issuing a final report.

1.2 Project Overview

The purpose of this report is to assess options for replacement of the weir at Coats Marsh Regional Park on Gabriola Island. The 47.5 ha regional park property includes approximately 10 ha of wetland and falls within the Hoggan Lake watershed. Coats Marsh is naturally occurring but has been modified over time by human activities. The marsh was historically drained for agriculture by ditching and blasting of the natural outlet (SRM, 2020), but the marsh was reflooded by construction of a concrete weir some time in the late 1960s to 1980s (Doe, 2022; RDN, 2011). The existing concrete weir is about 3.2 m high, 6 m wide, 0.6 m thick, and has flashboards positioned in a central notch. The weir does not have a water licence but is currently regulated as a dam under the *Water Sustainability Act* and the BC Dam Safety Regulation (B.C. Reg. 40/2016).

The existing condition of the weir has several deficiencies relative to current dam safety standards and therefore action is required to achieve compliance. Presently, beavers (*Castor canadensis*) have constructed a beaver dam upstream of the weir, with a top elevation above that of the weir. This has established a main marsh pool, whose level is determined by the beaver dam elevation, and a lower-level weir pool between the beaver dam and weir. A study in 2020 noted several concerns with structural deterioration at the weir, including concrete cracks (SRM Projects, 2020). SRM noted that beaver dam failure could cause downstream property damage, particularly if the outflow also resulted in failure of the weir. In August 2021, a siphoning system was installed across the beaver dam to lower the water level of the main marsh pool to below that of the weir’s spill elevation. However, the long-term goal for Coats Marsh is to phase out this siphoning system and restore the marsh to a state where water levels require little to no active management by RDN. Notably, these siphoning and water level management works yielded an abundance of community interest relating to environmental conservation and demonstrated that Coats Marsh is an important ecological area to local Gabriola Island residents.

Given the need to address the weir structure’s deteriorating condition, the objective of this study is to determine the engineering and environmental implications of dam replacement or decommissioning, considering the following five (5) scenarios:

1. A replacement dam structure, set to a lower elevation than the existing weir, which allows the existing berm to remain in place.
2. A replacement dam at the same elevation as the existing weir structure.
3. A replacement dam at an intermediate elevation between the existing weir structure and the top of the site’s beaver dam at present conditions.
4. A replacement dam at the same elevation as the beaver dam at present conditions.
5. Decommissioning the weir and restoring the site to an unregulated condition, including removal of the existing beaver dam.

This study includes a summary of the hydrologic risk and environmental implications of each scenario, as well as regulatory considerations, preliminary drawings and cost estimates, and long-term management planning. For Scenario 5 (decommissioning), NHC’s scope of work is limited to providing a general summary of the design components involved with decommissioning; outlining the regulatory process and consultation requirements; and identifying environmental considerations such as habitat offsetting/compensation that could impact the scope and cost of decommissioning. The final report will provide RDN with information to help make an informed choice about how to proceed with final design of a replacement structure.

This study is organized according to the following major work activities:

1. Site characterization
2. Field assessment
3. Assessment of dam elevation scenarios
4. Conceptual engineering design
5. Options evaluation
6. Recommendations

1.3 Design Standards and Guidelines

This assessment and conceptual design reference the following design standards and guidelines.

- Regulations and EGBC professional practice guidelines:
  - British Columbia Dam Safety Regulation (B.C. Reg. 40/2016)
  - *Sustainability – APEGBC Professional Practice Guidelines V1.1* (APEGBC, 2016b)
  - *Site Characterization for Dam Foundations in BC – APEGBC Professional Practice Guidelines V1.2* (APEGBC, 2016a)
  - *Practice Advisory – Determining Dam Hydrologic Loading V1.0* (EGBC, 2022)
- Provincial guidelines:
  - *Plan Submission Requirements for the Construction and Rehabilitation of Small Dams* (BC FLNRORD, 2018)
  - *Dam Decommissioning Guidelines – BC Dam Safety Program* (BC FLNRORD, 2019)
  - *Downstream Consequence of Failure Classification Interpretation Guideline* (BC FLNRORD, 2017)
  - *Estimating Dam Break Downstream Inundation* (BC MFLNRO, 2016)
  - *Manual of Operational Hydrology in British Columbia* (BC MOE, Water Management Division, 1991)
  - *Project Cost Estimating Guidelines* (MOTI, 2020)
- Federal guidelines:
  - Canadian Dam Association *Dam Safety Guidelines* (CDA, 2013)

1.4 Datums and Coordinate Systems

The survey datums and coordinate systems used throughout this report include:

- Elevations are geodetic and referenced to CGVD2013.
- Horizontal coordinates are referenced to UTM Zone 10N.
- References to left and right banks or left and right dam abutments assume a downstream view.

2 SITE CHARACTERIZATION

2.1 Regulatory Context

At the time of project initiation, past project documentation made it unclear whether the *Water Sustainability Act* (WSA) and the Dam Safety Regulation (B.C. Reg. 40/2016) would apply to the Coats Marsh Weir.

The BC Dam Safety Regulation under force of the *Water Sustainability Act* defines a dam as a barrier constructed for the purpose of enabling the storage or diversion of water from a stream or aquifer. A dam is subject to the regulation if it is more than 7.5 m high or impounds more than 10,000 m^3 of water.

Previous engineering assessments by Madrone Environmental Services Ltd. (2013, 2021) identified that the WSA and the Regulation do not apply to Coats Marsh and provided the following justification:

"*Based on previous advice from the Section Head of the West Coast Region of the Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO), and recent correspondence with a Habitat Officer from the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (MFLNRORD), Coats Marsh does not qualify as a 'stream' under the Water Sustainability Act (including the outlet drainage.)*"

During project startup both NHC and EDI identified to RDN that the WSA includes wetlands within the definition of a "stream," whether or not the wetland usually contains water or has been modified. The weir also impounds sufficient water volumes to meet the minimum threshold for regulation. NHC subsequently contacted DSO and requested clarification on applicability of the WSA and the Regulation to Coats Marsh; a DSO representative, David Johnson, attended the field assessment (Section 3) to review site conditions along with representatives of NHC, EDI, and RDN. Following the field assessment, DSO provided a written determination that Coats Marsh is a "stream" under the *Act* and that the weir is subject to the Regulation. RDN's obligations under the Regulation were specified in writing and are included as recommendations in Section 6 of this report.

The present study has been carried out on the basis that Coats Marsh is a "stream" and that any future dam replacement or decommissioning must meet applicable dam safety standards.

2.2 Coats Marsh Regional Park and Adjacent Lands

Coats Marsh and weir are located on Gabriola Island, British Columbia. The reservoir is not used for agricultural or other water supply purposes, but presently supports a valuable Gulf Islands wetland habitat. Coats Marsh Regional Park was established in 2008; the land is co-owned by the RDN and The Nature Trust of BC and was received in part via a land acquisition through the federal Ecological Gifts Program, administered by Environment and Climate Change Canada (ECC). In 2018, the previously existing 707 Community Park on Gabriola Island was expanded to incorporate lands immediately north and east of Coats Marsh Regional park, creating contiguous park lands of 465 hectares (RDN, 2018). The Regional Park is intended for continued provision of ecological services and recreation by non-motorized trail-users. An overview map of the project site is shown in Figure 2.1.

Figure 2.1 Project overview map, modified from (RDN, 2022).

According to the Gabriola Island Official Community Plan (Islands Trust, 2019), the lands in the Coats Marsh watershed and downstream areas are designated as a combination of Park, Resource, and Large Rural Residential. Subdivision of any of these land uses to less than 2.0 hectares is not permitted. Restrictions on intensification of land use are in place due to community values and servicing limitations, as well water and septic systems must be managed internally on privately owned lands. BC's Riparian Areas Protection Regulation (BC MFLNRORD, 2019) applies to all lands within 30 m of the highwater mark of Coats Marsh Creek downstream of the existing weir; this places restrictions on new development close to the creek on both public and private lands. The outlet of Coats Marsh flows through two large rural residential properties with some existing alterations within the riparian area, but otherwise flows through Park and Resource land use zones which largely restrict future development.

Water flows from Coats Marsh west to Hoggan Lake. The land surrounding Hoggan Lake downstream of South Road is designated as BC Agricultural Land Reserve (PALC, 2022). This restricts use of the site to lower intensity uses, but could allow for some future home-based business or alternate agricultural uses. Part of these lands are presently used as a 9-hole golf course, a private residence, and for greenhouses.

2.3 Coats Marsh Weir

2.3.1 Weir History

The Coats Marsh Weir is located at the west end of Coats Marsh. The current state of knowledge on the weir's history relies on accounts and anecdotes from local residents; to date, no original design plans or documentation have been obtained for the structure. The following provides an overview of the weir's history based on excerpts from the Coats Marsh Regional Park Management Plan (RDN, 2011), local Gabriola resident Mr. Nick Doe (2022), and other sources where cited:

- Historically, the marsh was drained for agricultural purposes by blasting and trenching a channel through the sandstone ridge at the west end of the marsh. This likely occurred in the 1940s.
- Sometime around the late 1960s to 1980s, the former landowner constructed the present-day concrete weir within the blasted channel. The weir consisted of two concrete walls formed against the sandstone bedrock; vertical grooves along the walls allowed installation of flashboards to manually adjust the marsh operating level (Doe, 2022). The weir was reportedly used to store additional water to augment the owner's 160 kW hydro-electric plant at the Hoggan Lake Dam. At one time there were plans to use the flooded marsh as a berry farm; however, those plans were never realized.
- The marsh was reportedly drained in the 1990s; aerial imagery available from RDN indicates that the marsh remained drained until at least 2002 (Figure 2.2.) Between 2002 and 2005, the marsh was re-flooded by installing flashboards at the weir. When RDN and TNT acquired the property in 2008, beavers had established themselves within the marsh. RDN and TNT installed a beaver-proof 0.2 m Clemson pond leveller to reduce water levels and alleviate flooding of private property at the west end of the marsh.
- In 2013, a berm was constructed at the west end of the marsh to further reduce flooding along private property. The berm was designed by a professional engineer who provided oversight during construction; however, the berm was not intended to meet provincial dam safety or diking standards, as the dam safety regulations were not applied to the site at that time. Construction records and drawings from the original design engineer (Madrone Environmental Services Ltd., 2013) have been reviewed for the present study .
- After 2013, the beaver(s) at Coats Marsh became more active and established a dam approximately 60 m upstream of the weir structure. The beaver dam elevation is greater than that of the weir and controls water levels in the upstream marsh; the weir now only exerts control over the small portion of the marsh between the weir and the beaver dam. In 2020 and 2021, peak water levels upstream of the beaver dam were approximately 0.7 m above the crest of the weir concrete (Doe, 2021).
- In 2020, SRM Projects Ltd. completed a condition assessment of the Coats Marsh Weir. The assessment identified notable signs of deterioration in the weir concrete, including cracks and spalling. The assessment also noted that the beaver dam impoundment may be a threat to the weir and downstream assets if it were to breach; it was recommended that RDN lower water levels upstream of the beaver dam by installing a second Clemson leveller through the beaver dam.
- In 2021, RDN installed four 0.1 m dia. siphons over the beaver dam to reduce upstream water levels. The siphons were designed by a professional engineer; available design reports (Madrone

Environmental Services Ltd., 2021) have been reviewed for the present study. The siphons do not have sufficient capacity to convey flood flows over the beaver dam; they are intended to increase beaver dam freeboard during typical winter flows, such that there is available storage depth to buffer peak flows during larger flood events.

- In November 2021, an atmospheric river event resulted in severe flooding throughout BC. Observations by Mr. Nick Doe (2021) indicate that the existing siphons were overwhelmed and both the beaver dam and weir were overtopped, though they did not suffer known damages (Photo 2.1).

Figure 2.2 Aerial imagery of Coats Marsh in 2002 during drained conditions (left) and in 2020 during flooded conditions (right). All imagery was obtained from publicly available RDN mapping data. Note that the drainage ditch visible in the 2002 imagery remains visible in the 2020 imagery as a deeper water area where floating vegetation has not been able to establish.

Photo 2.1 Overtopping flow at Coats Marsh Weir during the November 15, 2021 atmospheric river event (Doe, 2021).

2.3.2 Summary of Key Dam Features

Table 2.1 summarizes the key features of the Coats Marsh Weir and its related structures, based on previous studies and results of the NHC field and desktop assessments. Select photos (2.2 to 2.5) illustrate the weir and embankment arrangement; Appendix C provides an existing site plan.

Table 2.1 Summary of key dam features.

Dam Feature	Value
General	
DSO file no.	D720188
Location	UTM 10N 440530 E 5444730 N
Proposed consequence classification	High (see Section 4.2)
Original construction	Unknown (est. 1970s to 1980s)
Water license no.	Currently unlicensed
Reservoir[1]	
Surface area	4.6 ha at the concrete weir elevation
Volume at the flashboard elevation	16,080 m^3

Dam Feature	Value
Volume at the concrete weir crest elevation	38,950 m^3
Concrete Weir and Spillway	
Weir crest elevation	97.0 m
Max. weir height above downstream channel	3.3 m
Weir width	0.6 m
Weir length	6.2 m
Flashboard elevation	96.4 m
Width of flashboard opening (i.e., spillway width)	0.6 m
Width of downstream channel	1.5 to 1.7 m at base with steep side slopes
Foundation conditions	Fractured sandstone bedrock
Concrete design parameters	Unknown concrete mix design. The presence or absence of reinforcement, dowelling, and keyways is unknown.
Embankment	
Embankment type	Homogeneous earthfill with a geotextile wrap
Embankment crest elevation	97.3 m
Normal freeboard above flashboard	0.9 m
Normal freeboard above weir crest	0.3 m
Crest width	2 m
Embankment height	1.5 m
Side slopes	Approximately 2H:1V
Foundation conditions	Marsh bottom sediments. No key excavation or stripping.
Other Features	
Outlet pipe	0.2 m diameter PVC Clemson pond leveler
Instrumentation	Staff gauge at the weir and the beaver dam
Access features	Footbridge constructed directly over the weir
Signage	None
Debris boom	None

1. Surface area and volume estimates do not include the additional storage depth between the weir and the beaver dam

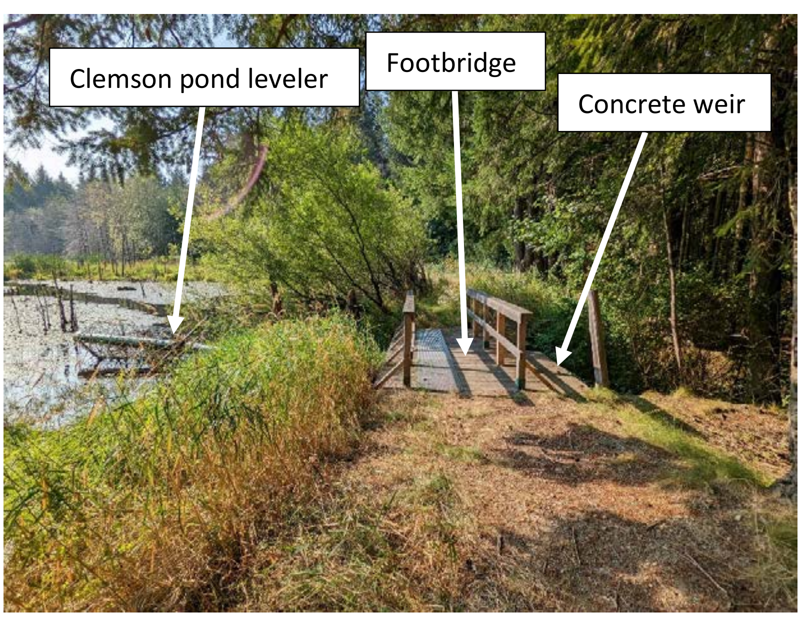

Photo 2.2 Coats Marsh Weir, viewed from the right abutment (NHC, Sep. 2022).

Photo 2.3 Coats Marsh Weir, viewed from the right channel bank (NHC, Sep. 2022).

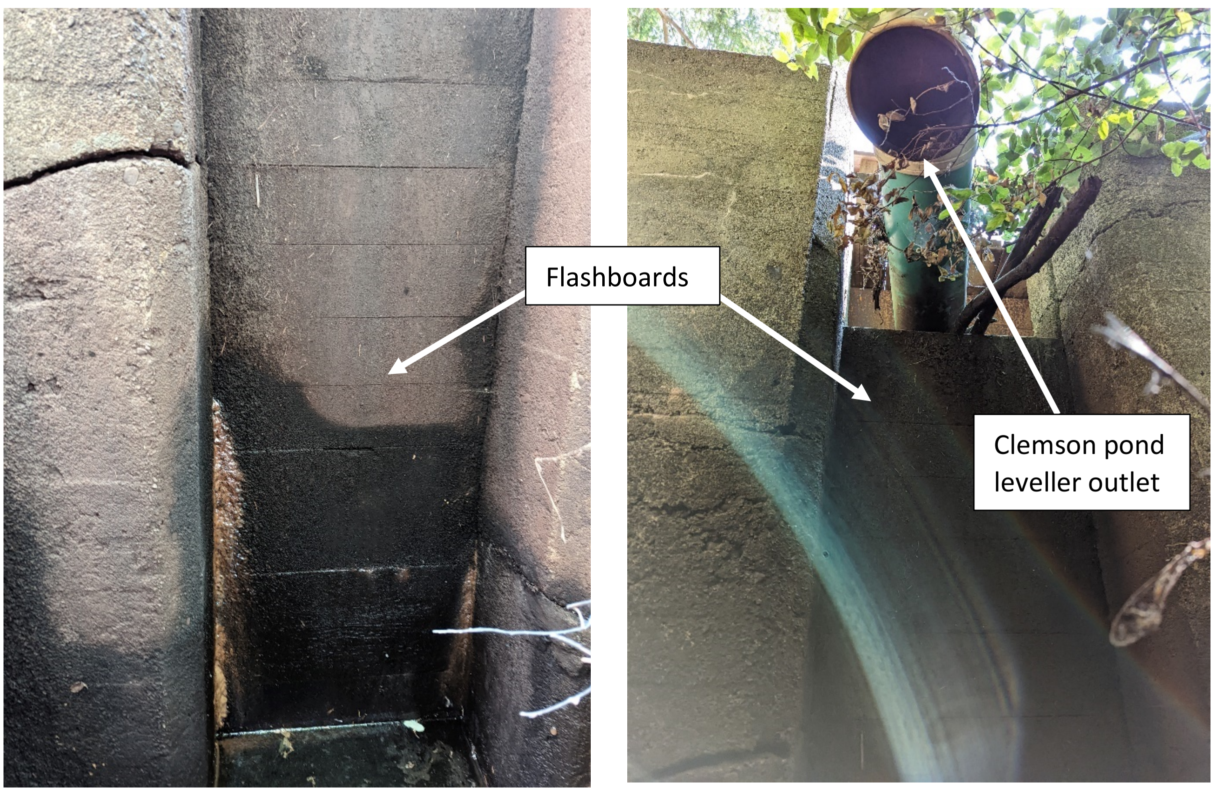

Photo 2.4 Lower (left) and upper (right) portions of the weir outlet slot and flashboards, viewed from the downstream channel. Note cracks in the concrete at several locations (NHC, Sep. 2022).

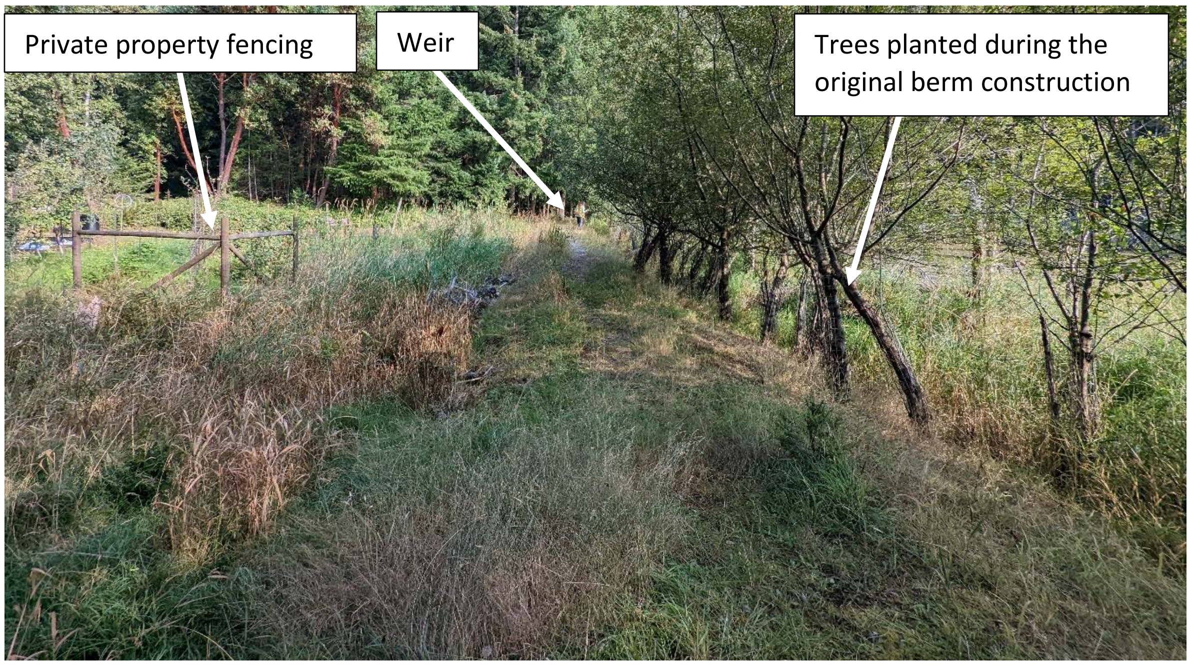

Photo 2.5 Typical condition of the berm, view looking north (NHC, Sep. 2022).

2.4 Hydrologic Conditions

2.4.1 Coats Marsh Watershed

A delineated watershed boundary for the region that supplies overland flow to Coats Marsh was determined using LidarBC (Government of British Columbia, 2021) ground cover data and is provided in Figure 2.3. The watershed is confined to a portion of southwestern Gabriola Island. The southern boundary is formed by part of Coats Drive in the southwest and a well-defined ridge crest between Coats Drive and South Road. The eastern portion of the watershed contains poorly drained wetlands that likely only convey flow toward Coats Marsh in oversaturated conditions. Portions of Hess Road and Chernoff Drive form part of the watershed boundary near their intersection. The Coats Marsh watershed drains an area of 1.45 km^2 upstream of the Coats Marsh weir. Key watershed characteristics for the Coats Marsh watershed upstream of the weir are summarized in Table 2.2. Land cover is mostly forested with some cleared areas used for agricultural purposes (including a nearby cidery) and private yards. Approximately 22 private properties have houses or structures located within the watershed boundary, which are rural in character and sized about 2.0 ha or larger each. Existing land use plans for the area do not support substantial changes to present uses. No portions of the Coats Marsh watershed are protected by BC's Agricultural Land Reserve designation (only the downstream area immediately adjacent to Hoggan lake).

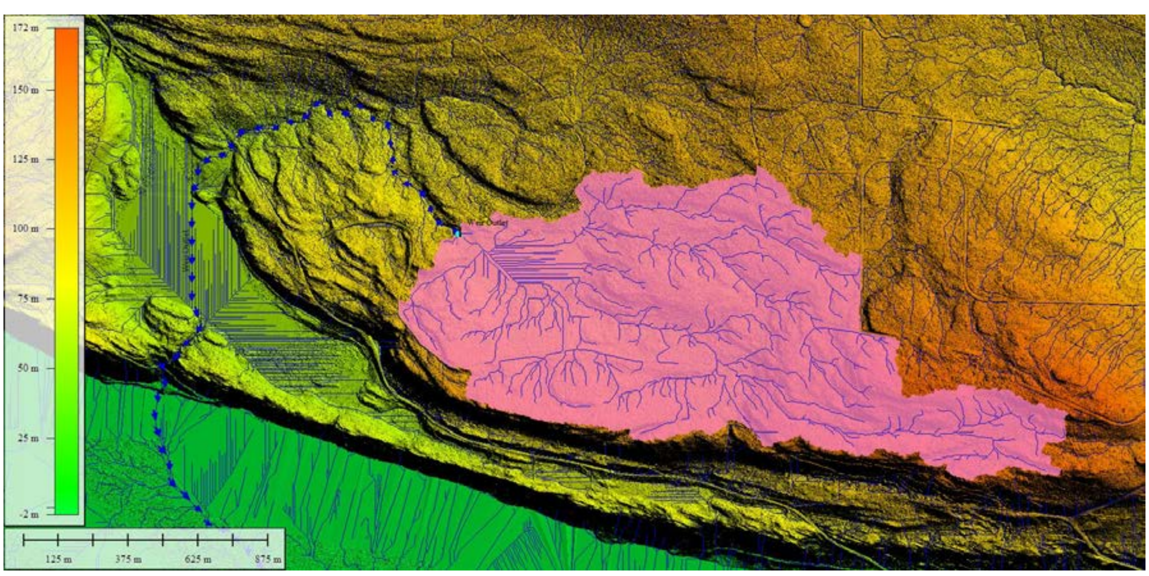

Figure 2.3 Coats Marsh watershed determined from LidarBC ground cover data. Blue arrows show the path of the outlet creek from the weir to Hoggan Lake to the west.

Table 2.2 Coats Marsh watershed characteristics, for all surface runoff toward the weir.

Watershed Characteristic	Description
Watershed area	1.454 km^2
Elevation range	96 - 162 m
Land cover estimates	Moist Maritime Coastal Douglas Fir Forest (CDFmm) – 78% Clearings, grass yards, and agriculture – 13% Wetlands – 6% Impermeable surfaces (paved roads, roofs) – 3%
Watershed slope (average slope method)	3.0%
Groundwater aquifers	Low-yield fractured bedrock aquifer (Peirce & Doe, 2010)
Surficial geology	The marsh is likely underlain by very impermeable clay material, bedrock in the area is sandstone (Agriculture Canada, 1990; Doe, 2020)

The hydrologic region of east Vancouver Island is characterized by a drier climate when compared to west Vancouver Island due to the rainshadow effect of the Vancouver Island Ranges. Long-duration winter storms bring much of the precipitation to the area, though a minimal portion falls as snow that rarely lasts longer than a few days. Select 1981-2010 climate normals from the Enviroment Canada climate station on Gabriola Island located 6 km from the Coats Marsh watershed are provided in Figure 2.4.

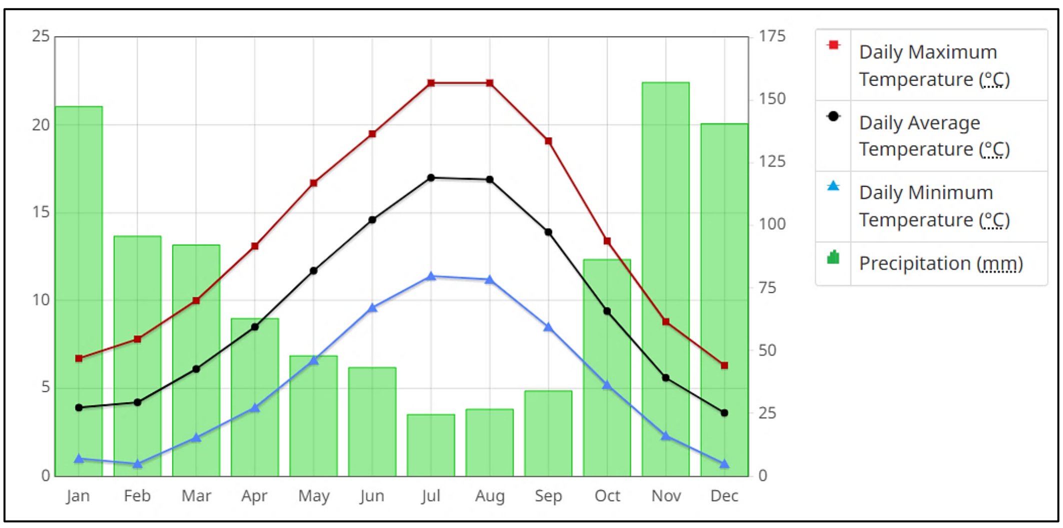

Figure 2.4 1981-2010 climate normals for Gabriola Island (Environment Canada, 2019).

2.4.2 Watercourses

The watershed supplying Coats Marsh extends over an area of 1.454 km^2, supplying runoff to Coats Marsh from the east through a collection of small seasonal creeks and surface runoff. The most significant seasonal inlet creek, known unofficially as East Path Creek, flows into Coats Marsh from the northeast. Poorly maintained beaver dams are present on East Path Creek near its mouth at Coats Marsh. Some wetlands are located in the upstream Coats Marsh watershed.

Coats Marsh Creek flows from the Coats Marsh weir outlet to Hoggan Lake. Figure 2.5 shows a profile created from LidarBC data. The stream length is approximately 1.4 km with an average gradient of 2 to 2.5%. A historical bedrock shelf was located at the location of the existing weir but was blasted likely sometime in the 1940s. Immediately downstream of the weir is a 1.5 m wide channel with nearly vertical bedrock sides over a stream length of 20 m. The creek bed is composed of rough sandstone bedrock, which creates small pools of standing water in dry conditions due to uneven slope.

20 metres downstream of the existing weir, the creek widens and runs through two private properties at 1040 and 1034 Coats Drive. Overbank areas are generally low-gradient and vegetated. Within the properties, the creek is traversed by at least 4 small bridges. A small rock weir at 1040 Coats Drive forms a pond close to a log cabin structure occasionally used as a guesthouse; however, the main houses for the two properties are located on significantly higher ground to the west.

Downstream of 1034 Coats Drive, the creek flows back into Coats Marsh Regional Park, crosses under an access road (easement and walking trail) via a masonry culvert, then flows west into private property (Resource land use classification), flowing through a culvert underneath South Road and then into Hoggan Lake. The South Road access and a fire department pump station are the only infrastructure located near Coats Marsh Creek within the private property where it enters Hoggan Lake.

Hoggan Lake has a typical surface area of approximately 227,290 m^2 and linear perimeter of 2,430 m. Land around Hoggan Lake is gently sloped, with some wetland areas to its southeast. The lake sits about 59.4 m above sea level. Its major inflows are Coats Marsh Creek from the northeast and the larger Goodhue Creek from the northwest. Hoggan Lake drains by a 325 m long outlet channel at its south, which falls over a substantial cliff to sea level at Northumberland Channel. On this outlet, a small privately owned hydroelectric dam regulates water levels in the lake. The dam is a concrete gravity structure rated with a Low Consequence dam safety classification.

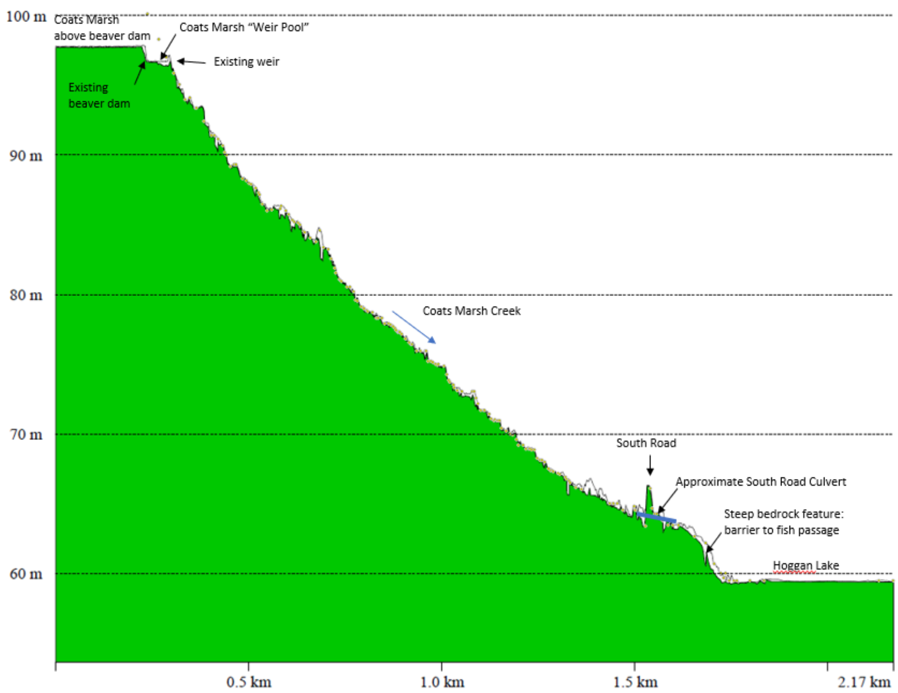

Figure 2.5 Vertical profile from Coats Marsh to Hoggan Lake. Created using Global Mapper with LidarBC data only.

2.5 Geotechnical Conditions

The surficial geology of Gabriola Island is generally characterized by thin soils overlying bedrock, with bedrock outcroppings visible throughout the island.

Bedrock geology on the island consists of sedimentary formations of the Nanaimo Group. Extensive fracturing is present due to the uplifting and folding associated with previous tectonic events; open bedding planes are also common due to post glaciation uplift and isostatic rebound (Burgess and Allen, 2016). At Coats Marsh, the dominant formation is Gabriola sandstone. Fractured bedrock is visible at the surface near the weir structure and in the downstream channel (Photo 2.6).

Surficial deposits on the island are predominantly glaciomarine sediments formed from bedrock weathering and deposits of glacial till and outwash materials (Burgess and Allen, 2016). Provincial well records from nearby properties indicate overburden depths to bedrock in the range of 0.15 m to 2.1 m; the Coats Marsh Management Plan (RDN, 2011) indicates that limited test pits around the perimeter of the marsh showed depths to bedrock greater than 1 m. Soils maps from Agriculture Canada (1990) indicate that the marsh is underlain by organics and poorly drained silty soils, with some areas of diatomaceous earth. These literature values are supported by field observations and test auger holes by local resident Mr. Nick Doe (2020), who noted that the marsh is underlain by a "thick layer of clay".

During the field assessment, NHC staff dug a small test pit immediately downstream of the existing berm to a depth of approximately 0.9 m. Organic soils were present to a depth of 0.1 to 0.2 m, below which was a fine-grained silty soil (Photo 2.7). The silty soil showed some consolidation, though its density varied with depth. To 0.6 m below ground level, the soil was soft and easily dug with a shovel. Below 0.6 m, the soil increased in firmness until digging became difficult near the bottom of the pit. The silty soil layer may have sufficiently low permeability and strength to serve as a foundation for future embankment construction, provided that stripping is carried out to a depth of competent (firm) material. Detailed design should include a series of drill holes along the proposed embankment alignment to confirm subsurface conditions; additional stripping, potentially to bedrock, may be required if subsurface conditions vary from those encountered at the test pit.

Seismic hazards are outside the scope of the present study but should be evaluated during detailed design in accordance with CDA and EGBC guidelines. Peak ground accelerations during the design earthquake will be used for assessing embankment slope stability and designing concrete elements of the dam replacement; a liquefaction triggering assessment should also be carried out if the drill holes identify subsurface materials that may be susceptible to liquefaction.

Photo 2.6 Typical condition of fractured bedrock downstream of the weir.

Photo 2.7 Typical condition of fine-grained silty soil from the NHC test pit.

2.6 Environmental Conditions

EDI's wetland assessment report (Appendix A) provides a detailed description of environmental conditions at Coats Marsh and downstream areas.

In summary, the marsh is a complex of wetland classes currently dominated by shallow water (aquatic), where permanent inundation occurs. The shallow water area transitions into a marsh, where emergent vegetation and seasonal drying occurs. Beyond the marsh area a forested swamp is presented. The forested swamp has been classified as a Western Red Cedar – Indian Plum ecological community.

The wildlife community within the marsh is predominantly birds and amphibians. Bird occurrence includes several species of wading birds, swans, geese, and waterfowl. Confirmed amphibian populations include northern red-legged frogs and pacific chorus frogs. It should be assumed that other native amphibian species such as northwestern salamanders and rough-skinned newts could also inhabit the wetland. It is notable that the northern red-legged frog is a federally listed species of concern and a provincially blue-listed species. To date, no fish have been detected within Coats Marsh, though this does not definitely confirm their absence. Both Cutthroat Trout and Rainbow Trout were observed at Hoggan Lake in 1972. Mammal presence around the marsh includes beavers and deer.

3 FIELD ASSESSMENT

The field assessment was carried out over two days and included the following activities:

- September 14, 2022: Nathan Valsangkar and Evan Arbuckle (NHC), Rachelle Robitaille (EDI), Jordan Vander Klok and Chris van Ossenbruggen (RDN), and David Johnson (DSO) completed an initial site assessment with the following objectives.
    - Review of the weir and embankment conditions.
    - Evaluation of downstream assets potentially at risk during a dam failure.
    - Review of environmental conditions within the marsh, including the beaver dam.
- September 19, 2022: NHC technicians established geodetic survey control monuments and completed a detailed topographic survey of the weir, berm, and adjacent weir pool marsh areas to support the engineering assessment and design tasks.

NHC's key findings from the initial field assessment are summarized as follows; Appendix B provides annotated site photos. EDI's observations are included in Appendix A.

3.1 Weir Condition

- The condition of the weir's upstream face could not be reviewed due to the presence of vegetation, standing water in the marsh, and the footbridge. The footbridge is a known flow obstruction when marsh water levels rise and overtop the weir. Vegetation and wood debris upstream of the weir also obstruct flow and should be removed.
- The dam crest and downstream face showed similar conditions to those noted by SRM in 2020. Cracking was identified at several locations, including one significant crack between the left abutment and the flashboard opening that may extend to the upstream face of the weir. This crack may be the result of a poorly formed cold joint from the dam's original construction. It did not appear that the existing cracks had worsened in extent or width since 2020.
- Seepage was identified at both dam abutments along the interface between the weir concrete and the sandstone bedrock substrate. Seepage is likely the result of voids and fractures in the bedrock, as well as an uneven concrete/rock contact surface. Seepage appears to have worsened since 2020, despite water levels that were lower in the 2022 inspection than in the 2020 inspection.
- The wooden flashboards appeared to be in similar condition to the 2020 inspection and were well wetted. The lowest flashboards were firm when probed with a knife. The flashboard opening width and depth (approximately 0.6 x 0.6 m) do not meet current provincial standards, which require a minimum 4.0 m wide x 1.0 m deep spillway.
- The presence and condition of reinforcement within the weir could not be confirmed during the field assessment. It is also unclear whether the concrete is dowelled (pinned) into the bedrock or supported against sliding with keyways. A probable failure sequence for the weir could involve separation of one or both concrete walls from the rock face and failure into the downstream channel.
- Considering the foregoing, there are several deficiencies with the existing weir structure, including inadequate spillway width and freeboard, spillway obstructions, concrete cracking, and abutment seepage. NHC has not completed structural stability calculations as part of the assessment; however, it appears likely that the overall concrete weir design does not meet current stability standards. Seismic loading is a particular concern. Corrosion of reinforcing steel, if present, may also weaken the structure over time.

3.2 Berm Condition

- The berm forms part of the overall dam structure because it impounds water above the elevation of downstream ground. The overall berm condition was similar to that recorded in SRM's 2020 report.

- The berm geometry included a 2 m crest width and approximately 2H:1V side slopes. These dimensions do not meet current provincial standards for crest width and slopes. The berm crest elevation is approximately 0.9 m above the flashboard crest and 0.3 m above the concrete weir crest. The November 2021 flood event resulted in near overtopping of the berm, indicating that there is inadequate freeboard.
- We understand that the original berm construction involved placement of bulk fill along the marsh bed with no foundation stripping. There is evidence of seepage along the toe of the berm, though no open boils or other evidence of piping were identified.
- The berm was covered with a geotextile on all sides during its original construction; the geotextile has since become exposed at several locations. Geotextiles can become clogged over time, leading to increased saturation within the fill and reduced stability under static and seismic loading. Alders and other trees have been planted into the berm in accordance with the original design; several trees now have stem diameters on the order of 0.15 m. Trees should not be allowed to grow on embankments due to the potential for root growth and windfall to impact the integrity of the fill. We recommend that RDN cut the trees close to the ground as soon as possible.

3.3 Marsh Environment

- The marsh environment was reviewed at several locations on foot. There was an abundance of dead trees around the marsh, likely resulting from elevated water levels upstream of the beaver dam. The RDN representative noted that there is limited deciduous vegetation around the marsh compared to when the property was first acquired.
- The beaver dam upstream of the weir appeared to be actively maintained by beavers, with no overflow channels or breaches identified. The water level difference across the beaver dam was approximately 1.2 m, with the water level upstream of the beaver dam being approximately 0.6 m above the concrete weir crest.
- The four siphons over the beaver dam were overgrown with vegetation and could not be reviewed in detail.

3.4 Downstream Conditions

- Immediately downstream of the weir, the Coats Marsh outlet stream flows through an incised channel with fractured bedrock walls. Void spaces and cracks in the bedrock were up to approximately 0.10 m in places. Bedrock in minimally fractured areas was hard and difficult to break with a handheld hammer. In areas with a high degree of fracturing and voids, the bedrock was more easily broken and could likely be dislodged in plates or blocks using heavier construction equipment.
- Farther downstream, the outlet stream runs through private property at 1040 and 1034 Coats Drive. Neither property owner gave his permission for NHC to access their property to evaluate stream conditions. However, SRM was able to access the properties in 2020 and site photos and observations from the SRM report have been reviewed for the present study (see Section 4.2).
- NHC reviewed two downstream culvert crossings, one located at the RDN access road to Coats Marsh and the second at South Road upstream of Hoggan Lake. The RDN access road culvert is a masonry structure, with evidence of scour at its outlet. The adjacent floodplains are broad and well vegetated. The South Road culvert is a 1.2 m dia. corrugated steel pipe; approach road sections have good visibility. The area of road that could be overtopped by a dam breach flood is relatively broad, with well vegetated downstream slopes.
- NHC did not review conditions downstream of South Road due to private property boundaries. From available topographic LiDAR and aerial imagery, there are no structures within the likely inundation area and the overall topography is broad and low gradient.

4 ASSESSMENT OF DAM ELEVATION SCENARIOS

4.1 Overview

The objective of this assessment task was to evaluate the engineering and environmental implications of four replacement dam elevation scenarios and one decommissioning scenario:

- Scenario 1: A replacement dam at an elevation that maintains the existing berm with adequate freeboard. This corresponds to a dam crest placement at 96.1 m.
- Scenario 2: A replacement dam at the same elevation as the existing weir structure. We have assumed that this corresponds to the top of the existing wooden flashboard, at elevation 96.4 m.
- Scenario 3: A replacement dam at an intermediate elevation between the existing weir structure and top of the site's beaver dam. We have assumed that this corresponds to the top of the weir concrete, at elevation 97.0 m.
- Scenario 4: A replacement dam at the same elevation as the beaver dam. We have assumed that this corresponds to the top of the beaver dam at the time of the NHC 2022 survey, at elevation 97.7 m.
- Scenario 5: the existing weir is removed, and the site is decommissioned from status as a dam. Detailed assessment for this scenario is not conducted because of data and budget limitations, but regulatory and ecological impacts are discussed.

The engineering assessment includes a review of the dam safety regulatory considerations under each scenario, an Inflow Design Flood (IDF) analysis to inform the replacement dam spillway sizing, and a seasonal water balance to characterize the hydrologic characteristics of each scenario. The environmental assessment includes an evaluation of how the overall wetland characteristics will change with each scenario, and whether this could result in significant changes or effects to important wildlife habitat.

4.2 Dam Consequence Classification Review

A dam's downstream consequence classification is determined by the BC Dam Safety Regulation and sets the safety standards for a given structure. The dam classification considers several consequence categories, including the population at risk; potential loss of life; environmental and cultural values; and infrastructure and economic impacts associated with a hypothetical dam breach flood. The category with the worst potential consequences determines the final consequence classification.

NHC has carried out a consequence classification review for the existing weir, with consideration of how the classification may change as a result of dam replacement under Scenarios 1 through 4. The assessment is based on the Dam Safety Regulation and related guidelines available from DSO (BC FLNRORD, 2017; BC MFLNRO, 2016), including the following steps:

- Downstream assets were inventoried using available studies, mapping data, and field observations. Note that NHC did not have permission at the time of the site visit to access private property immediately downstream of the weir and has relied solely upon previous studies and correspondence with the land owner to characterize their downstream assets at 1040 Coats Drive.
- The magnitude of potential breach outflows was approximated for the weir, assuming a sudden catastrophic failure. Detailed hydraulic computations are provided in Appendix D.
- The breach outflows were reviewed against the channel and floodplain characteristics to qualitatively assess the potential for downstream consequences. Hydraulic modelling and floodplain mapping were outside the scope of the assessment. EDI provided comment on the potential for a dam breach to impact sensitive aquatic and riparian values (see Appendix A).

The following summarizes key findings of the consequence classification review.

- Environmental values include fish and amphibian habitat. There is potential Cutthroat Trout spawning habitat in the lower reach of Coats Marsh Creek upstream of Hoggan Lake, though available reports suggest the habitat quality is low. Downstream areas provide foraging and dispersal opportunities for the blue- and SARA-listed northern red-legged frogs. The greatest environmental value that could be impacted by a dam breach is the marsh itself, which provides ideal breeding habitat for the frogs. Per provincial guidelines, if there is significant loss or deterioration of habitat for blue-listed species, then the dam classification is High Consequence. However, existing habitat mapping for northern red-legged frogs does not identify Coats Marsh as critical habitat.

- Infrastructure and economic values include foot bridges, an ornamental rock weir, a culvert, and a small cabin on private property downstream of the dam. Farther downstream, there is a masonry culvert on the RDN's park access road and a cross culvert at South Road upstream of Hoggan Lake. Loss or damage of these assets meets the Significant Consequence classification.
- There is a small cabin located on private property at 1040 Coats Drive, approximately 60 m downstream of the weir (Photo 4.1 and Photo 4.2.) The cabin is raised on concrete piers and is sited immediately adjacent to the stream channel near an ornamental rock weir. RDN contacted the property owner to obtain additional information on the structure; he indicated that the cabin is uninhabited, but occasionally used as a guest house for visitors. Photos from previous studies indicate that the cabin has a wood burning stove and an electrical line from the main house on the lot. The property owner also indicated that water runs under the cabin during periods of intense rainfall and high-water flow. Based on provincial guidelines (BC FLNRORD, 2017), the cabin likely meets the definition of a "seasonal cottage" and populations at risk are considered permanent rather than temporary. This interpretation is also relevant if the cabin becomes more regularly inhabited in the future. If there is low potential for loss of life in a dam breach, the consequence classification is Significant. If loss of life is possible, the consequence classification is High. Other downstream populations at risk are temporary only, such as park users and the travelling public along South Road; these populations at risk fall under the Significant classification.
- Peak outflows during a dam failure depend on several factors such as the location of the breach (i.e., at the berm vs. at the weir structure), the breach geometry and formation time, and antecedent water level and flow conditions. The most critical location for a breach is likely at the weir, due to the height of the structure above the downstream channel. The estimated peak breach outflows for Scenarios 1 through 4 are approximately 9, 11, 15, and 20 m^3/s respectively, not including additional streamflow that would be present if failure occurred during the IDF. Breach outflows would be less than these values if the failure occurs slowly.
- In all four dam replacement scenarios, water is likely to flow beneath and potentially against the cabin. The adjacent floodplain is low-gradient and velocities during the breach may be on the order of 1 to 2 m/s. In our opinion, loss of life appears possible in all scenarios because the cabin sits unanchored on concrete piers and could be knocked over by floodwaters, with limited to no warning time. The likelihood for loss of life is greatest in Scenario 4.
- In all four dam replacement scenarios, dam failure could result in drainage of Coats Marsh, though some water would possibly remain in local depressions. The loss of emergent vegetation and general reduction in wetted area following a dam failure would equate to a loss or deterioration in habitat quality for red-legged frogs at this location, though this habitat is not critical habitat for the species. Dam failure could also result in scour and erosion of spawning habitat upstream of Hoggan Lake if cutthroat trout are indeed present. A consequence classification of Significant is considered appropriate.
- Based on the foregoing, we recommend that the existing weir be classified as **High** consequence due to the potential for loss of life at the cabin.
- A High consequence dam has much greater safety requirements than a Significant dam, including a larger spillway, requirements for weekly site surveillance, and a legislated Dam Safety Review every ten years. With respect to loss of life potential, future dam replacement options could be reduced to Significant with appropriate mitigation. The most technically straightforward approach is for RDN to form an agreement with the land owner to carry out one of the following actions:
  - Removing or relocating the cabin to another area of the property.
  - Removing the stacked rock weir adjacent to the cabin, thereby greatly increasing the channel capacity and reducing flood levels at the cabin. The dam is likely low enough to avoid being classified as a dam, but it does obstruct a stream and would normally require a water license. No water license currently exists for the rock weir.

- If neither of these options is tenable, the following alternative actions could be considered:
  - The cabin could be made resilient to flooding through one or a combination of foundation improvements, anchoring, or raising the cabin to a higher elevation. However, a qualified structural engineer would be required to design any such improvements, and we note that the work would fall within the Riparian Area Regulation and may not be permitted under Gabriola bylaws.
  - The replacement spillway could include extensive rockfill on its downstream side to reduce the potential for a sudden, catastrophic failure of the dam, thereby reducing peak outflows and flood hazards during a breach.
  - If either of these alternatives is proposed for implementation, dam breach inundation modelling should be completed to confirm that the mitigation work will reduce flood hazard levels to acceptable levels for a Significant consequence dam.

Photo 4.1 Flow over ornamental rock weir at 1040 Coats Drive, March 6, 2014 (SRM Projects, 2020).

Photo 4.2 Condition of cabin at 1040 Coats Drive (SRM Projects, 2020).

4.3 Inflow Hydrology Assessment

Any replacement dam structure must be designed to withstand an Inflow Design Flood (IDF) as specified in the Canadian Dam Association (CDA) dam safety guidelines. The magnitude of the IDF is commensurate with the dam's downstream consequence classification:

- The IDF for a Significant class dam is between the 1/100-year and the 1/1000-year event; event selection should consider incremental exposure and consequences of failure for the structure.
- The IDF for a High consequence dam is one third of the way between the 1/1000-year event and the Probable Maximum Flood (PMF). The PMF is generally viewed as the flood resulting from the Probable Maximum Precipitation (PMP), as applied to assumed antecedent basin conditions. The PMF is considered the upper limit flood that could theoretically be generated within the basin.
- For Scenario 5 (decommissioning), removal of the existing weir will transition the marsh back to its former condition, with a defined stream channel along the historical drainage ditch (see

Figure 2.2). Provincial guidelines require that that the restored channel be designed to pass a 1/100-year flood event without causing significant bank erosion or failure (BC FLNRORD, 2019).

Coats Marsh and Coats Marsh Creek are ungauged. For ungauged watersheds, the CDA guidelines state that regional flood frequency analysis and/or flood flow estimates from precipitation data may be used to estimate the IDF. NHC adopted the following methodology to estimate the IDF for Coats Marsh:

- Regional precipitation data in the area has a longer period of record and is generally of higher quality than streamflow records. Rainfall-runoff analysis was used as the primary estimator of IDF values; regional streamflow records were used as a secondary check on the magnitude of the IDF estimates.
- Rainfall-runoff analysis was carried out using the Rational Method (BC MOE, Water Management Division, 1991), which is considered appropriate for small catchments like Coats Marsh. The Rational Method outputs a single peak flow value rather than a hydrograph; flow attenuation through the marsh was not accounted for. Peak flow estimates were computed for the 1/2- to 1/1,000-year events. As an initial check, peak flow estimates were compared to the estimated maximum flow at the Coats Marsh weir during the November 2021 flood event, which had a return period between 5 and 10 years.
- Regional flood frequency analyses were obtained from a recent IDF study completed by NHC for the Province (NHC, 2021). Flood flow estimates from proxy watersheds were scaled to Coats Marsh based on watershed area and used as checks on the Rational Method calculations. Peak flows from watersheds containing lakes were compared to peak flows from watersheds with no lakes to estimate the degree of peak flow attenuation that could be expected for Coats Marsh.
- Local PMP estimates were obtained from a recent IDF study completed for the Province (DTN and MGS Engineering, 2020). PMP values are only available for storm durations of 24 hours to 96 hours; the ratio of the 24-hour PMP to 24-hour 1/1000-year rainfall was used to scale the Rational Method 1/1000-year peak flow to estimate the PMF.
- An overview climate change assessment was carried out to evaluate the potential impacts of future climate change on flood flow magnitudes.

Appendix D provides detailed hydrologic computations. Table 4.1 summarizes the recommended IDF peak flow values for spillway sizing.

Table 4.1 Summary of IDF peak flow estimates.

Flood Frequency	IDF Peak Flow at Spillway[1] (m^3/s)
1/100-Year	2.7
1/1,000-Year	3.5
1/3 Between the 1/1,000-Year and the PMF	4.5
PMF	6.5

The following summarizes key assumptions and limitations of the assessment:

- There is uncertainty in the input parameters used for the Rational Method, such as rainfall values, watershed time of concentration, and the ratio of rainfall to runoff. The assessment used reasonably conservative values throughout; however, there is limited to no field data available to validate the results at high flows.
- The assessment did not use hydrograph analysis to evaluate peak flow attenuation through the marsh. Hydrograph analysis should be carried out during detailed design to refine the IDF estimates and confirm spillway sizing criteria. For Scenario 5 (dam decommissioning), peak flow attenuation through the marsh will be lost, and the 1/100-year design flow rate will increase compared to that presented in Table 4.1.
- All assumptions and limitations from the referenced IDF and PMP studies (DTN and MGS Engineering, 2020; NHC, 2021) are inherited when considering the results of the regional flood frequency analysis and PMF estimates.

4.4 Seasonal Water Balance

The best available source from which to estimate water balances for Gabriola Island was found in a groundwater study of Gabriola Island by Burgess and Allen (2016), and further documented in Burgess (2017). The study included development of a calibrated groundwater model for the local region; key model outputs included monthly water balances of precipitation, runoff, evapotranspiration, and groundwater processes.

NHC developed a preliminary water balance for Coats Marsh by adapting the monthly water balance distributions from the Burgess and Allen study to the local watershed, but using longer-term averaged precipitation values as shown in Figure 2.4. The water balance considers runoff generation within the watershed, outflow from the weir, and open water evaporation from the marsh surface; groundwater interactions were outside the scope of the present study. The months of May to September yield net losses from the reservoir when seasonal summer drawdowns are controlled by evaporation.

Seasonal water balance values were compared to semi-regular elevation measurements taken by Doe (2021) in recent years as a check to compare to existing conditions. In Mr. Doe's measurements, water levels in the marsh have regularly shifted upwards of 0.7 m over the course of a year, but this is influenced by the more complicated existing two-phase weir pool and upper marsh system, the fact that the beaver dam allows leakage, and the capacity limitations on outflow due to the narrow weir flashboard opening.

Based on NHC's seasonal water balance calculations, estimated summer evaporation-driven drawdown for all four dam design scenarios is 0.3 m. During higher flows in the winter months, water levels can be expected to rise about 0.1 m above the dam crest during frequently occurring precipitation events, but would rise higher during severe flood events. Table 4.2 provides a summary of the typical seasonal fluctuations of the geometry in Coats Marsh for each proposed scenario.

NHC completed an overview climate change assessment to evaluate how the seasonal water balance might evolve in the future in response to reduced summer precipitation and increased temperatures. The assessment relied on climate change projections from the Burgess and Allen report, as applied to the Coats Marsh watershed. The total seasonal drawdown depth was estimated to increase by an average of 10% and 15% by the 2050s and 2080s, respectively, for all four dam elevation scenarios. Scenario 1 would experience the greatest relative change in drawdown due to its generally shallow depth, while Scenario 4 would experience the lowest relative change.

Table 4.2 Seasonal water balance effects on marsh geometry by scenario.

Weir Scenario	Elevations (m, CGVD2013)			Storage Volumes (m3)		Wetted Areas (m2)		Maximum Depth (m)		Hydraulic Mean Depth (m)	
	Weir Crest	Seasonal High Water	Seasonal Low Water	Seasonal High	Seasonal Low	Seasonal High	Seasonal Low	Seasonal High	Seasonal Low	Seasonal High	Seasonal Low
Scenario 1	96.1	96.2	95.8	10,428	2,084	25,878	13,778	2.1	1.7	0.4	0.2
Scenario 2	96.4	96.5	96.1	19,265	7,959	33,128	23,482	2.4	2.0	0.6	0.3
Scenario 3	97	97.1	96.7	43,665	26,386	48,454	38,084	3	2.6	0.9	0.7
Scenario 4	97.7	97.8	97.4	83,961	59,374	66,857	56,246	3.7	3.3	1.3	1

For Scenarios 1 through 4, water levels can be expected to remain fairly stable throughout the winter months, as the much larger spillway than is currently present will permit outflow to more closely match inflow to the marsh. NHC supplied EDI with cross-sections indicating seasonal water level boundaries that can be found in Section 4 of Appendix A. Seasonal extents of water levels are also depicted in plan view in the concept drawings in Appendix C.

For Scenario 5 (decommissioning), the marsh will transition back to having a defined stream channel and banks. It is likely that portions of the marsh would re-flood seasonally during the winter, but most of the wetted area and volume would be limited to the footprint of the stream channel. The stream would likely run dry during the summer and early fall due to low precipitation, similar to other ephemeral streams on Gabriola Island. If regulators permit the beaver dam to be left in place as part of the weir decommissioning process (see Section 5), the seasonal water balance will be most similar to Scenario 4. However, the total seasonal drawdown may increase due to greater seepage rates through the beaver dam associated with a loss of tailwater.

4.5 Wetland Assessment

EDI professional biologists prepared a detailed assessment of wetland conditions for Coats Marsh, which provides insight regarding ecological conditions of the wetland for the proposed dam replacement elevation scenarios. Their report is attached as Appendix A.

In Scenario 1, the lowest water levels would expose lands along the edges of presently wetted areas and allow them to revegetate with shrubs and trees, which could serve as substantial new forage sources for beavers, potentially allowing returning beavers to become established. Due to the shrinkage of the surface area and perimeter edges, marsh habitat and emergent vegetation would be reduced and yield less habitat for amphibian and waterfowl species. The reduced storage of water in Scenario 1 exposes the marsh to the highest climate change impacts because the smaller volume and depth is more sensitive to temperature changes and increased surface evaporation.

Scenario 2 will decrease the area of shallow water and will increase the marsh ecological community area, potentially re-introducing more swamp ecological community area. Similar to Scenario 1, this lower-depth scenario is anticipated to have reduced habitat value for amphibians compared to current conditions due to a reduction in marsh fringe breeding habitat and increased water temperatures. This scenario also has a high possibility of creating a "drier" edge area, thereby allowing the potential re-establishment of shrubs and trees along the periphery of Coats Marsh.

Scenario 3 would reduce water levels upstream of the existing beaver dam, but shallow open water habitat would remain. With slightly less water depth than Scenario 4, this scenario would yield a similar or larger amount of marsh-like habitat due to shallow transitional conditions along the edges. Scenario 3 should not create any significant changes affecting wildlife habitat, such as amphibians. Foraging and nesting habitat for birds may improve due to greater encroachment of woody vegetation along the wetland edge.

Scenario 4 is the most beneficial for maintaining present species diversity within the marsh. The larger storage volume in Scenario 4 would also allow for better climate change resilience during summer drought periods. Water temperatures would remain moderately cooler than the other scenarios, which is of benefit for northern red-legged frogs and particularly during egg development.

Scenario 5, decommissioning of the existing weir without replacement, would result in near complete drainage of Coats Marsh. Ephemeral streams would continue to flow toward the historical drainage ditch that runs linearly to the outlet. Dry season wetted area would be minimal, and there would be a significant reduction in amphibian habitat compared to present conditions. One or more low rock weirs could be constructed along the drainage ditch to provide some storage and seasonal wetted area.

If regulators permit the beaver dam to be left in place as part of the weir decommissioning process (see Section 5), it is expected that most of the marsh area would have similar values to the present conditions but these values could potentially change over time based on the level of local beaver activity. If local beavers abandon the marsh, this could lead to a future deterioration of the beaver dam. This deterioration could cause fluctuations in water levels within the marsh area and could lead to uncontrolled flooding downstream of the beaver dam.

5 CONCEPTUAL DESIGN

This section summarizes the design components, costs, and constructability considerations associated with weir replacement or decommissioning.

5.1 Summary of Design Components for Dam Upgrades (Scenarios 1 to 4)

Any future replacement of the Coats Marsh weir will involve a series of design components, such as embankment replacement, structural upgrades, and outlet works upgrades. The following summarizes the design components associated with each dam elevation scenario, based on current CDA guidelines (2013) and provincial DSO guidelines (2018).

5.1.1 Embankment Replacement

Based on the field and desktop assessments, the existing berm at Coats Marsh does not meet geotechnical design standards. It is unlikely that DSO would allow raising the existing berm due to the lack of foundation preparation and fill compaction during its original construction. We recommend removing the berm and replacing it with a new dam embankment for Scenarios 2, 3, and 4. For Scenario 1, there is adequate freeboard on the existing berm to avoid replacing it with a new embankment. The Scenario 1 dam structural upgrades also include an abutment wall that will maintain water retention if the berm fails in the future. The following are minimum design standards that have been adopted for conceptual design of new dam embankments under Scenarios 2, 3, and 4:

- Foundation stripping is required to remove any loose or liquefiable soils and organics. A key trench will likely be required to minimize seepage through the foundation.
- The embankment will have a crest width of 4.0 m, with slopes of 2.5H:1V and 3H:1V on the downstream and upstream faces, respectively. The dam crest elevation is 1.0 m above the spillway crest elevation.
- The embankment will consist of suitably compacted fill materials. A zoned embankment will likely be prescribed during detailed design, comprising an impermeable core, one or more granular filters, and shells of engineered or bulk fill (Figure 5.1). Erosion protection rock may be recommended on the upstream face of the dam; surfacing gravels are recommended along the entire embankment crest to reduce erosion from pedestrian traffic.

Table 5.1 summarizes the dam embankment conceptual design parameters for each dam elevation scenario.

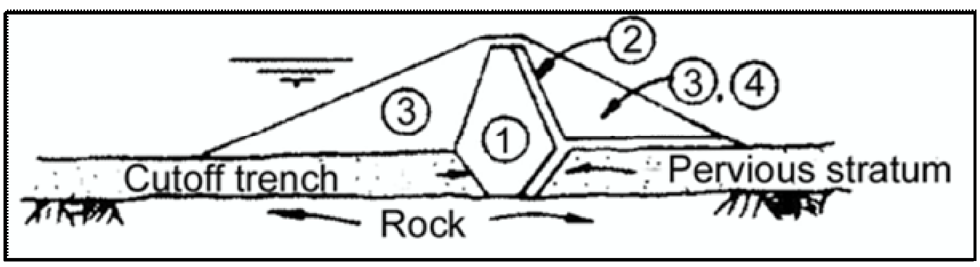

Figure 5.1 Example of a zoned embankment dam section (2012). Legend: Zone 1, impervious core; Zone 2, filter drain material (may require a two-stage filter); Zones 3 and 4, engineered and (if suitable) bulk fill.

Table 5.1 Summary of dam embankment conceptual design parameters.

Design Parameter	Scenario 2	Scenario 3	Scenario 4
Crest elevation	97.4 m	98.0 m	98.7 m
Maximum height[1]	1.9 m	2.5 m	3.2 m
Maximum bottom width[2]	14.5 m	17.8 m	21.6 m
Embankment length[3]	73 m	82 m	105 m
Estimated fill volume	1,000 m^3	1,700 m^3	3,300 m^3

1. Assumes stripping to a base elevation of 95.5 m, based on NHC's initial test pit results and the existing marsh bathymetry
2. Calculated based on the crest elevation, crest width, side slopes, and maximum dam height
3. Total length of embankment required to tie into high ground at the abutments

5.1.2 Dam Structural Upgrades

Based on the results of the field and desktop assessments, the existing concrete weir does not have adequate capacity to convey the IDF, shows signs of concrete deterioration, and does not meet current structural standards. All four dam replacement scenarios will require replacing the weir with a new spillway structure designed to meet current structural and hydrotechnical criteria.

NHC's design concept involves constructing a new concrete overflow structure on the downstream side of the existing weir, including filling the existing flashboard opening with concrete up to the design dam crest elevation (Figure 5.2). For Scenarios 1 and 2, the reduction in height from the existing weir may justify complete removal of the existing weir and replacement with a new structure. The new concrete would be reinforced, including rock dowels into the surrounding sandstone to improve the structure's overall resistance to sliding and overturning. Rock excavation (i.e., blasting or hammer breaking) will be required to accommodate the design spillway width. Rockfill should be incorporated downstream of the new concrete dam to improve energy dissipation during floods and buttress the dam concrete. Wingwalls or a reinforced concrete slab and cutoff wall would be provided upstream of the overflow structure to tie into the main dam embankment. Foundation improvement, such as injection grouting, may be required.

A potential alternate configuration of the dam could involve siting the new structure close to where the existing beaver dam is. Relocating the structure is not likely to significantly reduce embankment lengths or volumes, and would render the present weir area pool dry, shrinking the overall footprint of the marsh. However, this option would leave a larger buffer from the structure to private property, which may improve constructability in terms of access and design options for a replacement spillway structure. At this time, no designs for this option are pursued. Note that geotechnical investigations would be required to evaluate subgrade suitability at this location.

For Scenarios 2, 3, and 4, the replacement spillway dimensions must be adequate to maintain embankment freeboard during the IDF. Freeboard should account for wind-wave effects, hydraulic uncertainty, and the potential for debris blockage during floods; a preliminary freeboard value of approximately 0.3 to 0.6 m is likely adequate for the replacement spillway. Preliminary spillway dimensions were calculated for the IDF using the broad crested weir equation, with results summarized in Table 5.2. The minimum spillway size considered was 4.0 m wide x 1.0 m deep, in accordance provincial guidelines (BC FLNRORD, 2018).

If the replacement dam remains as a High Consequence structure, a 6.0 m wide spillway would likely provide adequate capacity to convey the IDF while maintaining freeboard. If the replacement dam is a Significant Consequence structure, a 4.0 m wide spillway is likely adequate. The spillway dimensions should be refined during detailed design based on flood hydrograph routing analysis (see Section 4.3).

Table 5.2 Summary of preliminary spillway dimensions

Spillway Width	Spillway Depth	Max. Reservoir Level above Spillway Crest	Freeboard
Significant Consequence Dam – IDF of 3.5 m^3/s			
4.0 m	1.0 m	0.64 m	0.36 m
6.0 m	1.0 m	0.49 m	0.51 m
8.0 m	1.0 m	0.40 m	0.60 m
High Consequence Dam – IDF of 4.5 m^3/s			
4.0 m	1.0 m	0.76 m	0.14 m
6.0 m	1.0 m	0.58 m	0.42 m
8.0 m	1.0 m	0.48 m	0.52 m

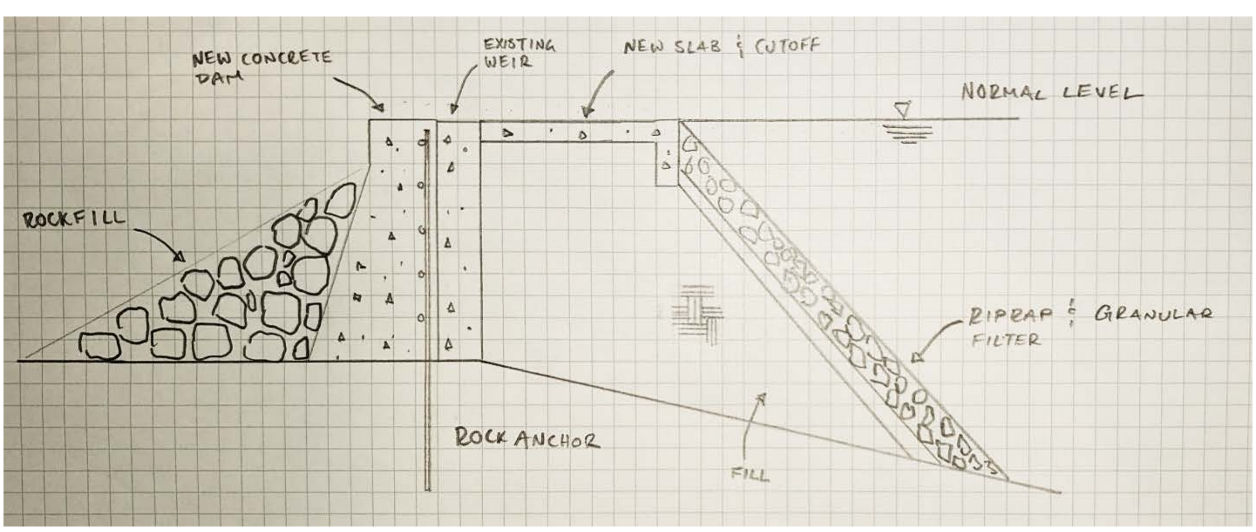

Figure 5.2 Typical section of proposed concrete structural upgrades (not to scale)

5.1.3 Outlet Works Upgrades

Provincial guidelines typically require all dams constructed on a stream channel to have a low-level outlet (LLO). The LLO provides a method of drawing down the reservoir in an emergency, as well as a method for controlling water levels if the spillway or embankment requires maintenance or repairs. The following design standards have been adopted for conceptual design and are applicable to all four dam replacement scenarios:

- The LLO diameter must be adequate to facilitate inspection, or a minimum of 0.6 m. For conceptual design, we consider a diameter of 0.45 m to be adequate to facilitate inspection while providing sufficient reservoir draining capacity. A 0.45 m pipe size can be retrofitted to the existing weir flashboard slot without needing to widen the opening. Furthermore, there is a cost savings for a 0.45 m diameter valve compared to a 0.6 m diameter valve.
- The pipe should be cast in place within the flashboard opening; one or more flanges and waterstops should be included around the pipe to mitigate leakage and thrust cracking at the pipe-concrete interface. High density polyethylene (HDPE) pipe or galvanized steel pipe would be suitable in this application.
- A watertight gate valve is required on the upstream side of the dam. Valve operation is expected to be manual, typically by providing a permanent stem and handwheel, or by a nut and a removable t-handle. Any valve actuators should be made secure to prevent vandalism or misuse. If the bridge over the spillway is sited just upstream of the spillway structure, a valve can be sited there for ease of access by operators. Siting the bridge just upstream of the weir structure also allows for easier maintenance of the spillway, such as clearance of debris.
- Due to high outlet velocities, it may be warranted to apply dental concrete or re-contour portions of the downstream channel walls if there are areas where the rock has been over-fractured and weakened by historical blasting.

5.1.4 Other Design Components

Other design components applicable to Scenarios 1 through 4 include:

- We recommend full removal of the beaver dam as part of the weir replacement. In our opinion, it is unlikely that the province will accept the presence of an active beaver dam upstream of a regulated structure, **regardless of the real or presumed stability of the beaver dam**. Correspondence to date with DSO indicates that they consider the beaver dam to be a safety concern. Even if one or more pond levellers were installed through the beaver dam, they would need to have sufficient capacity to convey the IDF. Otherwise, they would be overwhelmed during the design flood and subject the beaver dam to overtopping flow, similarly to what occurred with the existing siphons in November 2021. Beaver dam removal could occur in summer 2023 as an immediate risk reduction measure, or as part of the dam reconstruction. Apart from environmental considerations, the main drawback to removing the beaver dam in 2023 is that it couldn't be used as part of a cofferdam/site isolation system during future construction.
- A debris boom is recommended to mitigate blockage of the spillway. A typical debris boom arrangement is shown on the conceptual design drawings and consists of 0.3 m diameter logs, 20 mm chain, and 2 tonne modular concrete block (e.g., lock block) anchors. The anchors should be attached to embankment structures at an elevation above the dam crest with sufficient slack in the chains to allow for fluctuations in water levels.
- A new pedestrian footbridge will likely be required to span the upgraded spillway channel. The bridge materials and configuration should be determined during detailed design in coordination with RDN.
- A new staff gauge should be installed in the marsh upstream of the dam and surveyed in to geodetic elevations. Regular water level measurements will likely form part of the recommended dam monitoring protocol.
- Dam safety signage is recommended as a best practice, though installing signage is not a regulatory requirement at this site because it is not on Crown land. Dam safety signage typically includes the dam and stream names, along with emergency contact information for the dam owner and provincial emergency program.

- Post-construction planting will be required to restore disturbed ground areas. This will likely include a combination of grading, seeding, and planting. Site restoration plans should be prepared during detailed design, including post-construction monitoring for invasives.
- For Scenarios 1 through 3, water levels in the marsh and associated habitat areas will be reduced compared to existing conditions. No specific habitat compensation is anticipated due to the presence of blue- and SARA-listed northern red-legged frogs as the species is not presently endangered or threatened and the area has not been established as a Wildlife Habitat Area that would afford protection for the species. However, wetlands are afforded protection under the BC Water Sustainability Act, and removal of wetland area could trigger habitat offsetting requirements. Further feedback from provincial regulators would be required to determine offsetting requirements, which may be less than typical for a similar wetland given the history of anthropogenic disturbance at this site. Effects on fish populations in downstream reaches could potentially trigger fish habitat offsetting requirements. Fish sampling and habitat assessment of the downstream reach would be required to understand potential effects, which would include consideration of downstream flow seasonality in Coats Marsh Creek with timing of spawning for fish that may use the downstream reaches. If this investigation results in adverse effects, in-stream fish habitat improvements would be required. The likelihood of triggering compensation requirements is greatest for Scenario 1.

5.2 Summary of Design Components for Decommissioning (Scenario 5)

Implementing Scenario 5 (dam decommissioning) will require a series of design components to remove the dam structures and restore the site to a safe and stable condition. The level of effort to develop a dam decommissioning plan is commensurate with the size and complexity of the structure; design and assessment expectations are typically established during an initial consultation with DSO. Additional information on the DSO consultation process is available in the provincial dam decommissioning guidelines (BC FLNRORD, 2019).

DSO's mandate under the Dam Safety Regulation is to ensure that dam decommissioning does not result in adverse impacts to people, the environment, or land and other property. Dam decommissioning normally requires a period of post-construction monitoring for beaver activity to ensure that beavers don't re-dam the reservoir and create a public safety hazard. However, we recognize that the case at Coats Marsh is somewhat unique in that the beaver dam is already present and represents a natural feature that could have existed with or without the presence of the Coats Marsh weir.

From a risk management and public safety perspective, NHC recommends that the beaver dam be removed as part of the decommissioning process. This approach will result in the least long-term liability for the RDN and be most acceptable to the DSO. However, recent discussions with DSO indicate that it **may** be permissible to decommission the weir structure while leaving the beaver dam in place (D. Johnson, pers. comm.) The advantages of this approach are that the environmental values of the marsh would be largely retained, and that costs associated with restoring/stabilizing the exposed stream channel and marsh bottom would be greatly reduced. We note the following disadvantages of this approach for RDN's consideration:

- NHC is not prepared to certify, warranty, or otherwise "sign off" on the stability of a beaver dam. We note that by removing the weir, the stability of the beaver dam is likely to decrease. This is because the ponded depth in the weir pool would be eliminated, roughly doubling the total water level differential supported by the beaver dam. The beaver dam's stability may decrease over time if forage material around the marsh continues to decrease, and the beavers become less active.
- DSO would likely require that the residual hazards/risks associated with the beaver dam be documented in the decommissioning plan. Under the *Water Sustainability Act*, RDN would retain the liability associated with keeping the beaver dam in place. If there are residual life safety risks, it is likely that mitigation would be included in the decommissioning plan.

We anticipate the following design components would be required for decommissioning if the beaver dam is removed:

- It will be necessary to remove of all or a portion of the dam structure, such that the upstream water level is reduced to its pre-dam condition. At a minimum, the concrete weir structure would need to be removed down to bedrock. The berm could potentially be left in place to reduce construction costs but may be considered "residual works" under the Dam Safety Regulation. From a liability perspective, damage from residual works rests with the owner. For example, if the outlet channel was to become blocked and the marsh allowed to refill, a failure of the berm could result in damages of which the dam owner could be found liable.

- The former drainage/stream channel through the marsh will need work to restore streamflow processes and limit the mobilization of sediment downstream. This may involve widening the stream or completing bank grading to improve stability and flood flow conveyance. Armouring and sediment removal may be required at select locations if there is potential for erosion. A series of low rock weirs could be installed along the channel to re-establish grade, raise the water table, and provide some seasonal wetted area.
- Erosion control measures may be required to limit mobilization of the exposed marsh sediments to downstream areas. The need for erosion control will likely depend on the quantity of sediment present, and potential consequences in the event of increased turbidity (e.g., fisheries values and drinking water intakes at Hoggan Lake). Given that the marsh has only been continuously flooded for approximately 15-20 years, the quantity of bottom sediment should be relatively low. Erosion control could involve seeding and straw/mulch application on exposed soils or capturing sediment within the stream channel by installing a low concrete weir/sill at the outlet.
- Restoration planting will be required in disturbed areas. At a minimum, the area around the dam site will require planting to restore areas directly impacted by construction. For the remainder of the marsh, planting requirements will likely be determined through engagement with regulators. It may be possible to allow natural succession to proceed without any planting; however, this carries an increased likelihood that the exposed marsh bottom will be colonized by invasive plants. A combination of limited planting and invasives monitoring may be appropriate.
- No specific habitat compensation is anticipated due to the presence of blue- and SARA-listed northern red-legged frogs as the species is not presently endangered or threatened and the area has not been established as a Wildlife Habitat Area that would afford protection for the species. However, wetlands are afforded protection under the BC Water Sustainability Act. Removal of wetland area could trigger habitat offsetting requirements. Further feedback from provincial regulators would be required to determine offsetting requirements, which may be less than typical for a similar wetland given the history of anthropogenic disturbance at this site. Effects on fish populations in downstream reaches could potentially trigger fish habitat offsetting requirements. Fish sampling and habitat assessment of the downstream reach would be required to understand potential effects, which would include consideration of downstream flow seasonality in Coats Marsh Creek with timing of spawning for fish that may use the downstream reaches. If this investigation results in adverse effects, in-stream fish habitat improvements would be required.
- A performance monitoring and management plan will need to be developed as part of the decommissioning design. This typically includes monitoring and maintenance of channel stability, plant watering and survival monitoring, and invasives management. Adaptive responses may be included, such as increased efforts to revegetate exposed soils and bank erosion control. Based on previous projects, we expect the lifespan of the performance monitoring program to be approximately 1 to 3 years.

5.3 Conceptual Design Drawings

Appendix C provides conceptual design drawings for each of the four dam replacement scenarios; the first sheet shows a plan view of existing conditions. The drawings are intended to illustrate the approximate extents of required grading and construction works for replacement dam structures with appropriate embankments; note that NHC has not prepared detailed grading plans or surfaces, but we recommend doing so during detailed design to confirm project footprints and fill volumes. Conceptual design drawings also show wetted area extents driven by seasonal fluctuations in water levels, along with front view sections of dam configurations on the downstream side.

5.4 Cost Estimates

NHC has prepared preliminary cost estimates for the five scenarios in accordance with BC MOTI cost estimating guidelines (2020). The cost estimates are considered Class 4 (preliminary) and suitable for project planning; the estimates' accuracy is on the order of -30% to +50%. Tables 5.3 provides construction and professional services cost estimates for each scenario. The lowest estimated cost estimate is $390,000 for Scenario 1, while the highest is $1,080,000 for Scenario 4.

The following summarizes the methodology used to prepare the cost estimates, as well as assumptions and limitations:

- Preliminary quantity take-off was estimated for cut and fill materials. Unit rate construction costs were applied to the quantity take-off estimates based on previous project experience. Lump sum construction costs such as contractor general requirements, access preparation, and environmental protection were developed based on previous project experience.
- An allowance for professional services was developed based on the anticipated level of effort during design and construction of the works. Professional services are expected to include geotechnical field investigations, engineering design, environmental permitting, services during construction, and preparation of dam OMS and DEP documents.
- A general contingency of 20% was applied to the total project cost (professional services and construction).
- The following are limitations associated with the cost estimates:
    - The estimates are presented in 2023 dollars and do not account for inflation or cost escalation due to market conditions. Actual costs will be higher or lower than those provided in these estimates. Taxes are additional.
    - The estimates are based on preliminary embankment and spillway structural dimensions. Further analysis during detailed design, including geotechnical investigations, may recommend additional stripping or other work that increases the project footprint and required material quantities.
    - Environmental permitting agencies may identify requirements for offsetting (compensation) work, particularly for the lower dam elevation scenarios. The cost estimates only include site restoration work, such as planting and seeding, within the area of disturbance.
    - For Scenario 5 (decommissioning), there is significant cost uncertainty due to the range of potential requirements for site restoration and habitat compensation. Costs are presented assuming that decommissioning includes beaver dam removal. Costs would likely be lower than those presented if the beaver dam can be left in place.

Table 5.3 Cost estimates for Scenarios 1 through 5

Cost item	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Contractor general requirements	$15,000	$25,000	$30,000	$50,000	$15,000
Site access preparation and clearing	$10,000	$10,000	$10,000	$10,000	$25,000
Environmental controls and mgmt.	$30,000	$30,000	$30,000	$30,000	$30,000
Embankment work	$5,000	$135,000	$215,000	$400,000	$0
Dam decommissioning work	$0	$0	$0	$0	$20,000
Spillway and outlet works	$105,000	$105,000	$150,000	$225,000	$0
Channel reconstruction	$0	$0	$0	$0	$70,000
Site restoration	$35,000	$35,000	$35,000	$35,000	$55,000
A: Construction Cost	**$200,000**	**$340,000**	**$470,000**	**$750,000**	**$215,000**
B: Professional services	$125,000	$150,000	$150,000	$150,000	$125,000
C: Project subtotal (A + B)	$325,000	$490,000	$620,000	$900,000	$340,000
D: General contingency	$65,000	$100,000	$120,000	$180,000	$70,000
E: Project Total (C + D)	**$390,000**	**$590,000**	**$740,000**	**$1,080,000**	**$415,000**

5.5 Detailed Design and Permitting Requirements

Following RDN's selection of a preferred scenario, detailed design and permitting will be required to advance to conceptual design to construction. The following components are anticipated:

Scenarios 1 through 4:

- Geotechnical drilling or test pit investigation to confirm subgrade conditions.

- Additional engineering analysis for IDF routing and dam consequence classification.
- Detailed engineering design of the embankment, spillway, and pipe works.
- Preparation of Issued for Tender design drawings.
- Preparation of a Dam Development Report, draft OMS and DEP documents, and engineering field review plans in accordance with provincial requirements (BC FLNRORD, 2018).
- Preparation of an environmental management plan, and obtention of work permits and authorizations. We anticipate that the following permits will be required (see discussion in Appendix A):
    - Finalized water licence authorization.
    - DSO construction authorization under Division 3 of the Dam Safety Regulation. The DSO authorization covers WSA approvals, so a separate Section 11 approval is not normally required.
    - Fisheries and Oceans Canada Request for Review.
    - A provincial wildlife permit to allow amphibian salvage during construction.
    - For Scenarios 1 and 2, which reduce water levels from present conditions, consultation with regulators could identify that wetland area habitat compensation may be required for offsetting.

Scenario 5:

- Selection of a preferred decommissioning alternative, including full vs. partial dam removal and whether to remove the beaver dam.
- Additional studies and engagement to support the decommissioning approvals process. The scope of additional studies is typically determined through engagement with DSO; for Coats Marsh, the following studies are likely to be required:
    - Public engagement, referrals with other government agencies, and First Nations consultation. The DSO leads both First Nations consultation and government agency referrals, but public engagement is the responsibility of the dam owner. The scope of public engagement can vary, but typically involves public notices (e.g., mail-outs, signage, newspaper), a community meeting or individual meetings with stakeholders, and a formal comment period with associated documentation.
    - An overview-level social impact assessment **may** be required, including aesthetic concerns; potential for archeological sites; recreational objectives; First Nations considerations; and any other known community values.
    - If the beaver dam is left in place:
        - An analysis of residual hazards and potential consequences, as well as the development of mitigation recommendations.
    - If decommissioning includes beaver dam removal:
        - Detailed bathymetric survey of the marsh to confirm ground elevations and the dimensions of the existing drainage ditch/stream.
        - Sediment sampling around the pond to support site revegetation and sediment control plans.
        - Hydrologic and geomorphic assessment to determine the effects of decommissioning on flood flow attenuation and downstream channel stability.
        - Additional environmental assessments (desktop-based and field-based). The scope of environmental assessment will depend in large part on engagement with regulators, particularly around the blue- and SARA-listed red legged frogs.
- Detailed decommissioning designs, such as site grading, concrete and embankment removal, stream restoration, planting, and any compensation features.
- Preparation of Issued for Tender design drawings and construction supervision plans.
- Preparation of performance and adaptive monitoring plans.

- Preparation of an environmental management plan, and obtention of work permits and authorizations. We anticipate that the following permits will be required:
  - DSO construction authorization under Division 3 of the Dam Safety Regulation. The DSO authorization covers WSA approvals, so a separate Section 11 approval is not normally required.
  - Fisheries and Oceans Canada Request for Review.
  - A provincial wildlife permit to allow amphibian salvage during construction. Consultation with regulators may also identify specific authorization requirements related to blue- and SARA-listed species.

5.6 Construction Considerations

The following summarizes construction considerations applicable to all five scenarios:

- Site access for machinery is available vis the existing RDN trail network. The trails may require brushing, but otherwise appeared usable based on the field assessment. For Scenarios 2 through 5, access into the marsh for construction may require the use of swamp/rig mats or other approaches due to the soft bottom conditions.
- A beaver dam removal plan will be required to ensure that upstream dewatering does not result in adverse effects to amphibians, and that downstream areas aren't affected by high flows or sediment.
- Site dewatering will be required to prepare the embankment foundation and complete work in the dry. The means and methods of dewatering are ultimately the contractor's responsibility; however, the following approaches could be considered:
  - Using the existing beaver dam to provide site isolation. This could be accomplished by lowering the water level behind the beaver dam prior to construction and pumping out the work area downstream of the beaver dam. The beaver dam would be removed following completion of the dam replacement.
  - Using a man-made cofferdam (i.e., bulk bags or similar products) in lieu of the beaver dam to provide site isolation.
- The seasonal timing of construction should be considered. From a flood risk perspective, it is preferable to complete the work during the summer low-flow period. However, fire restrictions on Gabriola Island can be significant during dry conditions and authorities may not allow construction work to proceed during the summer (J. Vander Klok, pers. comm.) We recommend that RDN initiate early discussions with the fire department to evaluate any seasonal constraints. Any planned work activities should also avoid the breeding periods for birds and amphibians. Table 5.4 summarizes the applicable construction windows for this area.

Table 5.4 Summary of construction windows

Valued Component	Least Risk Window	Notes
Breeding/nesting birds	Late Mar. to mid-Aug.	Bald Eagles and Great Blue Herons can have breeding periods from January to September. If working during the breeding bird period cannot be avoided, then a pre-clearing nest survey is required.
Cutthroat Trout	Aug. 1 to Oct. 31	Default window, as there is not enough available data to confirm or refute downstream fish presence and spawning utilization. This requirement could be removed if downstream sampling is conducted and identifies no fish presence.
Northern Red-Legged Frog	Jan. to late Aug.	No formal regulated window: work should be completed after dispersal of newly metamorphosed adults (July-August, typically). Breeding season begins in February (see EDI report, p.30.) Construction could possibly be completed earlier (late-June or July) if the marsh level is maintained using temporary cofferdams or other approaches.

6 OPTIONS EVALUATION

Final selection of a preferred option will likely be a balance of several factors such as capital cost, maintenance requirements, environmental value, risk/liability, and community values. To assist RDN with evaluating the five scenarios, NHC has prepared a semi-quantitative options evaluation matrix with a series of values identified in consultation with RDN. Values presented in the options assessment matrix are assigned on a relative scale from 1 to 5; with 5 being the best possible score, such as lowest cost or highest environmental benefit, and 1 being the worst possible score, such as the highest cost or least climate change resiliency. Scores of 1 and 5 are highlighted in the table for ease of identification; cost estimates are presented in dollar values. We note that all costs and scores presented for Scenario 5 assume that the beaver dam will be removed.

Table 6.1 Options Evaluation Matrix

Evaluation Criteria	Scenario ID and Weir Elevation				
	1	2	3	4	5
	96.1 m	96.4 m	97.0 m	97.7 m	N/A
Cost Considerations					
Capital Cost (-30% to +50% uncertainty level)	$390,000	$590,000	$740,000	$1,080,000	$435,000
O&M Cost	3	2	2	1	5
Management Considerations					
Dam consequence class & regulatory involvement	2	2	2	1	5
Long-term structural liability	3	2	2	1	5
Environmental Considerations					
Wetland habitat	3	4	5	5	1
Climate change resiliency	3	4	5	5	1
Implementation Considerations					
Need for additional studies and data gap filling	4	3	3	2	1
Schedule and budget risk due to unforeseen site conditions or weather	3	2	2	1	5
Ease of site access and construction-related impacts	4	2	2	2	1
Ease of permitting and approvals	3	3	3	3	1

7 RECOMMENDATIONS

The following summarizes recommended short-term actions to improve dam safety at the site, as well as next steps to support detailed design and construction.

7.1 Short-Term Actions

- RDN should inform DSO that the proposed classification for the existing dam is High Consequence. RDN should initiate discussions with the land owner at 1040 Coats Drive regarding options for reducing flood hazards to the existing downstream cabin.
- A provincial water licence application is required to authorize surface water storage. We understand that RDN submitted a water licence application on November 24, 2022 (J. Vander Klok, pers. comm.)
- RDN must meet requirements under Part 2 and Part 3 of the Dam Safety Regulation. A High consequence dam requires weekly site surveillance. All Significant and High consequence dams require an operations, surveillance, and maintenance manual and a dam emergency plan. RDN could prepare the plans using templates available from the province or opt to have them prepared by a qualified engineer.
- RDN should remove trees from the existing berm by cutting as close to the ground as possible. Root wads should be left in place.
- Depending on their risk tolerance, RDN could consider removing the beaver dam this summer (2023) if beaver dam removal is a component of their preferred dam elevation scenario. Apart from environmental considerations, the main drawback to removing the beaver dam is that it couldn't be used as part of a cofferdam/site isolation system during construction of a future weir replacement or decommissioning.
- RDN could consider installing a temporary log boom upstream of the weir to mitigate spillway blockage in the event of beaver dam failure or other debris entrainment.

7.2 Detailed Design and Implementation Planning

An options assessment matrix is presented in Section 6 of this report to explore the trade-offs involved in selecting a replacement dam elevation. In general, a lower dam would be the least expensive option and have the lowest construction footprint and disruption, but a higher dam may be able to retain more of the characteristics of the present ecosystem and provide greater storage to mitigate against potentially higher summer evaporation losses due to climate change. Dam decommissioning (Scenario 5) would relieve RDN of its monitoring and maintenance requirements under the Dam Safety Regulation, as well as its liability in the event of a dam failure; however, this option would result in the greatest adverse environmental effects within the marsh. Following RDN's selection of a preferred scenario, detailed design will be required to advance to conceptual design to construction.

Detailed recommendations for future design and implementation, including construction windows, are provided in Section 5.

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APPENDIX A

WETLAND ASSESSMENT

Coats Marsh Replacement Weir Elevation Study: Wetland Assessment

Prepared For
Regional District of Nanaimo
1490 Springhill Road
Parksville, BC V9P 2T2

Prepared By
EDI Environmental Dynamics Inc.
208A – 2520 Bowen Road
Nanaimo, BC V9T 3L3

EDI Contact
Randy Morris
Senior Biologist

EDI Project
22N0419
Version: 3.0
April 2023

ENVIRONMENTAL DYNAMICS INC.
Down to Earth Biology

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EXECUTIVE SUMMARY

EDI Environmental Dynamics Inc. (EDI) was retained in partnership with Northwest Hydraulics Consultants (NHC) to conduct a study investigating and comparing five water management scenarios for Coats Marsh in Coats Marsh Regional Park, Gabriola Island, BC on behalf of the Regional District of Nanaimo. EDI was retained to consider potential environmental impacts, with a particular focus on characterizing wetland function for five proposed scenarios. This report describes the potential environmental impacts for each scenario, including wetland size, composition and availability of habitat for aquatic and wetland species.

Coats Marsh is controlled at the downstream end of the wetland by a concrete outlet weir. Additionally, a beaver dam is located approximately 60 m east (upstream) of the weir and is currently the main controlling factor for water level in most of the wetland. The beaver dam effectively elevates the wetland's water level above the existing weir's "design" spill level. Currently, a siphon system is in place to draw down the wetland's water levels. The long-term management goal of the RDN is to phase out the siphon system to return the marsh hydrology to a more naturally regulated state while protecting the wetland habitat.

A Qualified Professional from EDI specializing in wetland assessments conducted a site visit along with staff from RDN and NHC on September 14, 2022. The biologist completed eight assessment plots, including 4 wetland assessment surveys and 4 visual checks.

Based on the results of the field assessment, Coats Marsh is comprised of 65% shallow water, 25% marsh and 10% swamp. The shallow water ecological community is dominated by water smartweed, although yellow pond lily and a bladder wort species are also noted. Marsh areas have a high cover of reed canarygrass interspersed with other marsh species like pink spirea.

Based on elevational cross sections generated by NHC, the field assessment of current conditions, and an understanding of wetland function, the five water elevation scenarios have been evaluated for their respective environmental value.

The scenarios are defined as follow:

- Scenario 1 is defined as the new weir replaced without replacement of existing berm (weir crest of 96.1m).
- Scenario 2 is defined as the new weir set to the stop-log elevation of the existing weir (weir crest of 96.4m).
- Scenario 3 is defined as the new weir set to the concrete elevation of the existing weir (i.e., 0.6 m above the stop-log) (weir crest of 97.0m).
- Scenario 4 is defined as the new weir set to the current beaver dam elevation (weir crest of 97.7m).
- Scenario 5 is defined as the full decommissioning and removal of the weir.

The implementation of Scenario 1 will cause the greatest reduction in wetland water levels except for the decommissioning of the weir (Scenario 5). Scenario 1 (except for Scenario 5) has the highest possibility of creating the driest edge area, reducing emergent vegetation cover and associated egg-laying habitat for pond-

breeding amphibians, reducing open water habitat for waterfowl, and allowing the potential re-establishment of shrubs and trees along the periphery of Coats Marsh.

In contrast, the implementation of the highest water scenario (Scenario 4) would result in the largest wetland complex with a large area of shallow water wetland and a fringe of marsh/shrubby wetland comparable to current conditions. From an ecological perspective, Scenario 4 is the most beneficial. Increased water storage capacity can help buffer against changing climatic conditions and increased summer drought periods as it provides a mechanism that maintains the current wetland ecological diversity. Scenario 4 would likely have the greatest number of benefits to wetland species, such as northern red-legged frogs and waterfowl, given the overall availability and coverage of habitat.

The most dramatic changes to current conditions are noted with the decommissioning of the weir (Scenario 5). Based on historic air-photos of Coats Marsh area, the loss of the weir will likely result in the creation of an ephemeral stream with periodic seasonal flooding and ponding through the wettest times of the year. The cover of open water areas will be very limited in this scenario, and no permanent feeding or resting habitat for waterfowl is anticipated. Similarly, the loss of sustained flood conditions will likely result in the loss of breeding opportunities for amphibians such as the northern red-legged frog.

Although the assessments focused on different weir elevations accompanied by the removal of the beaver dam, consideration was also given to a scenario where the weir is decommissioned but the beaver dam retained. Assuming the beaver dam could function effectively on its own, it is expected that the marsh area would remain similar to present day conditions. This condition would be susceptible to change, however, if local beavers abandon the site for whatever reason, allowing the dam to deteriorate.

Despite the benefits of retaining water in Coats Marsh with a weir, some environmental risks remain in the case of a dam failure. A dam failure could result in a wash-out of the stream channel, simplifying the habitat and washing out any potential redds and eggs that might have been present from spawning Cutthroat Trout at the downstream reach of Coats Marsh stream. Cutthroat Trout would be most sensitive to a dam failure between February to May during spawning season and for the next 7-8 weeks as the eggs hatch and the fry emerge from the nests. Spring spawning surveys are recommended in the watercourse to confirm the value of this lower reach for Cutthroat and/or Rainbow Trout and how it might be affected by the Project.

In addition to fish, other aquatic and riparian species may also be present that could be sensitive to a dam failure. Northern red-legged frogs, a federally and provincially listed species, are confirmed to be present in Coats Marsh and in the surrounding forest and watercourses. The flooded marsh conditions and ample emergent vegetation provide suitable breeding habitat for red-legged frogs. The impacts of a dam failure on red-legged frogs would depend on the timing, with greatest risk being during spring breeding, egg mass development and tadpole development (February to July).

AUTHORSHIP

Team members from EDI Environmental Dynamics Inc. who contributed to preparing this report include:

Rachelle Robitaille, B.Sc., R.P.Bio .... Primary Author

Randy Morris, M.R.M., R.P.Bio., P.Ag. .... Secondary Author and Senior Review

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1 INTRODUCTION

Coats Marsh Regional Park is the first protected wetland on Gabriola Island and is managed by the Regional District of Nanaimo (RDN). This regional park is in the traditional territory of the Snuneymuxw First Nation. As identified in the 2010 Management Plan, the primary management objective for the park is environmental conservation. The water levels within the wetland are controlled by a concrete outlet weir. In 2020, it was determined that the weir has deteriorated and there is a risk of private property flooding downstream if the weir fails.

Coats Marsh weir is a concrete outlet weir that is approximately 3.3 m high (downstream side), 6 m wide and 0.6 m thick with a wooden bridge built to cross the water outlet. The weir, bridge and berm are located on Coats Marsh Creek at the west end of Coats Marsh on Gabriola Island (Photo 1-1). The design water storage of the weir is approximately 22,000 cubic meters.

Photo 1-1. Wood bridge over Coats Creek and adjacent to cement weir with berm on the other side

An existing beaver dam is located approximately 60 m east of the weir and it is currently the main controlling factor for water level in most of the wetland. The beaver dam effectively elevates the wetland's water level above the existing weir's "design" spill level. Currently, a siphon system is in place to draw down the wetland's water levels. The long-term management goal is to phase out the siphon system in order to return the wetland hydrology to a more naturally regulated state and to protect wetland habitat.

RDN requires a report which examines four different weir elevation scenarios, decommissioning and removal of the weir and recommends an optimum long-term elevation of the new replacement weir.

The five potential weir elevation scenarios that require study are:

1. Maintain an elevation where the weir structure can be replaced without having to remove and replace the existing berm.
2. Maintain the status quo. Reinforce or replace the weir at the existing elevation.
3. Raise the weir to an intermediate elevation above existing and below the top of the beaver dam.
4. Raise the weir to match the elevation of the existing beaver dam.
5. Full decommissioning and removal of the weir.

The following information has been compiled for each of the weir elevation scenarios in the report:

A. Regulatory considerations, including information on any relevant provincial or federal legislation that will impact the work.

B. A conceptual plan showing the approximate extents of required grading and construction works needed to retain the water at the proposed elevation and maintain the path connections and bridge over the weir.

C. A summary of the anticipated environmental and hydrological impacts of the proposed water elevation(s).

D. A Class 'C' cost estimate.

E. The report should include recommendations on long-term management of the siphons, the beaver dam, and any other recommended water level controls.

The main report is to recommend which scenario provides an optimum elevation for the weir and summarize the supportive evidence. The primary considerations in determining the optimum weir elevation are construction costs, environmental impact, and management of long-term hydrological risk (i.e. downstream flooding due to an adverse event.

EDI Environmental Dynamics Inc. (EDI) has been retained to provide a summary of the environmental impacts of the proposed water elevations on Coats Marsh. The focus of this report is to provide a wetland assessment of Coats Marsh based on the current conditions and on the various proposed scenarios.

1.1 GENERAL SITE DESCRIPTION

Gabriola Island is within the Coastal Douglas-fir (CDF) biogeoclimatic zone. This zone is restricted to low elevation (<150 m) coastal areas in the rain shadow of Vancouver Island. Coats Marsh is located within the

Hoggan Lake Watershed on Gabriola Island and is within the Coats Marsh Regional Park (Regional District of Nanaimo 2011).

The following text was taken directly from the Coats Marsh Regional Park 2011-2021 Management Plan (Regional District of Nanaimo 2011).

> "*Prior to its designation as a Regional Park, Coats Marsh Regional Park (RP) was a parcel of farmland owned by the Coats family and known locally as the 'Stump Farm'. The Coats Marsh property has recovered from a series of human activities including logging, burning, draining and flooding. The wetland area in the southern half of the park is not contained entirely within park boundaries. Approximately 6,000 m² of the marsh extend into neighbouring private forestry land to the east of the park, and 300 m² of marsh extend into a neighbouring private residential lot to the west of the park (Map 1-1).*
>
> *Although the wetland complex is a natural occurring feature based on topography and soil composition, its properties have been manipulated over the course of private ownership by way of draining and flooding. For approximately 20 years prior to park designation, woody debris was stockpiled on the northern margins of the wetland and burned in the autumn.*
>
> *There is 10 ha of wetland that has evolved as a shallow palustrine basin wetland. The location of two springs on the east end of the wetland were identified by planning consultants. Reed canary grass is an invasive plant species that has already become established along most of the shore of the Coats Marsh area. Reed canary grass is very aggressive and once established can achieve near total dominance over native vegetation wetland species.*"

Coats Marsh occupies an elongated somewhat oval depression of approximately maximum width of 200 m in the north-south direction and approximately 425 m long in the east-west direction (Photo 1-2). The marsh is a complex of wetland classes currently dominated by shallow water (aquatic), where permanent inundation occurs. The shallow water area transitions into a marsh, where emergent vegetation and seasonal drying occurs. Beyond the marsh area a forested swamp is presented. The forested swamp has been classified as a Western Red Cedar – Indian Plum ecological community.

Madrone (Madrone Environmental Services, Ltd 2021) state the following in their report:

> "*Since the beaver dam was constructed, there has been a transition towards a deeper aquatic component east of the dam and associated extension of seasonally flooded marsh and forested swamp beyond. Increases in wetland area have been evident for at least 10 years, related to previous beaver activity around the vicinity of the outlet weir and current beaver dam. This is evident by the occurrence of dead or dying coniferous trees (mainly Douglas fir (Pseudotsuga menziesii)) around the wetland margin that have become inundated.*"

They describe the marsh area as being vegetated with a dense coverage of sedges (*Carex* sp.) and interspersed with cattails (*Typha latifolia*), which transitions into patches of swamp areas dominated by dense hard hack (*Spirea douglasii*). Reed canary grass (*Phalaris arundinacea*) has been observed within the margins of the marsh wetland. Within the more aquatic sections of the wetland, ribbon leaf pondweed (*Potamogeton epiphydrus*) dominates most of the area (Photo 1-3) with some small patches of yellow pond lily (*Nuphar variegate*). A forested ecosystem surrounds much of the wetland and this mature forested ecosystem consists mainly of

Douglas fir and western red cedar (*Thuja plicata*). Red alder (*Alnus rubra*) also occurs along the wetland edge (Madrone Environmental Services, Ltd 2021).

Photo 1-2. Looking east towards Coats Marsh from the beaver dam.

Photo 1-3. Area between cement weir and beaver dam (looking north).

1.2 REGULATORY CONSIDERATIONS

1.2.1 FEDERAL LEGISLATION

1.2.1.1 Fisheries Act

The Fisheries Act provides for the protection and management of fish and fish habitat and defines permitting requirements for project development resulting in harmful alteration, disruption or destruction of fish habitat (Environment and Climate Change Canada 1985). Project work such as the construction of a new or upgraded weir structure in the watercourse should only proceed after review by Fisheries and Oceans Canada and the application of appropriate mitigation effort by a qualified biologist.

While no fish presence has been confirmed within the marsh, the marsh is connected to known fish habitat at Hoggan Lake. Three significant barriers to fish passage from Hoggan Lake to Coats Marsh have been documented but this does not eliminate the possibility that fish maybe present in Coats Marsh. A Fisheries and Oceans Canada (DFO) Request for Review would be recommended prior to any changes.

Under the Fisheries Act, several interim codes of practice have been published by Fisheries and Oceans Canada that provide guidance on how to undertake common instream activities to avoid potential harmful alteration, disruption, and destruction (HADD) to fish and fish habitat without requiring a more detailed assessment and review as a Notification or Authorization. One relevant interim code of practice focuses on beaver dam breaching and removal. Any alterations or removal of the beaver dam should aim to follow the best practices for the breaching and removal of a beaver that are described in the code of practice to avoid a HADD.

1.2.1.2 Migratory Birds Convention Act

The MBCA protects and conserves migratory birds (as individuals and populations), their eggs, and their nests in Canada through the implementation of the Migratory Birds Regulations and the Migratory Birds Sanctuary Regulations (Government of Canada 2018). As per the MBCA, removal of migratory birds, their eggs, or nests from a site is only permissible if the migratory birds are causing or may cause damage to property and equipment (subject to permitting). Clearing of trees or shrubs should occur outside the breeding bird window or proceed only after confirmation by a qualified biologist that active nests do not occur. Deposit of harmful substances to birds in areas or waters frequently visited by migratory birds is prohibited. The Migratory Birds Regulations are applicable to the Project. The Migratory Birds Sanctuary Regulations are not applicable to the Project as there are no Migratory Bird Sanctuaries within the region surrounding the Project development area (Environment and Climate Change Canada 2022).

For Vancouver Island and the Lower Mainland of BC, the Government of Canada generally recognizes the bird nesting period as being from late March to mid August but that some birds like Bald Eagles and Great Blue Herons may nest from January to September.

1.2.1.3 Species at Risk Act

The Species at Risk Act (SARA) provides for the legal protection of plant and wildlife species to conserve their biological diversity and prevent extirpation or extinction (Government of Canada 2016). Under SARA, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identifies and assesses plant and wildlife species considered at risk, which may then qualify for legal protection and recovery under SARA. There is the potential to encounter a species at risk, as defined under the SARA during construction of the Project. Prior to construction, appropriately timed species-specific wildlife surveys should be conducted in the proposed Project Area to determine the presence of SARA listed species. Research – Species Detection Permits are required to complete baseline surveys. If a SARA listed species is discovered prior to construction, representatives from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development should be contacted and species-specific activity restrictions and/or other mitigation measures may need to be implemented.

The presence of northern red-legged frogs which is a federally-listed species of concern and a provincially blue-listed species is already documented in the Madrone report (Madrone Environmental Services, Ltd 2021). The proponent will need to engage with FLNRORD to determine appropriate mitigations measures or any activity restrictions.

1.2.2 PROVINCIAL LEGISLATION

1.2.2.1 Water Sustainability Act

The Water Sustainability Act (WSA) regulates the licensing, diversion, storage and use of fresh water in BC and makes provision for alteration of natural watercourses or sources of water supply. Section 11 of the Water Sustainability Act requires that a person may only make "changes in and about a stream" under an Approval (or Notification).

A Section 11 approval (change approval) or notification could be required for all works within a stream.

"Changes in and about a stream" means:

> a) Any modification to the nature of a stream, including any modification to the land, vegetation and natural environment of a stream or the flow of water in a stream, or
>
> b) Any activity or construction within a stream channel that has or may have an impact on a stream or stream channel.

"Stream" means:

> a) A natural watercourse or natural body of water, whether or not the stream channel of the stream has been modified; or
>
> b) A natural source of water supply
>
> Including, without limitation, <u>a lake, pond, river, creek, spring, ravine, gulch, wetland</u> whether or not usually containing water, including ice, but does not include an aquifer. In support of the federal Fisheries Act, channelized streams and some constructed ditches that provide fish habitat are also considered streams.

"Wetland" means a swamp, marsh, fen or prescribed feature.

The "A Users' Guide for Changes In and About a Stream in BC", from January, 2022 states that: Wetlands are "considered streams under the Water Sustainability Act (WSA) and are defined as swamps, marshes, and fens, but not bogs".

The Provincial Dam Safety Officer (DSO) approval covers Authorizations under the WSA and a separate Section 11 application is not normally required.

1.2.2.2 Wildlife Act

The Wildlife Act defines wildlife as all native (and some non-native) amphibians, birds, mammals, and reptiles that live in British Columbia (BC Ministry of Forests, Lands and Natural Resource Operations 2019). The Wildlife Act provides for the protection, conservation, and management of wildlife populations and wildlife habitats within British Columbia. Under Section 34 of the Act, it is an offence to possess, take, injure, molest, or destroy a bird, its egg(s), or a nest that is occupied by a bird or its egg(s). The nests of certain species[1] are protected year-round. Wildlife species can be legally designated as endangered, threatened, or special concern under the Act, which enables penalties for killing or harming wildlife, or the establishment of Critical Wildlife Habitats in Wildlife Management Areas.

Appropriately timed wildlife surveys should be conducted in the proposed Project Area to determine the presence of species listed under the Wildlife Act. If a species listed under the Wildlife Act is found, representatives from the MOE should be contacted and species-specific activity restrictions (MOE 2017) and/or other mitigation measures may need to be implemented.

The presence of birds and amphibians have been noted within Coats Marsh. If any Project activities are planned during breeding windows or involve clearing of bird and amphibian habitat, then a wildlife management and monitoring plan should be developed before construction is initiated or a wildlife management section incorporated into the Construction Environmental Management Plan to mitigate any Project related affects on wildlife.

Under Section 9 of the Wildlife Act, it is an offence to disturb, molest or destroy a beaver house or den or beaver dam. This offence does not apply if the person is a trapper, licensed under the Act, under lawful authority for the protection of property or where the action is authorized by regulation (MELP 2001). The Ministry of Environment, Lands and Parks (MELP), Vancouver Island Region developed guidelines to assist managers towards more environmentally-sensitive management of beaver and beaver dams. The guidelines described in Beaver Management Guidelines should be incorporated into the Construction Environmental Management Plan (MELP 2001).

[1] Eagle, peregrine falcon (*Falco peregrinus*), gyrfalcon (*Falco rusticolus*), osprey (*Pandion haliaetus*), heron, pileated woodpecker (*Dryocopus pileatus*) or burrowing owl (*Athene cunicularia*).

2 DESKTOP REVIEW

2.1 ECOLOGICAL COMMUNITIES

A sensitive ecosystem inventory was completed for Gabriola Island by the Island Trust in 2007. Based on this mapping product (see Appendix B), the Coats Marsh is within polygon 50287 which is described as wetland complex composed of 60% shrubby swamp (Pink spirea – Sitka sedge swamp (Ws50)) and 40% open water and the area is surrounded by polygon 50295 which is described as being 90% Western redcedar – Indian plum (RP) ecological community and 10% rural residential (RW).

Madrone (Madrone Environmental Services, Ltd 2021) describes the Coats Marsh as a wetland complex consisting of a mix of cattail marsh and shallow water and the forest surrounding most of the wetland is described as being a forested swamp.

Coats Marsh is a wetland complex composed of the following wetland classes: 1) shallow water, 2) marsh and 3) swamp. Based on the BC guide to wetland identification (MacKenzie and Moran 2004):

Shallow water wetland classes are defined by MacKenzie and Moran (2004) as:

> "*Areas with shallow waters dominated by rooted, submergent and floating aquatic plants. These communities are always associated with permanent still or slow-moving waterbodies. Shallow-water sites are usually permanently flooded, rarely they may become exposed during extreme drought years. Shallow-water communities most commonly occur where standing water is less than 2 m deep in mid summer. Aquatic plants may root in mineral soils or in well-humified sedimentary peat (MacKenzie and Moran 2004).*"

A marsh wetland class is defined as:

> "*A marsh is a shallowly flooded mineral wetland dominated by emergent grass-like vegetation. A fluctuating water table is typical in marshes, with early season high water tables dropping through the growing season. Exposure of the substrate in late season or during dry years is common. The substrate is usually mineral, but may have a well-decomposed organic veneer primarily from marsh emergent (MacKenzie and Moran 2004)*"

This wetland class typically has low plant species diversity and is dominated by one or two plant species. Marshes have greater than 10% cover of emergent grasses, sedges, rushes, or on occasion forbs or horsetails. The moss, shrub and tree layers are usually absent or sparse (<10%) within a marsh and aquatic plants are common especially in marshes that retain standing water for all or most of the year (MacKenzie and Moran 2004).

The guide to wetland identification defines a swamp as:

> "*A forested, treed, or tall shrub, mineral wetland dominated by trees and broadleaf shrubs on sites with a flowing or fluctuating, semipermanent, near-surface watertable. Tall shrub swamps are dense thickets, while forested swamps have large trees occurring on elevated microsites and lower cover of tall deciduous shrubs. Both types of swamps have*

abundant available nutrients from groundwater and often have surface standing water (MacKenzie and Moran 2004)."

Forest swamps are often considered a transitional area between wetlands and uplands and often have a mix of terrestrial and wetland microhabitats. Depressions within swamps support hydrophytic plants and the elevated microsites under conifer trees are more favourable to terrestrial species. Swamps also frequently occur as small components of a larger wetland system (MacKenzie and Moran 2004).

2.2 WILDLIFE

Marshes are the most heavily used wetland class by wetland-dependent wildlife species. This is because marshes can support a large crop of palatable vegetation, plankton, and aquatic invertebrates. Amphibians, semi-aquatic mammals and waterfowl favour marshes because they provide a good food source, good cover, and open water for the young (MacKenzie and Moran 2004).

2.2.1 AMPHIBIANS

According to Madrone (Madrone Environmental Services Ltd 2021), Coats Marsh provides confirmed habitat for northern red-legged frogs (*Rana aurora*) which is a federally-listed species of concern and a provincially blue-listed species. The wetland may provide breeding habitat for this species since the wetland contains numerous egg-mass attachment media such as woody debris and emergent vegetation throughout the wetland area. The adjacent forest also provides security and forage habitat for dispersing native amphibians. Madrone noted at least 20 northern red-legged frogs during their site assessment and also noted the presence of Pacific chorus frogs (*Pseuadacris regilla*) within the wetland (Madrone Environmental Services, Ltd 2021). EDI also noted the presence of Pacific chorus frogs during our site assessment (Photo 2-1). It should be assumed that other native amphibian species such as northwestern salamanders (*Ambystoma gracile*) and rough-skinned newts (*Taricha granulosa*) could also inhabit the wetland.

2.2.2 BIRDS

According to Madrone (Madrone Environmental Services, Ltd 2021), Doe (Doe 2019) has confirmed the occurrence of at least 16 species of wading birds, swans, geese and waterfowl within the Coats Marsh area. Species observed include: yellowlegs (*Tringa melanoleuca*), northern shovelers (*Spatula clypeata*), trumpeter swans (*Cygnus buccinator*), Canada geese (*Branta canadensis*), ring-necked ducks (*Aythya collaris*), ruddy ducks (*Oxyura jamaicensis*), green-winged teals (*Anas carolinensis*), blue-winged teals (*Anas discors*), gadwalls (*Mareca strepera*), buffleheads (*Bucephala albeola*), American widgeons (*Mareca americana*), mallards (*Anas platyrhynchos*), American coots (*Fulica americana*), wood ducks (*Aix sponsa*), pied-billed grebes (*Podilymbus podiceps*), and hooded mergansers (*Lophodytes cucullatus*).

None of the birds observed by Doe are Provincially or Federally listed species.

Photo 2-1. Pacific chorus frog on a cattail leaf.

2.3 FISH AND FISH HABITAT

Various records and reports indicate that fish have not been detected in Coats Marsh although this does not definitely confirm their absence. According to *Appendix A: Ecological Features and Management Recommendations* (Foul Bay Ecological Research Limited, 2010), of the *Coats Marsh Regional Park 2011-2021 Management Plan* (Regional District of Nanaimo 2011), some fish sampling has occurred in Coats Marsh. Four minnow traps, baited with salmon eggs, were placed in Coats Marsh on December 1, 2010, and left for 24 hours. No fish were trapped. This does not eliminate the possibility that fish are present. It is highly unlikely that Coats Marsh supports a natural population of salmonid fish, predominantly due to historic drawdowns of the wetland for agricultural purposes as well as several documented barriers to any upstream fish passage from Hoggan Lake.

Three significant barriers to fish passage were identified in Appendix A of the Parks Management Plan (Foul Bay Ecological Research Limited, 2010). The first barrier is described as the concrete weir structure at Coats Marsh. This weir has a 2m drop between the top of the baffle and the water surface below. A second barrier, a 1.5 m constructed rock dam, is located approximately 50 m downstream from the weir, while a third barrier, another 1.5 constructed rock dam (resulting in a pool) is located approximately 90 m downstream from the weir.

Madrone (2021) also reported a barrier to fish passage along the outlet stream, located approximately 50 m from Hoggan Lake. As described, the barrier consists of a bedrock step consisting of a drop of 50% over a distance of more than 2 m. They concluded based on length and gradient of the step, there is no reasonable passage for fish from Hoggan Lake to pass upstream beyond this barrier.

The Coats Marsh stream is documented as dewatering seasonally in the late summer. Dry conditions (i.e. no connecting surface flow but with some residual pools) have been documented by Doe (2021) and during a field inspection on October 11, 2022 near the downstream reach (L. Chira, EDI, Pers. Comm., October 11, 2022). A stream survey by Madrone (2021) on July 23, 2021, noted that only sections of the stream were flowing, and the remaining flows were minimal.

Fish presence has been demonstrated in Hoggan Lake; it was stocked with Cutthroat Trout in 1924 and 1927 (FISS 2010). Both Cutthroat Trout and Rainbow Trout were observed in Hoggan Lake in 1972 (FISS 2010). Observations of Cutthroat Trout in 1972 indicate that either the stocked fish in the lake during the 1920's established a self-sustaining population, or that the lake has always had a natural population of Cutthroat Trout. Subsequently, the lake has been intensely sampled as part of ongoing research into populations and species of threespine stickleback. Targeted sampling by various academic researchers has occurred in Hoggan Lake from 2007 to 2009, 2012, 2015 and 2017. Although the research was targeting stickleback, no captures of salmonid species were documented across these years.

Interviews from the Coats family from 1972 suggested that some spawning by cutthroat or rainbow trout had occurred in the lower reach of the Coats Marsh stream, so utilization by these spring-spawning salmonid species can not be ruled out (Burns 1972).

3 WETLAND FIELD INVESTIGATION

The BC Government has several initiatives under development to assist with the protection, maintenance and restoration of wetlands. One of these initiatives is the development of wetland guidelines. The *Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in BC* (Province of British Columbia 2009) states that there are three primary objectives for the protection and management of wetlands:

- Protect and maintain habitats and species;
- Protect and maintain water quantity; and
- Protect and maintain water quality.

The initial step is to identify the extent and types of wetlands found within an area (Province of British Columbia 2009). Another step is to determine the features and functions that wetlands currently provide within an area. The goal of the following wetland survey was to collect information on Coats Marsh to assist in making an assessment on how the 3 proposed scenarios would affect the Coats Marsh wetland complex.

Wetland ecological function can be defined as the natural physical, chemical, and biological processes that are associated with wetlands. These natural processes are independent of considerations of the benefits of those processes to humans. Wetland ecosystems are dynamic and influenced by many factors which signifies that wetland function can be difficult to measure and valuate.

3.1 METHODS

Assessments of wetland are challenging due to the range of assessment methods, the range of level of detail required and the effectiveness of the evaluation methods that can be incorporated into the assessment (Fennessy et al. 2007). Wetland assessments can be conducted within a three-tiered approach from desktop landscape-scale assessments (Level 1), to rapid field assessments (Level 2) and the most detailed assessments (Level 3) that can include intensive field data collection and/or modelling, or long-term monitoring programs (Hanson et al. 2008). A Level 2 (rapid field assessment) approach was used to assess Coats Marsh.

Sample areas were placed within easily accessible areas along the periphery of Coats Marsh. Plots were placed in homogenous areas. A 5 m by 5 m plot area was used since there was only a narrow band of accessible wetland area. The assessment plots were made to fit within these narrow wetland communities and this also was completed to ensure no upland vegetation and soils were included in the wetland assessment. Soils were recorded from a soil pit of at least 50 cm in depth.

Two plot types were used to complete the wetland assessment: wetland assessment plots and visual checks. The EDI terrestrial ecologist completing the assessment recorded field data using EDI wetland assessment form (Appendix A) for all ground inspection plots. Ground inspection are a description of site, soil and vegetation conditions that help inform wetland class or other useful attributes (e.g., structural stage, soil moisture).

Visual checks were recorded in a field notebook. Visual checks entail a brief on the ground field description of the site and identifies general vegetation cover. Visual checks are intended to be rapid on the ground assessments. At all plot locations, GPS coordinates were recorded, and digital photographs were taken.

3.2 RESULTS

A rapid wetland field assessment was completed on September 14th, 2022, by an EDI terrestrial ecologist. Eight assessment plots were established: 4 wetland assessment forms (WAF) and 4 visual checks (Table 3-1, Appendix A). Representative plot photos are also provided (Photo 3-1 to 3-8). Table 3-2 describes the wetland classes and percent cover observed around each wetland assessment plot.

The SEI described Coats Marsh as being 60% swamp and 40% shallow water. The field verification estimates Coats Marsh as currently overall being 65% shallow water, 25% marsh and 10% shrubby swamp. The SEI was mapped in 2007 and there is the possibility that Coats Marsh was never field verified. Also, more recent beaver activity could have also changed the ecological communities associated with Coats Marsh since dead trees were present in all assessment plots as seen in representative plot photos.

Coats Marsh is currently a wetland complex composed of shallow water, marsh and swamp ecological communities with transitional areas between the ecological communities. The shallow water ecological community is dominated by water smartweed (*Persicaria amphibia*). The shallow water area between the beaver dam and the existing weir also contains yellow pond lily (*Nuphar variegate*) and a bladder wort species (*Utricularis* sp.).

The marsh component of this complex is currently dominated by reed canary grass (*Phalaris arundinacea*). There are patches of cattails (*Typha latifolia*) along the edges of the beaver dam and the weir berm. Like many marshes, plant diversity is low except in the transitional area between the shallow water and marsh. Currently most of the periphery of the shallow water and the adjacent forested area is a transitional area. The transitional area is composed of mixture of emergent and hydrophytic vegetation such as water smartweed, bladder wort, pondweed (*Potamogeton* sp.), sedges (*Carex* sp.), common rush (*Juncus effusus*), and marsh horsetail (*Equisetum palustre*). Some of the sections currently classed as marsh contain dead/dying trees which signifies inundation of these areas have occurred for a period long enough to modifying the wetland class from swamp to marsh.

In areas that were not inundated during the September site visit, the presence of shrub cover such as pink spirea (*Spirea douglasii*) was observed. These areas were considered more of a pink spirea swamp (portions of CM02 and CM08 see Map 1-1 for locations) than marsh.

Deer tracks were observed near plot CM03 (Map 1-1). While walking on the beaver dam more than twenty chorus frogs were observed on cattail leaves. A few ducks were observed swimming in the shallow open water. Many bird species were heard using the edge habitat between the wetland and the forested area.

Table 3-1. List of investigation plots with type of plot established and general location comments.

Plot #	Type	UTM Location		General Site Description
		East	North	
CM01	Visual check	440546	5444733	Plot is on the northern edge of Coats Marsh within the area between beaver dam and the cement weir. Plot is approximately 5 m from the forest edge (Photo 3-1). The edge between wetland and forest is slightly “bermed” (less than a 1 m in height).
CM02	WAF	440549	544683	Opposite of CM01 and west of the beaver dam. Here the edge between wetland and forest is not “bermed” (Photo 3-2). Dead trees present.
CM03	Visual check			This plot is on the same side as CM02 but on the other side of the beaver dam (Photo 3-3).
CM04	Visual check	440685	5444725	This plot is within the burn pile clearing and is “bermed” from the wetland and is adjacent to Coats Marsh (Photo 3-4).
CM05	WAF	440689	5444701	This plot is on the wetland side of the burn pile clearing “berm” (Photo 3-5)
CM06	WAF	440947	5444708	This plot is on the north east side of Coats Marsh (Photo 3-6). Another beaver dam was observed closer to the forest edge.
CM07	Visual check	440983	5444636	This plot opposite end of Photo 3-7
CM08	WAF	440884	5444518	Photo 3-8

Photo 3-1. Example of vegetation observed at CM01.

Photo 3-2. Looking east from center of plot CM02 towards the beaver dam.

Photo 3-3. Looking north from center of plot CM03.

Photo 3-4. Looking west from center of plot CM04 towards Coats Marsh.

Photo 3-5. Looking west from center of plot CM05.

Photo 3-6. Looking south from center of plot CM06.

Photo 3-7. Looking west from center of plot CM07.

Photo 3-8. Looking north from plot centre of CM08.

Table 3-2. Summary of site description of wetland assessment plots.

Plot	Elevation (m)	Drainage	Wetland area summary						General location
			% area P1	Class P1	% area P2	Class P2	% area P3	Class P3	
CM02	106	Imperfectly	60	Shallow water	30	Swamp	10	Marsh	Represents section between beaver dam and cement weir. Marsh is mostly cattails and Swamp is a pink spirea dominated swamp (Ws50).
CM05	100	Imperfectly	90	Shallow water	10	Marsh			Represents the section of Coats Marsh east of the beaver dam near the burn pile clearings
CM06	101	Moderately well drained	70	Shallow water	30	Marsh			Represents NE section of Coats Marsh.
CM08	99	Poorly	60	Marsh	30	Shallow water	10	Swamp	East side of Coats Marsh near trail from Stanley Place. The area is converting from a swamp ecological community to a marsh ecological community.

4 DISCUSSION

According to Mackenzie and Moran (2004) marshes are the easiest wetland class to create artificially. This is because they typically form naturally in recently created wetland environments such as roadside ditches, sewage lagoons, etc. Most marshes are tolerant of hydrological modifications that are not outside their broad natural range. If the hydrological regime of a marsh is maintained, it will recover from grazing or even severe mechanical disturbance (MacKenzie and Moran 2004). Both the proposed water level fluctuations and natural seasonal fluctuations should be tolerated by the marsh.

The proposed scenarios and removal of the existing beaver dam would create more stable and consistent seasonal water levels compared to current water level fluctuations. From an ecological perspective, this would allow the development of more stable ecological communities and associated wildlife habitat.

The scenarios are defined as follow:

- Scenario 1 is defined as the new weir replaced without replacement of existing berm (weir crest of 96.1m).
- Scenario 2 is defined as the new weir set to the stop-log elevation of the existing weir (weir crest of 96.4m).
- Scenario 3 is defined as the new weir set to the concrete elevation of the existing weir (i.e., 0.6 m above the stop-log) (weir crest of 97.0m).
- Scenario 4 is defined as the new weir set to the current beaver dam elevation (weir crest of 97.7m).
- Scenario 5 is defined as the full decommissioning and removal of the weir.

Note that the seasonal water level fluctuation for all four scenarios is approximately 0.4 m (0.1 m above the weir crest in winter, and 0.3 m below the weir crest in summer). This is lower than the current water level fluctuations experienced by the marsh. Water levels at the current weir have fluctuated much more due to the narrow weir slot opening restricting flow and creating a yo-yo effect during winter floods. It is anticipated that over time, this wider fluctuation in water elevation would influence vegetation composition and habitat availability within the drawdown zone. For example, species such as northern red-legged frogs, which lay their eggs on the margins of wetlands in emergent vegetation, could face stranding of egg masses with larger drawdowns in the spring (Maxcy 2004). The new weir will have a 4-6 m wide spillway and produce much more consistent winter water levels.

The following illustrates projected water levels for each scenario and at different cross-sections locations across the wetland complex area (Figures 4-1 to 4-5). The following assumptions have been made by the design team:

- The ground surface is based on a composite of 2010 bathymetry data, 2019 LiDAR, and limited NHC survey around the weir and berm area. The slope of the marsh fringe area shown in the cross sections are subject to uncertainty due to the 2010 bathymetry having limited data associated with this area.

- The seasonal high-water level for all scenarios is estimated as 0.1 m above the weir crest elevation. The water level will exceed this value during floods.
- The seasonal low water level for the first four scenarios is estimated as 0.3 m below the weir crest elevation. This is based on average water balance calculations for the summer; dryer than average summers would result in additional drawdown.
- The current beaver dam will be removed for all scenarios presented.

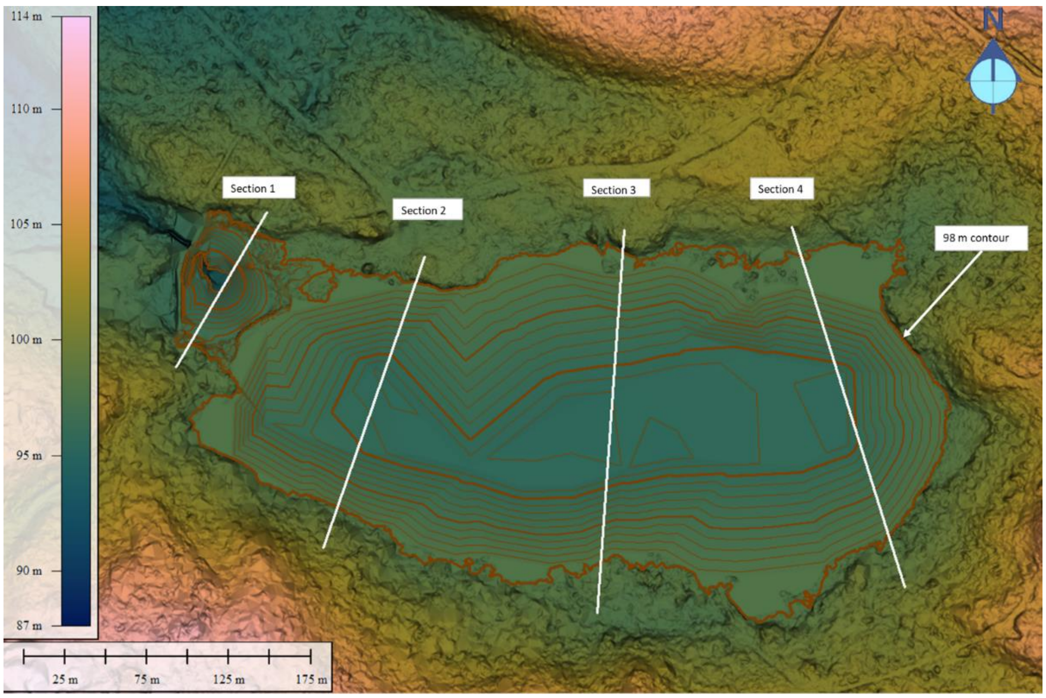

Figure 4-1. Combined 2019 LiDAR imagery and limited 2010 bathymetry of Coats Marsh section areas of cross-sections

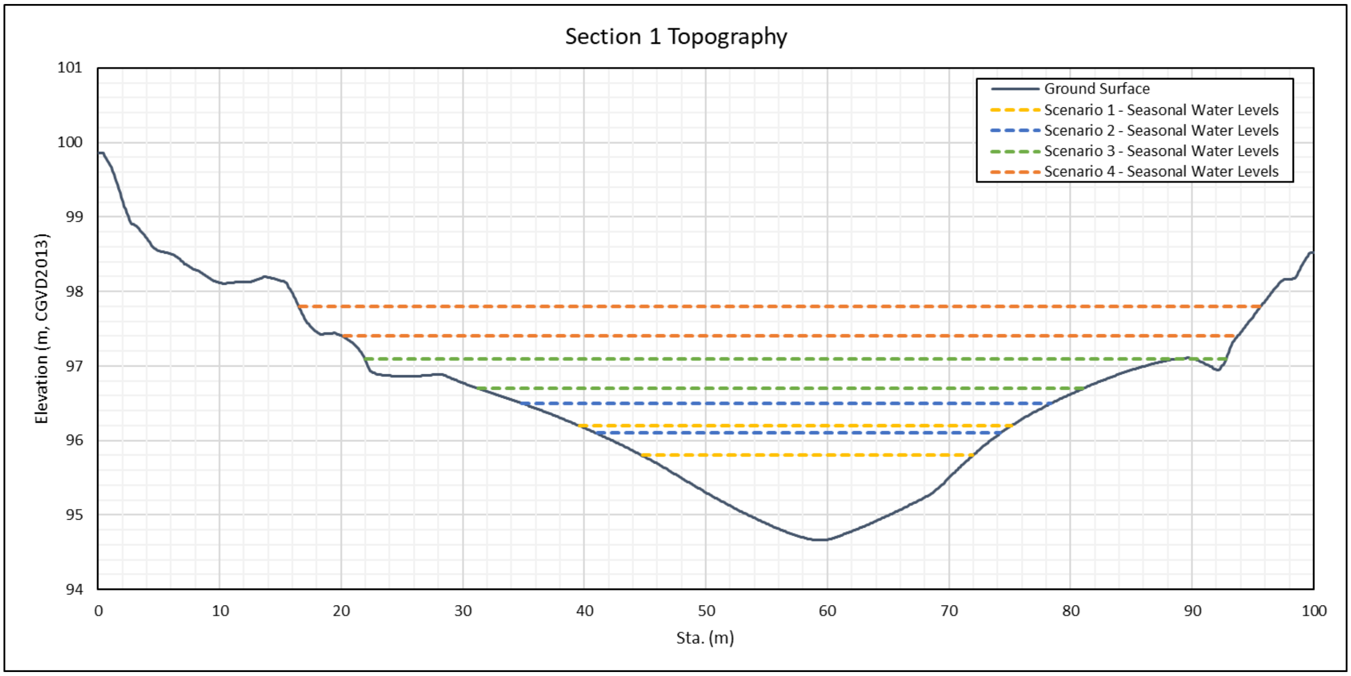

Figure 4-2. Cross section demonstrating seasonal water levels for all 4 scenarios at Section 1.

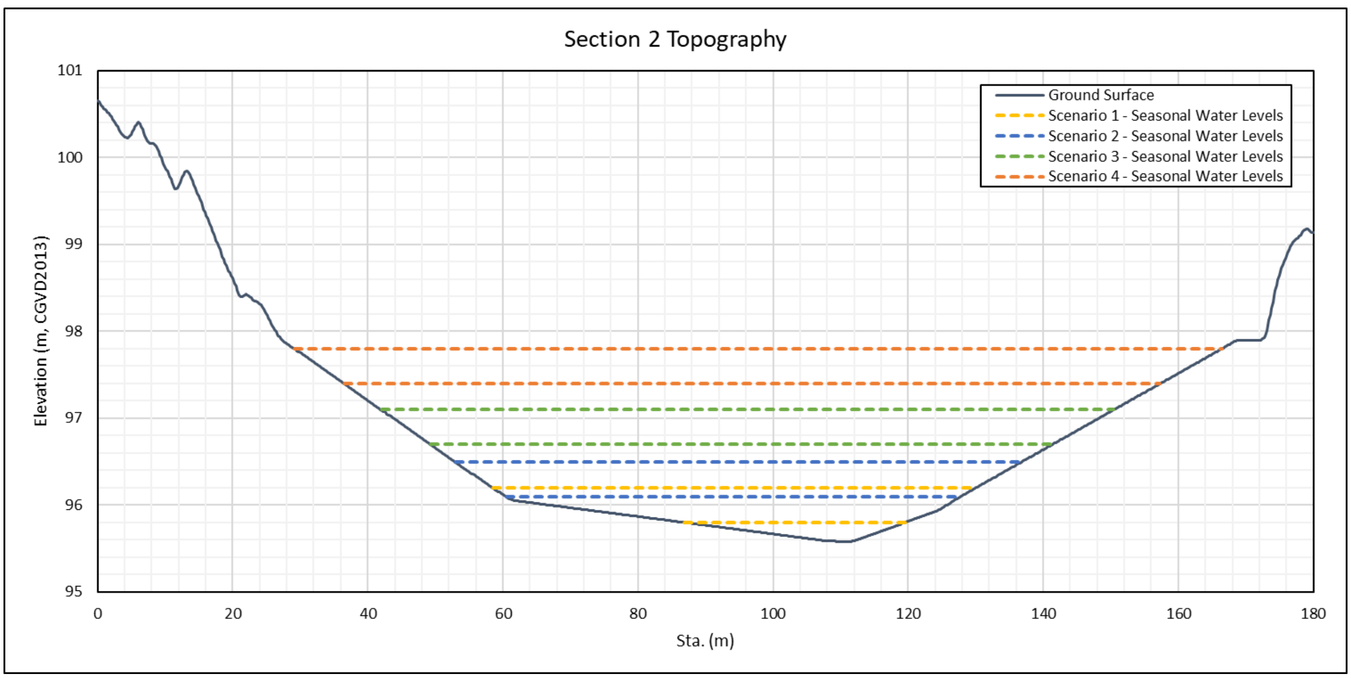

Figure 4-3. Cross section demonstrating seasonal water levels for all 4 scenarios at Section 2.

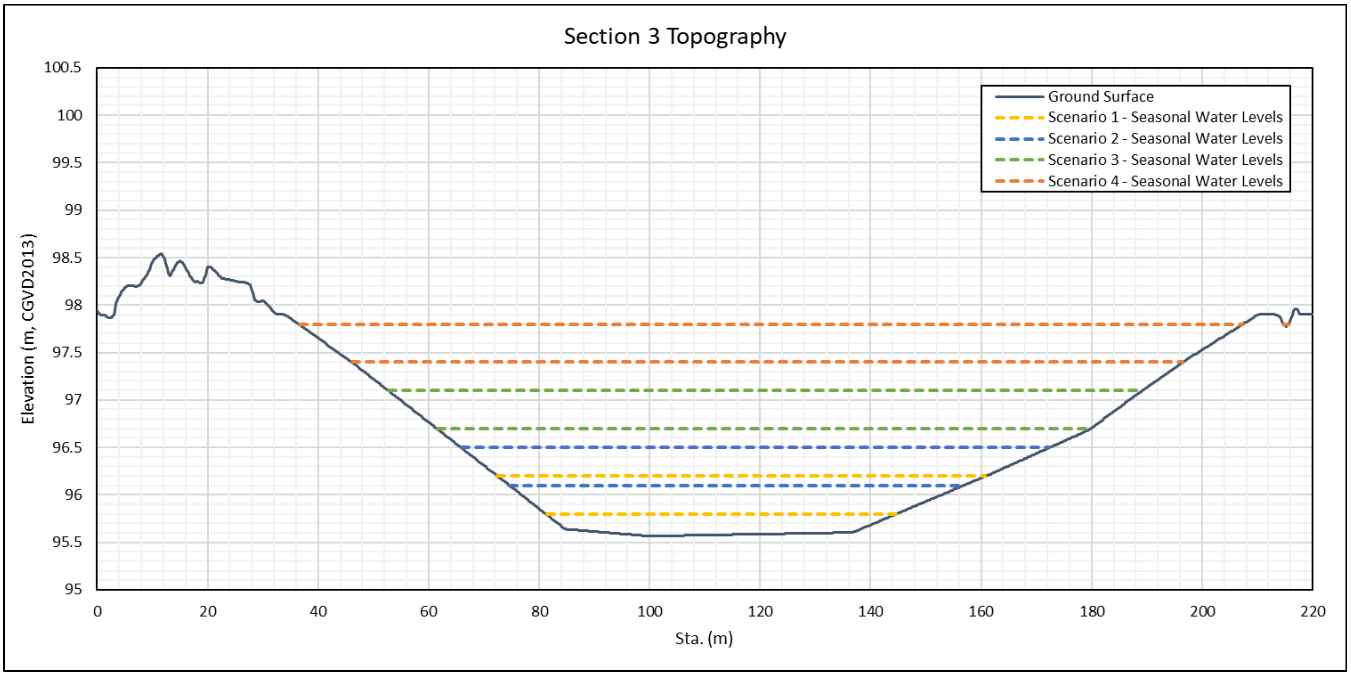

Figure 4-4. Cross section demonstrating seasonal water levels for all 4 scenarios at Section 3.

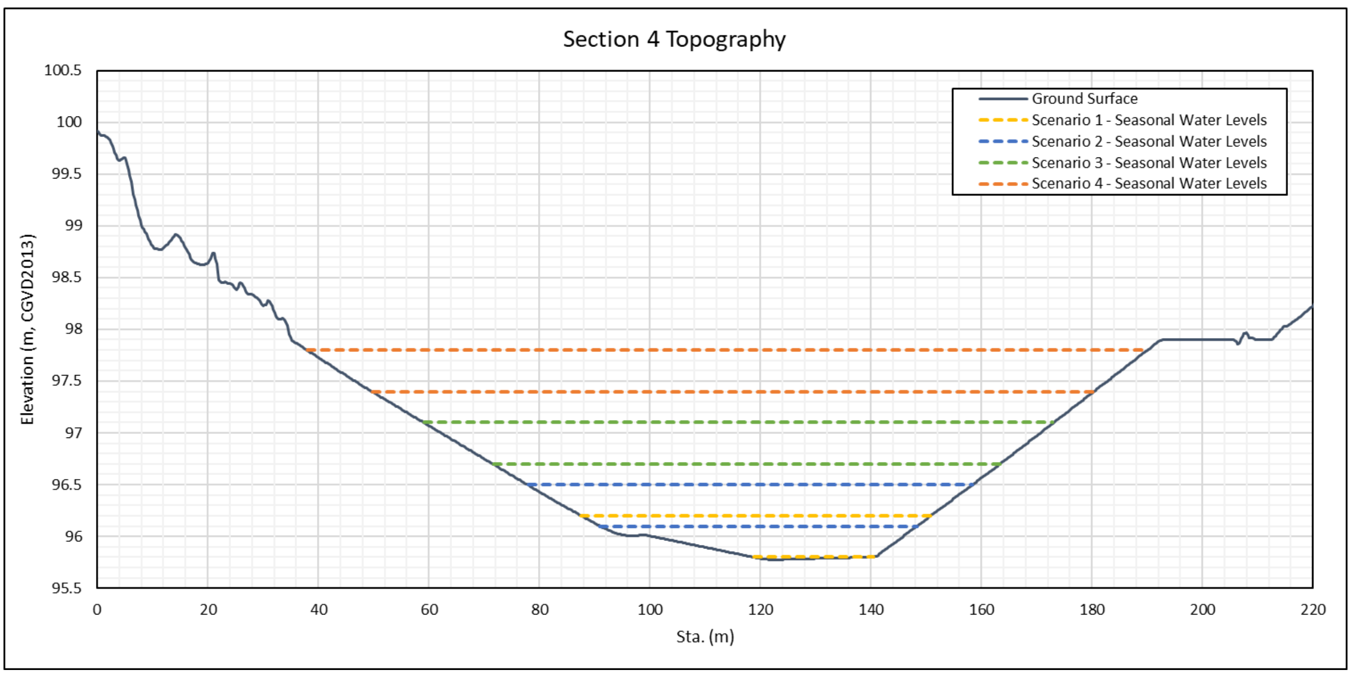

Figure 4-5. Cross section demonstrating seasonal water levels for all 3 scenarios at Section 4.

With the proposed removal of the existing beaver dam, RDN will be required to apply for an exemption to allow for the destruction of a beaver dam. The removal of the beaver dam should follow DFO's interim Code of Practice for beaver dam breaching and removal and the MELP Vancouver Island Region Beaver Management Guidelines. If the beaver dam removal can not meet all of the conditions of the DFO Code of Practice, at minimum, a Request for Review to Fisheries and Oceans Canada will be required.

The effects of the construction footprint from all scenarios will be limited in duration but Scenario 1 will have the smallest construction footprint and Scenario 5 will have the biggest construction footprint.

All Scenarios will reduce the amount of seepage through the weir potentially changing the timing and volume of downstream flows. The impact of this change is difficult to assess without a greater understanding of the volume of flows related to the seepage. At present, with seepage through the weir, the outlet stream typically dewaters in the late summer (Doe 2021). With a reduction in seepage, this dry period may happen sooner.

Cutthroat Trout, if present, are spring spawners (February-May) with fry emerging and leaving the redd seven to eight weeks later (April-July). Given the low elevation and latitude, spawning would be anticipated to occur earlier (February-March) in the season to coincide with colder water temperatures. To confirm the potential impacts to Cutthroat Trout of earlier seasonal dry conditions, a spring spawning survey would be recommended to determine if and when spawning is occurring in the watercourse.

4.1 SCENARIO 1

The implementation of Scenario 1 is to establish an elevation where the weir structure can be replaced without having to remove and replace the existing berm. The implementation of Scenario 1 will cause the greatest reduction in wetland water levels except for the decommissioning of the weir (Scenario 5). As illustrated in Figures 4-2 to 4-5 the highest water levels will be slightly higher than Scenario 2 lowest water levels across the marsh with many sections drying up during summer months such as the eastern border of the marsh (east of section 4 on Figure 4-1). Overall, the area will transition towards having a shallow aquatic component with a decrease in wetland area.

Scenario 1 (except for Scenario 5) has the highest possibility of creating the driest edge area, thereby allowing the potential re-establishment of shrubs and trees along the periphery of Coats Marsh. The reduction in open water area could reduce the use by waterfowl.

This scenario has the potential to create the most forage for beavers based on the assumption that deciduous vegetation or potential beaver forage material could encroach into areas that are currently inundated.

If beaver food sources become depleted, beavers tend to move into new habitat. But with Scenario 1 there is the potential for the wetland to start infilling naturally along the edges and for the re-establishment of a swamp ecological community. This would assist with early successional stage deciduous shrub vegetation to re-establish around the marsh and following re-establishment of an adequate food supply, there would be the potential for beavers to remain in the area or for beavers to move back in and create a dam or rebuild the existing dam and flood the area again.

As the scenario with the greatest reduction in water levels and reduction in wetted surface area, Scenario 1 is anticipated as having lower habitat value than the higher-water scenarios for amphibian species, particularly northern red-legged frogs, which rely on emergent vegetation on the margins of ponds and marshes for breeding and egg laying. In addition to the anticipated loss of breeding habitat in the reduced margins of the marsh, water temperatures in the shallowest scenario are also anticipated to warm up faster and to a higher temperature than the deeper water scenarios. This is supported by the typical relationship between light and water depth, where light decreases exponentially with depth in the water column. Increased water temperatures are generally considered less-desirable, particularly in consideration of amphibians such as the cold-adapted northern red-legged frogs (COSEWIC 2004).

Although fish absence has not been confirmed in the pond, the documented presence of multiple barriers to fish passage between Coats Marsh and Hoggan Lake and lack of fish detections during one documented fish sampling event (Foul Bay Ecological Research 2010) suggests that the pond likely does not support a population of salmonid fish.

Historic interviews with the Hoggan family, reported by Burns (1972), suggested that the downstream area of the Coats Marsh outlet stream near Hoggan Lake had spawning habitat for resident Cutthroat Trout although this is unconfirmed. Spawning and rearing is unlikely to be affected greatly by a reduction in water elevation, assuming that continued passive operation of the weir will result in natural seasonal flow regimes extending into early summer. To determine if the proposed changes in downstream flow conditions will have an impact, further studies will be required to confirm the presence of spring-spawning salmonid species in the outlet stream and to determine if the new conditions will supply sufficient flows to support spawning and fry emergence. Impacts to spawning may trigger the need for a DFO Authorization and/or habitat compensation. Aside from decommissioning (Scenario 5), of the four scenarios that include water retention with a weir, Scenario 1 is anticipated as having the greatest potential impacts to environmental values.

4.2 SCENARIO 2

The implementation of Scenario 2 will cause a reduction in wetland water levels to the existing stop-log elevation, which will cause a decrease in the depth and size of aquatic open water with an increase in marsh area. This scenario has a high possibility of creating a “drier” edge area, thereby allowing the potential re-establishment of shrubs and trees along the periphery of Coats Marsh.

Scenario 2 will decrease the area of shallow water and will increase the marsh ecological community area and potentially re-introduce more swamp ecological community area. This scenario will maintain an area of open water especially within the middle of Coats Marsh that will allow continued use by waterfowl. Overall, Scenario 2 will have lower water levels and decreased wetted areas.

This scenario also has the potential to create forage for beavers based on the assumption that deciduous vegetation or potential beaver forage material could encroach into areas that are currently inundated.

Similar to Scenario 1, this lower-depth scenario is anticipated as having a relatively lower habitat value for amphibian species such as northern red-legged frog than the status quo and the higher water level scenarios proposed (e.g. Scenarios 3 and 4). The reduction in general surface area of the margins of the marsh represents a likely reduction in the available emergent vegetation and subsequently, a reduction in breeding habitat. Additionally, the shallower waters of Scenario 2 are also anticipated to warm up more than the deeper water scenarios, which is generally considered less-desirable for northern red-legged frogs (COSEWIC 2004).

As discussed, the pond likely does not support a population of salmonid fish although the absence of salmonid species has not been confirmed. Also, spawning and rearing habitat in the Coats Marsh outlet stream near Hoggan Lake is unlikely to be affected greatly by a reduction in water elevation, assuming that continued passive operation of the weir will result in a natural seasonal flow regime that extends into early summer. The presence of spawning Cutthroat Trout in the lowest reach, and presence of sufficient instream flows during spawning and fry emergence should be confirmed with further field study to ensure there are no impacts to salmonid populations.

4.3 SCENARIO 3

It is assumed that this scenario would see the presence of shallow water albeit with smaller cover than the current condition (and Scenario 4). It is also anticipated that, with slightly less water depth than the existing condition (and Scenario 4), the wetland would have more of a transitional zone between shallow water and the marsh. This would likely ensure that marsh conditions remain prominent on the peripheries of the wetland complex, potentially even resulting in a larger marsh area than current marsh area and potentially more patches of shrubby swamp.

Scenario 3 should not create any significant changes or affects to the current wildlife habitat. For example, breeding habitat for northern red-legged frogs and other amphibians should still be in similar abundance given that the cover of marsh habitat in Scenario 3 is also anticipated to be similar or greater than Scenario 4. Also, nesting and foraging habitat for waterfowl should remain similar. Some encroachment of woody vegetation around the drier wetland edges can be expected and this would provide good foraging and nesting habitat for other bird species.

In this scenario, we assume that instream flows will be similar to existing conditions and unlikely to have any significant impact to potential spawning Cutthroat Trout in the outlet channel. This assumption should be confirmed based on spring fish sampling to confirm presence and an assessment of flow conditions to ensure that they are sufficient to support any spawning fish.

4.4 SCENARIO 4

It is assumed that this scenario would be equivalent to the current wetland complex proportions with a large area of shallow water wetland and a fringe of marsh/shrubby swamp wetland.

From an ecological perspective, Scenario 4 is the most beneficial, as it provides a mechanism that maintains the current wetland ecological diversity. With changing climatic conditions and an increase in severity and frequency of summer drought periods, a larger water storage capacity would also be beneficial to assist in maintaining the wetland ecological diversity.

Scenario 4 would likely have the greatest number of benefits to wetland species, given the overall availability and coverage of habitat. Northern red-legged frogs, a federally listed species, are currently present at the wetland complex, and are assumed to breed in the extensive cover of emergent vegetation in the marsh habitat.

Given the resilience that greater water retention offers to droughts and climatic changes, and the large area of wetland habitat, Scenario 4 is likely to offer the greatest ecological benefits overall.

Water temperatures in the deepest scenario are anticipated to remain moderately cooler and warm up slower than the shallower scenarios. For northern red legged frogs, cooler, more stable water temperatures are generally preferred, particularly during egg development.

No significant impacts to fish are anticipated in Scenario 4 as it will be similar to existing conditions. Salmonid fish species are unlikely in Coats Marsh, given a history of complete drawdowns for agricultural purposes and barriers to fish access from Hoggan Lake. Downstream flows and dry periods are anticipated to be similar to current operations with seasonally dry conditions encountered in the late summer and early fall. Based on existing flow patterns, the weir should be able to operate naturally (i.e., passive water management) and maintain seasonal flows throughout the spring without having any significant negative impacts on spawning or egg development if Cutthroat Trout are indeed present.

4.5 SCENARIO 5 DECOMMISSIONING

For Scenario 5, where the weir is decommissioned and the beaver dam removed, it is expected that the area would subsequently behave more like an ephemeral or nearly ephemeral stream. Water levels would fluctuate in the winter depending on flow conditions, and Coats Creek would likely dry out in the summer or be limited to pockets of standing water depending on topography.

It is assumed that the marsh would return to a state similar to the area before the construction of the beaver dam (Photo 4-1). It is assumed that with this scenario the area has the greatest possibility of transitioning into more of a periodically wet meadow dominated by grasses closest to Coats Creek and an increase in shrub cover as you move away from the creek. There would be the greatest change in plant species composition with this scenario, with the greatest transition from aquatic plant species to more upland plant species.

Photo 4-1. 2002 air photo of Coats Marsh (copied from RDN Public viewer).

There would be very limited open water areas within this scenario, and it is assumed there would be no permanent feeding or resting habitat for waterfowl. The area may provide some temporary open flooded water in the wettest times of year, such as winter and spring. There would be a change in wildlife use of the area and species composition and diversity.

Of the various scenarios, decommissioning of the weir is anticipated as having significant impacts on the habitat values for amphibian species. With the anticipated loss of permanent surface waters in the summer months and associated loss of emergent vegetation, breeding habitat for northern red-legged frogs will be significantly degraded.

Requirements for compensation are not anticipated associated with the loss of habitat for northern red-legged frog. The area is not mapped as critical habitat nor is it classified as a provincial Wildlife Habitat Area. As such, EDI does not anticipate the need for specific compensation associated with changes to Coats Marsh and its impacts to northern red-legged frog. Rather, EDI anticipates that any significant changes to Coats Marsh would require that a salvage be completed immediately beforehand, removing and relocating all captured amphibian specimens to suitable habitat nearby.

The proposed changes will need to be reviewed by the Province under the Water Sustainability Act, likely as a Notification. As the pond is man-made and controlled by the weir, decommissioning may not trigger any compensation for the loss of aquatic wetland habitat. The determination if any compensation would be required during decommissioning of the wetland is uncertain and must be determined beforehand with the regulators.

Alternatively, this Scenario was also considered in the alternative situation where the weir is decommissioned but the beaver dam is retained. In this situation, t is expected that most of the marsh area would have similar values to the present conditions but these values could potentially change over time based on the level of local beaver activity. If local beavers abandon the marsh, this could lead to a future deterioration of the beaver dam. This deterioration could cause fluctuations in water levels within the marsh area and could lead to uncontrolled flooding downstream of the beaver dam.

4.6 DAM FAILURE RISK

Dam failure has the potential to impact downstream resources, including aquatic and riparian values downstream of weir structure at Coats Marsh. Sensitive aquatic and riparian values that could be affected by a dam failure include fish and red-legged frogs.

Based on available fish data for the area and limited observations from South Road, habitat for Cutthroat Trout would be limited to the downstream end of the creek, near its outlet into the lake. As described by Madrone (2021), the outlet stream is steep-walled, with predominantly organic substrates with short sections of alluvial deposits. A barrier approximately 50 m upstream from the lake likely prevents all fish passage beyond this point. Our Professional biologists were not able to access this area due to private property restrictions to confirm these conditions. However, based on descriptions of substrate and the spawning requirements of Cutthroat Trout, the lower reach is likely to have low spawning potential and low rearing potential, although historical communications with the Coats family in 1972 suggested that trout species did spawn in this watercourse at the time, as well as in the small watercourse and wetland complex to the northwest of Hoggan Lake, although none of these potential spawning locations have been substantiated.

Given the uncertainty around spawning habitat in the lower watercourse and the current population status of trout in the lake, the risk of a dam failure to fish populations is difficult to determine. A dam failure could result in a wash-out of the stream channel, simplifying the habitat and washing out any redds and eggs that might have been present. Cutthroat Trout would be most sensitive to a dam failure between February to May (during spawning season) and for the next 7-8 weeks as the eggs hatch and the fry emerge from the nest. Given the low quality of spawning habitat in the stream, the impacts of a dam failure to fish are anticipated to be low. However, in order to address the uncertainty around the value of this lower stream reach for spawning Cutthroat and/or Rainbow Trout, spring spawning surveys are recommended in the watercourse.

Although past fish sampling at Coats Marsh has not been rigorous enough to prove fish absence, the presence of multiple fish barriers between Hoggan Lake and the wetland and the historic drawdowns for agricultural purposes at Coats Marsh suggest that a natural salmonid fish population in the pond is unlikely.

In addition to fish, other aquatic and riparian species may also be present that could be sensitive to a dam failure. Northern red-legged frogs are confirmed to be present in Coats Marsh and in the surrounding forest and watercourses. The flooded marsh conditions and ample emergent vegetation provide suitable breeding habitat for red-legged frogs (COSEWIC 2004). A dam failure poses a particular risk during breeding season, when egg masses are affixed to emergent vegetation. Rapid dewatering during the egg mass and tadpole life stages could strand egg masses and wash out tadpoles.

4.7 POTENTIAL COMPENSATION REQUIREMENTS

Each scenario proposes some form of change to the water management of the current wetland, with Scenarios 1 through 4 representing a range of water retention elevations and weir heights, from low to high (approximate current elevation), and Scenario 5 representing a complete decommissioning of the weir, reinstatement of a stream channel, and loss of the pond, open water and marsh areas.

Potential compensation and offsetting requirements may be triggered through various regulations, both provincially and federally. Federally, we must consider potential compensation for any losses of critical habitat for SARA-listed endangered and threatened species. The northern red-legged frog is listed federally as "special concern" (i.e., not endangered or threatened), does not have identified critical habitat, and therefore does not trigger compensation under SARA.

Provincially, the loss of northern red-legged frog habitat should not specifically trigger any compensation, if appropriate mitigative actions are taken to protect and salvage local specimens during the changes. Although the Province does offer protections to northern red-legged frogs through the establishment of approved Wildlife Habitat Areas (WHA), the project area is not identified as such and therefore the habitat is not offered special protections for this species.

The federal Fisheries Act may trigger offsetting requirements if a Fisheries Act Authorization is needed to address any significant adverse impacts to fish and fish habitat. Due to the lack of downstream fish passage and given the relatively short existence of Coats Marsh, the pond is unlikely to sustain any resident salmonid fish populations. The lowest 50 m of the stream reach between Coats Marsh and Hoggan Lake could provide spring spawning habitat for Cutthroat Trout or Rainbow Trout but several barriers have prevented fish migration further upstream into Coats Marsh. In order to determine whether any adverse impacts are anticipated to fish populations as a result of changes to Coats Marsh, fish sampling and a habitat assessment should be completed in the lowest reach of the outlet channel to confirm whether spring spawning occurs. If no spawning occurs, significant adverse impacts would be unlikely and an Authorization with associated offsetting would likely not be required. Should spawning be identified in the stream, further study would be required to assess if the proposed changes to water management in Coats Marsh will be sufficient to meet the seasonal instream flow requirements for resident Cutthroat Trout spawning (from February to May) and fry emergence (about six to seven weeks after spawning – e.g. mid-June). If the newly proposed seasonal water flows are too low to support spawning and fry emergence, then compensation would likely be required.

Offsetting requirements are uncertain when considered under the provincial Water Sustainability Act, which affords protections to watercourses that are defined as streams under the Act, including wetlands. Proposed removal of wetland areas can trigger offsetting, depending on the ecological values of the wetland and the type of proposed activity. Given that the wetland was artificially created due to construction of the weir, offsetting may not be necessary, but this will require feedback from provincial regulators. At a minimum, we anticipate that any wetland areas removed will need to be restored with appropriate riparian plant species.

The type and amount of compensation and offsetting will depend on the trigger for compensation, whether the requirement for compensation come from impacts to fish populations, or potentially from changes to stream or wetland. For example, decreases to the water retention at Coats Marsh may reduce the amount and duration of water flows in the downstream outlet stream (i.e., less water retention in the pond could equate to reduced late summer/fall flows). Depending on the timing, such changes could have an impact on potential spawning areas for Cutthroat Trout at the downstream end of Coats Marsh outlet. Compensation may include such things as the creation of instream habitat targeting the same fish population and riparian habitat restoration. The determination of whether compensation would be required will depend on quality of habitat available for spring-spawning salmonid species

4.8 GENERAL MITIGATION MEASURES

A wildlife management and monitoring plan (WMMP) should be developed once a scenario has been selected and before construction is initiated and in association to required wildlife permits. The WMMP should incorporate federal, provincial and municipal guidelines and best management practices.

Regardless of which scenario is selected, the following general mitigation measures should be incorporated into the WMMP to reduce potential affects to wildlife and ecological communities:

- Any planned work activities should avoid the breeding bird period for both migratory and resident birds that could potentially use affected proposed disturbance areas. If working during the breeding bird period can not be avoided then pre-clearing breeding bird surveys should be completed.

- Any planned work activities should be planned during applicable least-risk windows to also avoid potential affects to native amphibians.

- Confirm fish presence and spawning utilization, particularly for cutthroat trout, in downstream reach of Coats Marsh stream. In the absence of determining fish presence and spawning utilization of downstream reach of Coats Marsh stream, instream construction should be timed to the least risk work window for Cutthroat Trout. This spans from August 1 to October 31 for the South Coast of British Columbia.

- Monitoring for invasive hydrophytic vegetation species should be implemented since there is the potential for the further spread of reed canary grass or the introduction of new species such as yellow flag iris.

- Beaver dam removal should follow DFO's interim code of practice for beaver removal (https://www.dfo-mpo.gc.ca/pnw-ppe/codes/beaver-dam-barrage-castor-eng.html) to the extent possible. Due to the presence of SARA-listed northern red-legged frog, the removal of the beaver dam should be submitted for review under a Request for Review to Fisheries and Oceans Canada.
    - Plan in-water works, undertakings and activities to respect timing windows to protect fish and fish habitat as well as at-risk species. The least risk timing window for fish (i.e. Cutthroat Trout) is between August 1 and October 31.

  - Although no formal window exists for amphibians in BC, northern red-legged frogs breed in February until April. Hatching typically occurs during the first half of May and the larval (tadpole) period lasting another 11-14 weeks. Most tadpoles have metaphorphosed into adults by early July to early August. Important times of the year when increased numbers of adult frogs may be observed by the pond and adjacent upland areas are during the breeding season (February – April) and during dispersal of newly metaphorphosed adults (July – August). Beaver dam removal should be timed to coincide with the least risk fish window and after adult red-legged frog dispersal, from late August to October 31.
  - Work to be timed during period of low water levels (e.g. late summer/early fall) and dry, favourable weather.
  - When dewatering the beaver impoundment:
    - Remove the dam gradually, working from the top (or with a siphon), to draw down the water and prevent sediment at the bottom of the pond from being released downstream.
    - Ensure the width of the breach opening of the beaver dam does not exceed the width of the receiving stream channel.
  - Any fish that become trapped in isolated pools will be relocated to an appropriate location.
- Coats Marsh is not identified as critical habitat under SARA or an Approved Wildlife Habitat Area (WHA) provincially for northern red-legged frogs. As such, no specific permitting is anticipated. Rather, works should be timed to avoid critical life stages (e.g. early spring spawning and egg laying). All specimens should be salvaged at the time of dewatering by a qualified professional with the appropriate wildlife handling permits.
- A review of potentially required permit applications includes the following:
  - Application for works in and about a stream (Section 11 of WSA)
  - Application for a permit for the destruction of a beaver dam.
  - Application for an amphibian salvage permit.
  - Application for a fish salvage permit.
  - Submission of a DFO Request for Review for beaver dam removal

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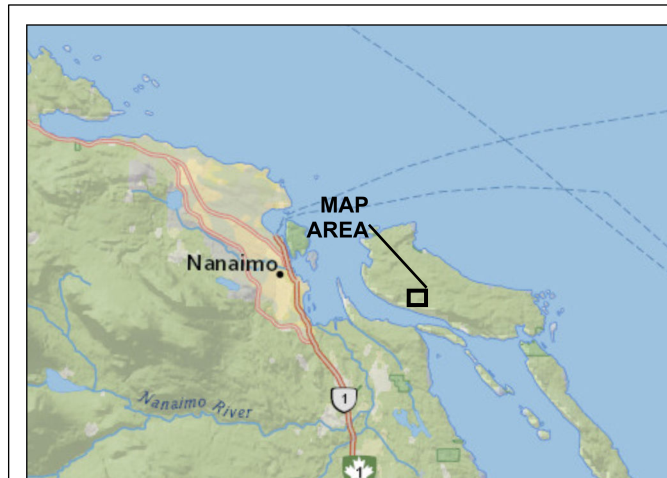
APPENDICES

APPENDIX A LOCATION OF COATS MARSH AND WETLAND ASSESSMENT POINTS

Location of Coats Marsh and wetland assessment points

Legend

- Wetland Assessment Points
- Road (Paved Divided) - Not Elevated - 1 Lane Each Way
- Road (Unimproved)
- Coats Marsh Regional Park



0 100 200 300
Meters

Map Scale = 1:4,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 10N

Data Sources

- Inset Basemap. National Geographic World Map: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
- Main Basemap. World Imagery: City of Nanaimo, Maxar

Disclaimer
EDI Environmental Dynamics Inc. has made every effort to verify this map is free of errors. Data has been derived from a variety of digital sources and, as such, EDI does not warrant the accuracy, completeness, or reliability of this map or its data.

Drawn: O. Leblanc	Checked: R. Robitaille	Map 1-1	Date: 2022-10-19

EDI

APPENDIX B EDI WETLAND ASSESSMENT FIELD FORM

EDI **Wetland Assessment Form** V1, March 2014

W ☐ T ☐	Photo:	Date: DD/MM/YYYY
Project ID:		Surv.:
Plot No.:		
Plot Representing:		
UTM Zone:	North:	East:
Aspect: ______ °	Elevation:	Accuracy: ±
Slope: ______ %	SMR:	SNR:
Meso Slope Position	☐ Crest ☐ Upper Slope ☐ Mid Slope ☐ Lower Slope ☐ Toe	☐ Depression ☐ Level ☐ Floodplain
Hydrogeomorphic Position	☐ Lacustrine (L) ☐ Palustrine (P) ☐ Fluvial* (F) ☐ Upland (U)	☐ Estuarine (E) ☐ Marine (M)
* Fluvial Modifier	Hydro. Subsystem	
Org. Soil Texture:	☐ Fibric ☐ Mesic	☐ Humic
Humus Form:	☐ Mor ☐ Moder ☐ Mull	pH
Organic Material Thickness: ______ cm	Estimated Rooting Depth: ______ cm	
Von Post:	1 2 3 4 5 6 7 8 9 10	
Mineral Soil Drainage:	☐ Very Rapidly ☐ Rapidly ☐ Well ☐ Mod. Well ☐ Imperfectly	☐ Poorly ☐ Very Poorly
Mineral Soil Texture:	☐ Sandy (LS, S) ☐ Loamy (SL, L, SCL, FSL)	☐ Silty (SiL, Si) ☐ Clay (SiCL, CL, SC, SiC, C)
Coarse Frags (%):	☐ 0 - 5 ☐ 5 - 20 ☐ 20 - 40 ☐ 40 - 60 ☐ 60 - 80 ☐ > 80	
BGC Unit:	Wetland Class:	
Site Series:	Association:	
Structural Stage:	Modifier:	

Wetland Polygon Summary			
	%	Class	Association
P1			
P2			
P3			

Notes:

Diagram:

SPP. LIST	COMP. ☐ PART. ☐	% COVER BY LAYER	TREE (A)	SHRUB (B)	HERB (C)	MOSS / LICHEN (D)	Associated Full Cruise Card ? ☐ No ☐ Yes

COL.	TREES & SHRUBS	A1	A2	A3	A	B1	B2	B	COL.	HERB LAYER (C)	%	COL.	MOSS / LICHEN / SEEDLING (D)	%

Notes/Diagram

Tree Mensuration

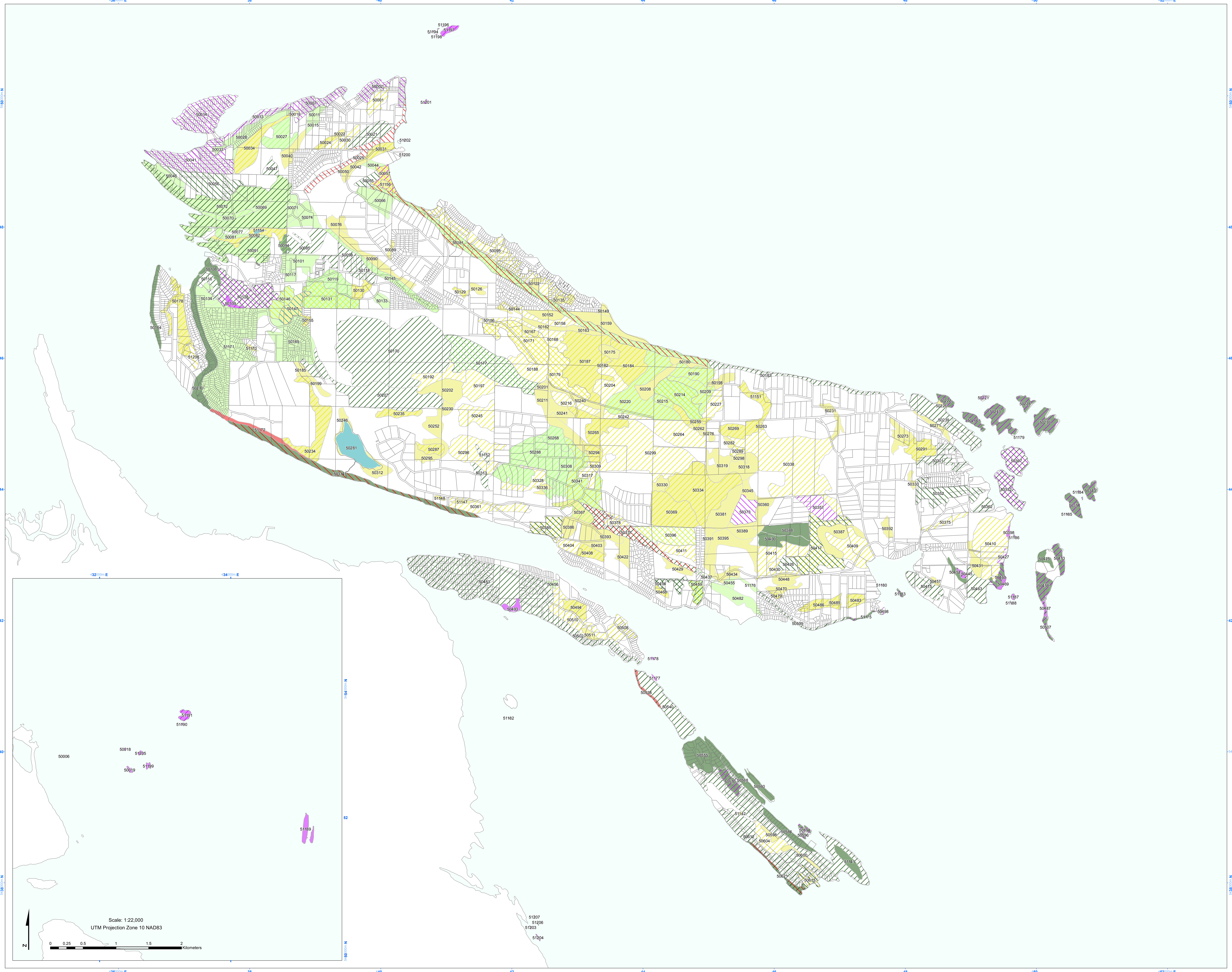
SPP.	dbh	Ht.	BH Age	Path. Y/N	Notes

FS 1333 HRE 2010/03

APPENDIX C SENSITIVE ECOSYSTEM MAP FOR GABRIOLA ISLAND

Sensitive and Terrestrial Ecosystems Label

50001	50002	50006	50007	50010	50011	50013
50014	50015	50018	50019	50021	50022*	50024
50025	50027*	50028*	50030*	50031	50033	50034*
50040	50041	50042	50044	50046	50047	50050
50055	50056*	50057	50066	50069	50070*	50071
50072*	50074	50076	50077	50081	50082	50085
50089	50090	50091*	50094	50095*	50098	50101
50108	50116	50117	50118	50119	50122	50126
50129	50130	50131	50133	50134	50135	50138*
50139	50144	50145	50146	50147	50149*	50152
50155	50156*	50158	50159	50162	50163	50164
50167	50168	50169	50170	50171*	50175	50177
50178	50178	50179*	50180	50181*	50182	50183
50184	50185	50187*	50188	50190	50192	50197
50198	50199	50201	50202	50204	50207	50208
50209	50210*	50211	50214	50215	50216	50220*
50221	50222	50226	50227	50228	50230	50231
50234*	50235	50239	50240	50241	50242	50243
50245	50246	50252	50255	50259	50262	50263
50264	50265	50266	50268	50269	50271	50273
50276	50281	50282	50287	50288	50289	50291
50294	50295	50296	50298	50299*	50301	50307
50308*	50309	50312*	50313	50314*	50317	50318
50319	50328	50330	50332	50333	50334	50336
50338	50341	50343	50345	50352	50354	50357*
50360	50361	50362	50367	50369	50371	50373
50375	50378	50381	50385*	50386	50387	50388
50389	50391	50392	50393	50395	50396	50398
50400	50403	50404	50408	50409	50410	50411
50413	50415	50417	50422	50425	50426	50427
50429	50430	50431	50434	50437	50445	50448
50452	50453	50454	50455	50456	50457	50458
50459	50460	50463	50468	50469	50470	50475
50479	50482*	50483	50485	50486	50487	50493
50494	50498	50502	50507	50508	50509	50510
50511	50534	50540	50555	50560	50568	50570
50584	50594	50596	50598	50600	50604	50612
50615	50621	51141	51142	51147*	51148	51151
51152	51154	51156	51170	51171	51172	51175
51176*	51177	51178	51179	51180	51182	51183
51184	51185	51186	51187	51188	51189	51190
51191	51192	51193	51194	51195	51196	51197
51198	51199	51200	51201	51202	51203	51204
51205	51206	51207				



Gabriola Island Sensitive Ecosystem Mapping Airphoto - 2007

Scale: 1:22,000
UTM Projection Zone 10 NAD83

Sensitive Ecosystems

Sensitive ecosystems are fragile and/or rare, or are ecologically important because of the diversity of species they support.

Old Forest (OF): Primary Ecosystem / Secondary / Tertiary

Definition: Conifer-dominated dry to moist forest types, structural stage 7, generally >250yrs.

Importance: Due to the lack of disturbance, old forest ecosystems are often associated with rich communities of plants and animals that may be dependent upon the unique environmental conditions created by these forests.

Subclasses:

co (conifer-dominated) - greater than 75% coniferous species
mx (mixed conifer and deciduous) - forests dominated with a mixture of coniferous and broadleaf trees (<75% coniferous and >25% broadleaf)

Woodland (WD): Primary Ecosystem / Secondary / Tertiary

Definition: Dry open forests, generally between 10 and 30% tree cover, can be conifer-dominated or mixed conifer and arbutus stands; because of open canopy, will include non-forested openings, often with shallow soils and bedrock outcroppings.

Importance: Woodlands are nationally, provincially and regionally rare and highly fragmented . A rich assemblage of plants, insects, reptiles and birds are drawn to these ecosystems due to the food sources, habitat and proximity to the ocean. Garry oak woodlands, for example support the highest plant species diversity of any terrestrial ecosystem in British Columbia and are especially vulnerable to rural development.

Subclasses:

bd (broadleaf) - dominant broadleaf with <15% coniferous species
mx (mixed conifer and deciduous) - mixed conifer and broadleaf with a minimum of 25% cover of either group is included in the total tree cover

Herbaceous (HB): Primary Ecosystem / Secondary / Tertiary

Definition: Non-forested ecosystems (less than 10% tree cover), generally with shallow soils. They include bedrock outcroppings, large openings within forested areas, spits, dunes and shorelines vegetetated with grasses and herbs.

Importance: Terrestrial Herbaceous ecosystems are characterized by thin soils which are easily disturbed. Herbaceous plants can be easily trampled or dislodged onto bare rock where they cannot re-establish. Thus they are highly vulnerable to a range of human disturbance factors including residential development and various recreational uses.

Subclasses:

hb (herbaceous) - non-forested, less than 10% tree cover, generally shallow soils, often with exposed bedrock, predominantly a mix of grasses and forbs, also lichens and mosses
cs (coastal herbaceous) - rocky shoreline or islet, influenced by the marine environment and characterized by less than 20% vegetation cover of grasses herbs, mosses and lichens.
sp (spit) - finger-like extension of beach, comprised of sand or gravel deposited by longshore drifting; low to moderate cover of salt-tolerant grasses and herbs
du (dunes) - ridge or hill, or beach area created by windblown sand; may be more or less vegetated depending on depositional activity, beach dunes will have low cover of salt-tolerant grasses and herbs
sh (shrub) - >20% of total vegetation cover is shrub cover, with grasses and herbs
ro (rock) - rock outcrops not dominated by shrubs

Wetland (WN): Primary Ecosystem / Secondary / Tertiary

Definition: Areas that are saturated or inundated with water for long enough periods of time to develop vegetation and biological activity adapted to wet environments. This may result from flooding, fluctuating water tables, tidal influences or poor drainage conditions.

Importance: Wetland ecosystems are sensitive and important because they exhibit rarity, high biodiversity, fragility, specialized habitat, specialized functions and connectivity.

Subclasses:

bg (bog) - nutrient poor wetland, on organic soils (sphagnum peat), water source predominantly from precipitation; may be treed or shrub dominated
fn (fen) - nutrient medium wetland (sedge peat) where ground water inflow is the dominant water source, open water channels common; dominated by sedges, grasses and mosses
ms (marsh) - wetland with fluctuating water table, often with shallow surface water, usually organically enriched mineral soils; dominated by rushes, reeds, grasses and sedges
sp (swamp) - poor to very rich wetland on mineral soils or with an organic layer over mineral soil, with gently flowing or seasonally flooding water table; woody vegetation
sw (shallow water) - standing or flowing water less than 2m deep, transition between deep water bodies and other wetland ecosystems (i.e. bogs, swamps, fens, etc.); often with vegetation rooted below the water surface
wm (wet meadow) - periodically saturated but not inundated with water, organically enriched mineral soils; grasses, sedges, rushes and forbs dominate

Cliff (CL): Primary Ecosystem / Secondary / Tertiary

Definition: Very steep slope, often exposed bedrock, may include steep-sided sand bluffs.

Importance: Open ledges and horizontal fissures on cliffs are known to provide nesting sites. Cliff crevices are used for roosting bats while deep crevices are used for shelter and overwintering of snakes and lizards.

Subclasses:

cc (coastal cliffs) - cliffs with a marine influence, generally near vertical bedrock with accumulation of soil limited to fissures and ledges.
ic (inland cliffs) - inland cliffs: typically formed as a result of erosion, catastrophic failures or mass wastage. Generally characterized by rapid drainage and the accumulation of soil that is limited to bedrock fissures and ledges

Freshwater (FW): Primary Ecosystem / Secondary / Tertiary

Definition: Freshwater ecosystem includes bodies of water such as lakes and ponds that usually lack floating vegetation.

Importance: Freshwater ecosystems are home to numerous organisms such as, fish, amphibians, aquatic plants, and invertebrates. Lakes and ponds play a vital role in the lifecycle of many species.

Subclasses:

la (lake) - a naturally occurring static body of water, greater than 2m deep in some portion.
pd (pond) - a small body of water greater than 2m deep, but not large enough to be classified as a lake

Rare Ecosystems

Other important ecosystems have high biodiversity values.

Mature Forest (MF): Primary Ecosystem / Secondary / Tertiary

Definition: Usually conifer-dominated, occasionally deciduous, dry to moist forest types, structural stage 6, generally >80yrs.

Importance: ***Future older forests*** Within 20 years, many Mature Forests that were logged early this century will become Older Forests. The biodiversity values of Mature Forests generally become higher with age. This means it will be able to sustain more and larger species of plants and animals.
Landscape connectivity Mature Forest stands provide connections between other natural areas that promote the movement and dispersal of many forest-dwelling species across the landscape.
Buffers Mature Forest can minimize disturbance to sensitive ecosystems that occur within or adjacent to the forest patch. Where they border or surround wetlands, patches of older forest or other sensitive ecosystems, the Mature Forest area serves an important role in buffering the adjacent sensitive areas.

Subclasses:

co (conifer dominated) - greater than 75% coniferous species
mx (mixed conifer and deciduous) - a minimum of 25% cover of either group is included in the total tree cover
bd (broadleaf) - greater than 75% broadleaf species

Other Mapped Ecosystems

Young Forest (YF):

Definition: Limited to areas of young forest dispersed amongst sensitive and important ecosystems. Forest is 40 - 80 yrs old depending on species and ecological conditions; canopy has begun to differentiate.

Seasonally Flooded Agricultural Fields (FS):

Definition: Limited to areas of annually flooded cultivated fields or hay fields dispersed amongst sensitive and important ecosystems.

Non-Sensitive (NA):

Definition: Limited to areas of disturbance or human impact dispersed amongst sensitive and important ecosystems.

Ecosystem Map Symbols

Ecosystem composition is complex and often contains a dominant ecosystem with secondary and tertiary ecosystems. In this map the dominant ecosystem has a solid shading and the secondary and tertiary ecosystems are identified by cross-hatched lines.

Example of a primary sensitive Woodland ecosystem with a secondary sensitive Herbaceous ecosystem

Occassionally sensitive ecosystems will mix with non-sensitive ecosystems. In this map a sensitive ecosystems mixed with non-sensitive is identified by cross-hatched lines with solid white shading.

Example of a secondary sensitive Herbaceous and tertiary sensitive Woodland ecosystems mixed with a non-sensitive primary ecosystem

Sensitive ecosystems can also mix with important ecosystems. In this map a sensitive ecosystem mixed with an important ecosystem is identified by cross-hatched lines with solid green shading.

Example of a tertiary sensitive Herbaceous ecosystem mixed with a primary important Mature Forest ecosystem

What is a Sensitive Ecosystem?

For the purpose of this study, an *ecosystem* is considered to be a portion of the landscape with relatively uniform dominant vegetation.

Sensitive ecosystems are those which are fragile and/or rare, or those ecosystems which are ecologically important because of the diversity of species they support.

Rationale

Intense development pressure fueled by population and economic growth has fragmented and degraded many terrestrial ecosystems. A high proportion of these ecosystems are now designated as 'at risk' in BC. Sensitive ecosystems typically have high biological diversity and are a vital part of the landscape. They provide ecosystem services for a healthy economy and for social well being. They regulate climate, clean water, generate and clean soils, recycle nutrients and pollinate our crops. To protect these areas, sensitive ecosystems must be located, identified and mapped. From 1993 to 1999 the Provincial and Federal Governments completed a Sensitive Ecosystems Inventory of East Vancouver Island and the Gulf Islands. This mapping product is an updated version of that product.

Purpose

The purpose of this Sensitive Ecosystems map is to identify the location of sensitive ecosystems. The goal of this mapping exercise is to encourage informed land use decisions that will conserve sensitive ecosystems. This map and the accompanying data provide site-specific ecological information that can be used to flag sites of conservation concern, to promote land stewardship and to prompt detailed field surveys and consideration of ecological values before changes to the land are initiated.

Methodology

Mapping methods are based on the Resource Information Standards Committee (RISC) Standard for Terrestrial Ecosystem Mapping (TEM) in BC. This Sensitive Ecosystems map was themed from TEM data using the RISC Standard for Mapping Ecosystems at Risk in BC. Field survey protocols followed Describing Terrestrial Ecosystems in the Field (RISC 1998).

Data Limitations

The Sensitive Ecosystems map is a tool to alert decision makers to the existence of sensitive ecosystems. However, **when land-use changes are proposed, detailed on-the-ground site assessments are necessary**. For sites that were not field checked, the accuracy of the data depends heavily on the expertise, local knowledge, and professional judgment of the mapper and the quality and quantity of available source data. Because the area is changing rapidly, reference to the data set(s) used as the information source is advised.

Due to the mapping scale of the aerial photographs, the minimum polygon size is generally ½ hectare. Enlargement of the data beyond the source scale may result in unacceptable distortion and faulty registration with other data sets.

What can be done to protect the sensitive ecosystems?

Direct and indirect impacts to these ecosystems can be avoided by:

- Retaining or creating vegetated buffers around sensitive ecosystems to isolate them from outside disturbances;
- Controlling land and water access to fragile ecosystems;
- Controlling invasive species;
- Allowing natural disturbances to occur;
- Maintaining water quality

If development must occur, develop carefully!

Conduct an ecological inventory to identify the existing flora and fauna and to locate any threatened or endangered plant and animal species, plant communities, and habitat features needing protection.

Plan and implement all development activities in a manner that will not adversely affect or disturb the sensitive ecosystem. Consult a qualified professional to interpret the ecological inventory data and work to incorporate designs that maintain the functions and values of the natural ecosystem.

Acknowledgements:

Project Co-ordination:
Kate Emmings – Islands Trust Fund
Brodie Porter – Islands Trust, Local Planning Services

Terrestrial Ecosystem Mapping:
Madrone Environmental Services Ltd.

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Carmen Cadrin - BC Ministry of Environment
Jo-Anne Stacey - BC Ministry of Environment
Andy MacKinnon - BC Ministry of Forests and Range
Todd Golumbia - Gulf Islands National Park Reserve

Sensitive Ecosystem Mapping Review:
Kate Emmings – Islands Trust Fund
Corey Erwin - BC Ministry of Environment
Sid Tsang - BC Ministry of Environment

GIS Mapping Support:
Mark van Bakel - Islands Trust

Sensitive and Terrestrial Ecosystems Label

Polygon Number
Biogeoclimatic Unit
* Indicates a field sample
7838*
CWHxm1
6WD:mx AM 5 ← Primary Ecosystem
2WD:co DC 4 ← Secondary Ecosystem
2WD:co DC 5 ← Tertiary Ecosystem
% of polygon (as decile)
SE Class
SE Subclass
Mapcode
Structural Stage

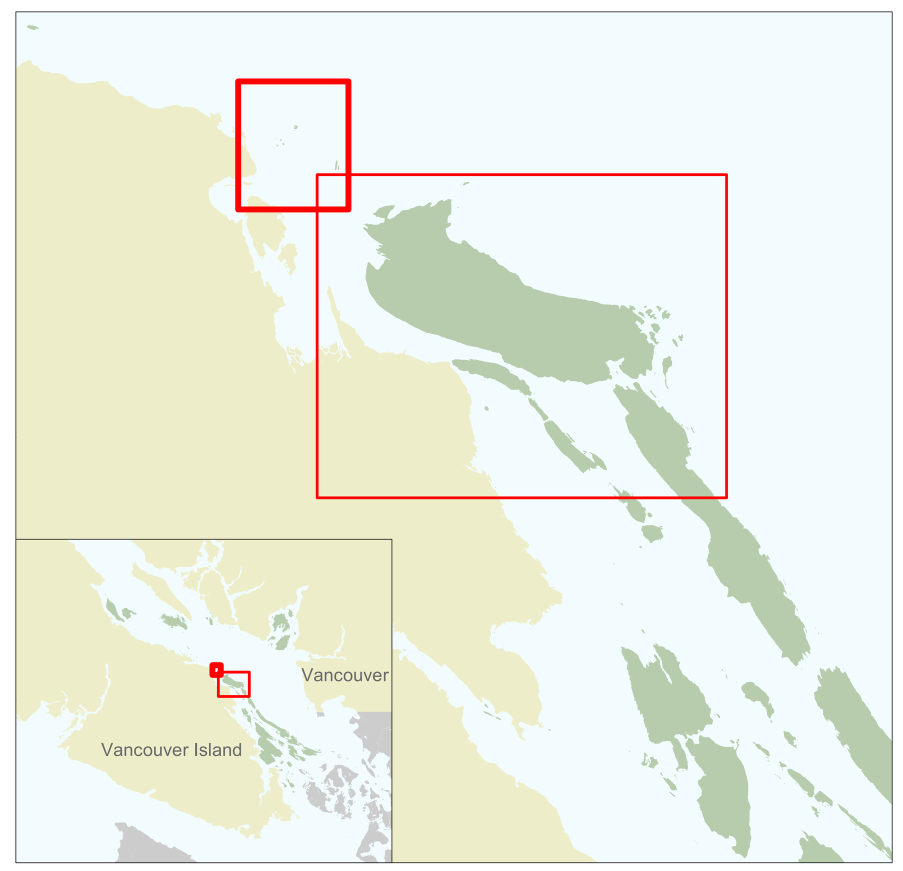
The example label above indicates the SEM and TEM attributes mapped for polygon 7838. The polygon occurs in the Coast Western Hemlock Eastern Very Dry Maritime variant; 60% of the polygon is WD:mx - Woodland: mixed conifer and broadleaf (Primary Ecosystem), map code AM - Arbutus - Hairy manzanita, structural stage 5. The remaining 40% of the polygon is WD:co - Woodland: conifer dominated, map code DC - Douglas-fir - Western hemlock – Cladina (Secondary and Tertiary Ecosystems). Of this 40%, 20% is structural stage 4 and 20% is structural stage 5.

Structural Stage & Biogeoclimatic Units

Structural Stage	Description
0	No Structural Stage (usually rock or open water)
1	Sparse/bryoid
2	Herb
3	Shrub/Herb
4	Pole/Sapling
5	Young Forest
6	Mature Forest
7	Old Forest
Biogeoclimatic Units	**Description**
CDFmm	Coastal Douglas-fir Moist Maritime Subzone

Terrestrial Ecosystem Map Codes and Site Unit Names

Map Code	Site Unit Name	Map Code	Site Unit Name	Map Code	Site Unit Name	Map Code	Site Unit Name
CDFmm - Forested		CDFmm - Non-Forested		CDFmm - Non-Forested		Anthropogenic	
AS	Aspen - Slough sedge	Ed01	Tufted hairgrass - Meadow barley estuarine meadow	Wf51	Sitka sedge - Peat moss fen	RE	Reservoir
CS	Western redcedar - Slough sedge	Em02	Glasswort - Sea-milkwort estuarine marsh	Wf52	Sweet gale - Sitka sedge fen	RW	Rural residential
CW	Black cottonwood - willow	Em03	Seashore saltgrass	Wf53	Slender sedge - White beak-rush fen	RZ	Road surface
DA	Douglas-fir - Shore Pine - Arbutus	Em05	Lyngbye's sedge estuarine marsh	Wm05	Cattail marsh	UR	Urban
DG	Douglas-fir - Grand Fir - Oregon Grape	FC	Fescue - Camas	Wm50	Sitka sedge - Hemlock-parsely marsh	Map Code	Site Unit Name
DO	Douglas-fir - Oniongrass	HL	Hardhack - Labrador tea	Ws50	Pink spirea - Sitka sedge swamp	Sparsely Vegetated	
DS	Douglas-fir - Salal	LM	Dunegrass - Beach pea	Ws51	Sitka willow - Pacific willow - Skunk cabbage swamp	BE	Beach
GO	Garry oak - Oceanspray	OM	Garry oak - moss	Map Code	Site Unit Name	CL	Cliff
LS	Shore pine - Sphagnum	OR	Oceanspray - rose	Anthropogenic		LA	Lake
RC	Western redcedar - Skunk cabbage	QB	Garry oak - Brome (or mixed grasses)	CF	Cultivated field	MU	Mudflat
RF	Western redcedar - Grand fir - Foamflower	RA	Nootka rose - Pacific crab apple	CO	Cultivated orchard	OW	Open water (< 2m deep)
RK	Western redcedar - Douglas-fir - Oregon beaked moss	SC	Cladina - Wallace's selaginella	ES	Exposed soil	PD	Pond (> 2m deep)
RP	Western redcedar - Indian-plum	SL	Sedge - Western lilaeopsis	GC	Golf course	RI	River
RS	Western redcedar - Snowberry	SS	Spirea - Sedge wetland	GP	Gravel pit	RO	Rock outcrop
RV	Western redcedar - Vanilla-leaf	Wb50	Labrador tea - Bog laurel - Peat-moss bog	IN	Industrial		



APPENDIX D PLOT SOIL AND VEGETATION RESULTS

Table 5-1. Summary of soil description from field investigation

Plot	Organic soil texture	Humus form	Organic material thickness (cm)	Estimated rooting depth (cm)	Von Post	Mineral soil texture	Coarse Fragments (%)	Seepage (cm)	Mottles / gleying (cm)
CM02	Humic	n/a	19	23	8	Clay[2]	0-5	30	Faint at 24
CM05	Mesic	n/a	16	37	6	Clay	5-20	0	none
CM06	n/a	Moder	16	22	n/a	Clay	0-5	16	none
CM08	Mesic	n/a	23		6	Clay	5-20	12	none

Table 5-2. Summary of vegetation observed in plots during the field investigation

Plot #	Vegetation observed		Percent cover (%)
	Common Name	Scientific Name	
CM02	Pink spirea/ hardhack	*Spirea douglasii*	3
CM02	Reed canary grass	*Phalaris arundinacea*	80
CM02	Water smartweed	*Percicaria amphibia*	5
CM02	Bur-weed species	*Sparganium sp.*	1
CM02	Marsh skullcap	*Scutellaria galericulata*	1
CM05	Marsh skullcap	*Scutellaria galericulata*	1
CM05	Reed canary grass	*Phalaris arundinacea*	40
CM05	Water smartweed	*Percicaria amphibia*	30
CM05	Bur-weed species	*Sparganium sp.*	1
CM05	Bladderwort species	*Utricularia sp.*	1
CM05	Common rush	*Juncus effusus*	0.5
CM06	Rose	*Rosa acicularis*	1
CM06	Salal	*Gaultheria shallon*	5
CM06	Reed canary grass	*Phalaris arundinacea*	70
CM06	Common rush	*Juncus effusus*	2
CM06	Bur-weed species	*Sparganium sp.*	1
CM08	Red alder	*Alnus rubra*	5
CM08	Pink spirea/ hardhack	*Spirea douglasii*	5

[2] Clay consists of the following textures: SiCL, CL, SC, SiC and C.

Plot #	Vegetation observed		Percent cover (%)
	Common Name	Scientific Name	
CM08	Reed canary grass	*Phalaris arundinacea*	25
CM08	Sedge species	*Carex sp.*	15
CM08	Pondweed species	*Potamogeton sp.*	1
CM08	Water smartweed	*Percicaria amphibia*	2
CM08	Bur-weed species	*Sparganium sp.*	2
CM08	Marsh horsetail	*Equisetum palustre*	1

APPENDIX B

SITE PHOTOS

Site Photos

This appendix provides photos of the site and relevant surrounding features. Photos were taken during the site visit on 14 September 2022 and are therefore typical of dry early fall conditions. Photos are roughly ordered hydrologically from the inlet creek at the east end of the marsh, through the marsh, the weir site, and then downstream locations.

B.1 East Path Creek Inlet

Photo B1 East Path Creek inlet at northeast of Coats Marsh, looking upstream. This is an ephemeral stream.

Photo B2 East Path Creek inlet at northeast of Coats Marsh, looking downstream.

B.2 Upper Marsh

Photo B3 View of Coats Marsh from inlet of East Path Creek.

Photo B4 Coats Marsh above the beaver dam, note waterlogged trees, swamp conditions.

Photo B5 Coats Marsh above the beaver dam, open-water area with less vegetation. Elevation marker in water.

B.3 Beaver Dam

Photo B6 View of beaver dam from north, thickly vegetated conditions.

Photo B7 Part of RDN installed siphon system in beaver dam, almost completely obscured by vegetation.

B.4 Weir Pool

Photo B8 View from weir toward beaver dam, with caged inlet pipe.

B.5 Weir Structure

Photo B9 Pedestrian footbridge and weir, looking toward berm.

Photo B10 Top view of weir.

Photo B11 Leaks visible in the weir structure from downstream.

Photo B12 Concrete cracks in weir.

Photo B13 Concrete cracks in weir.

B.6 Berm

Photo B14 Vegetated berm.

Photo B15 Berm, willows are caged near their bases to prevent beavers from cutting.

Photo B16 View of berm looking north. Weir pool is on the right and private property to the left. Leakage occurs through the berm, as evidenced by wetland vegetation.

B.7 Test Pit

Photo B17 View of test pit excavated by hand shovel immediately west of berm.

Photo B18 Excavated materials from test pit, representative of conditions for the foundation of the berm.

B.8 Coats Marsh Creek Outlet Channel

Photo B19 View in the narrow channel immediately downstream of the weir.

Photo B20 View of Coats Marsh Creek looking downstream, narrow channel with bedrock walls.

Photo B21 View toward private property where Coats Marsh Creek enters 1040 Coats Drive. Private wooden footbridge. Marker indicates property line.

B.9 Coats Marsh Regional Park Downstream of Private Properties

Photo B22 Culvert crossing below easement accessing Coats Marsh Regional Park from the west.

Photo B23 Culvert for Coats Marsh Creek below easement access.

Photo B24 Typical conditions of Coats Marsh Creek in western Regional Park area, uneven with exposed bedrock.

B.10 South Road Crossing

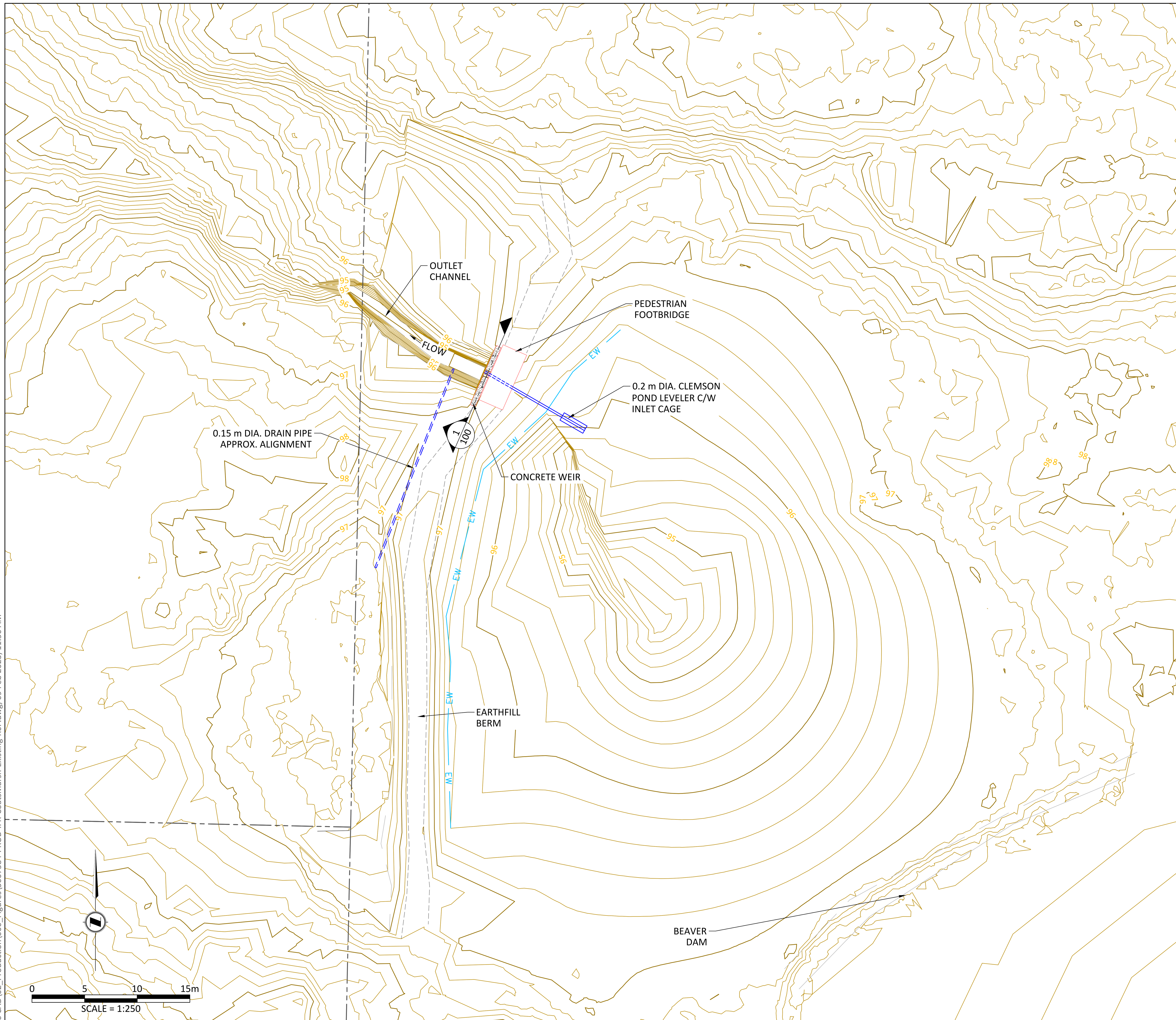
Photo B25 Fire hydrant and pump house located at South Road near Coats Marsh Creek.

Photo B26 Inlet of Coats Marsh Creek to culvert crossing below South Road.

Photo B27 Outlet of South Road culvert crossing. Coats Marsh Creek flows another 200 m through private property before entering Hoggan Lake. Bedrock step feature acting as barrier to most fish passage is downstream of this location within private property.

APPENDIX C

CONCEPT DRAWINGS



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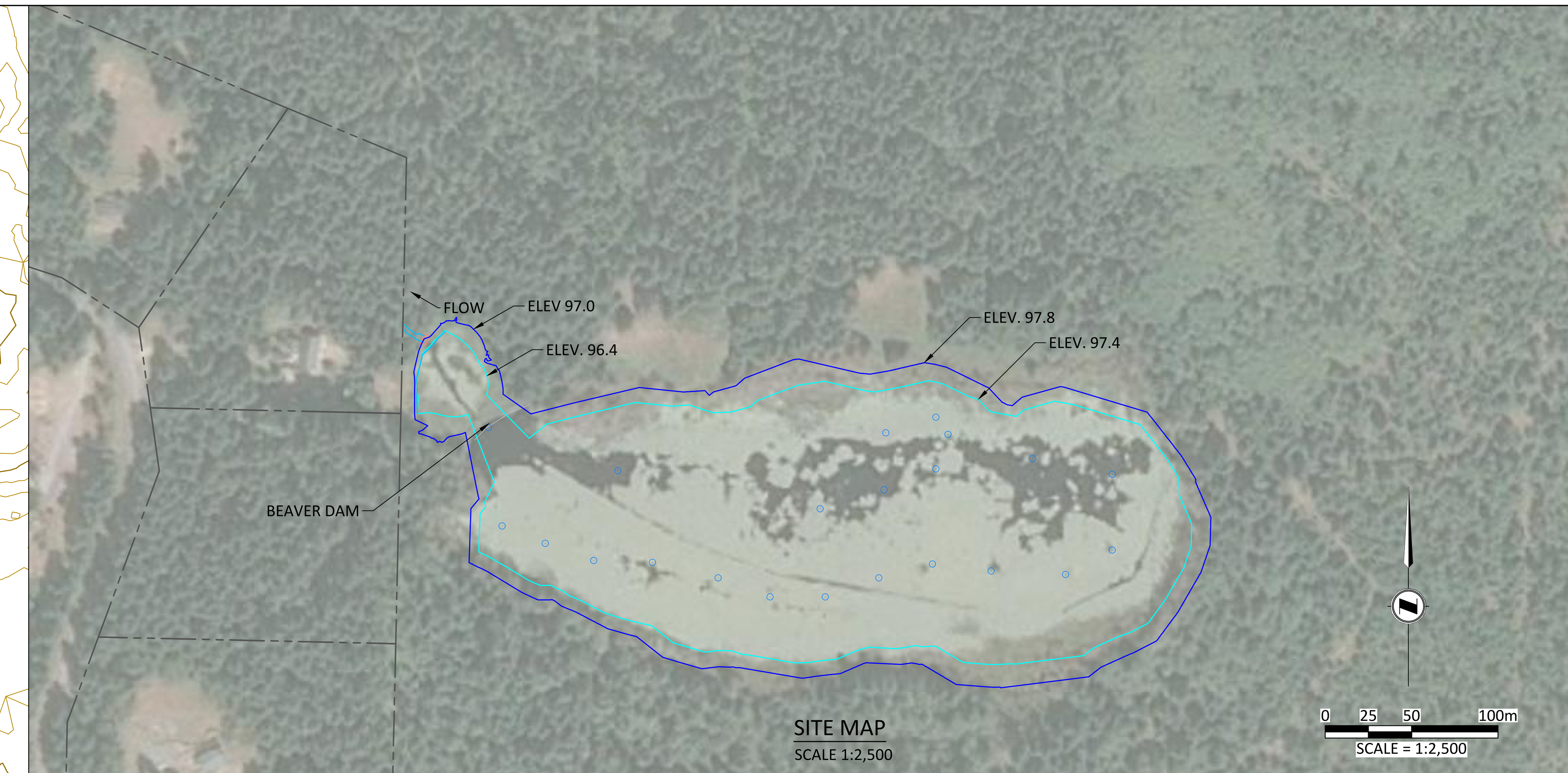
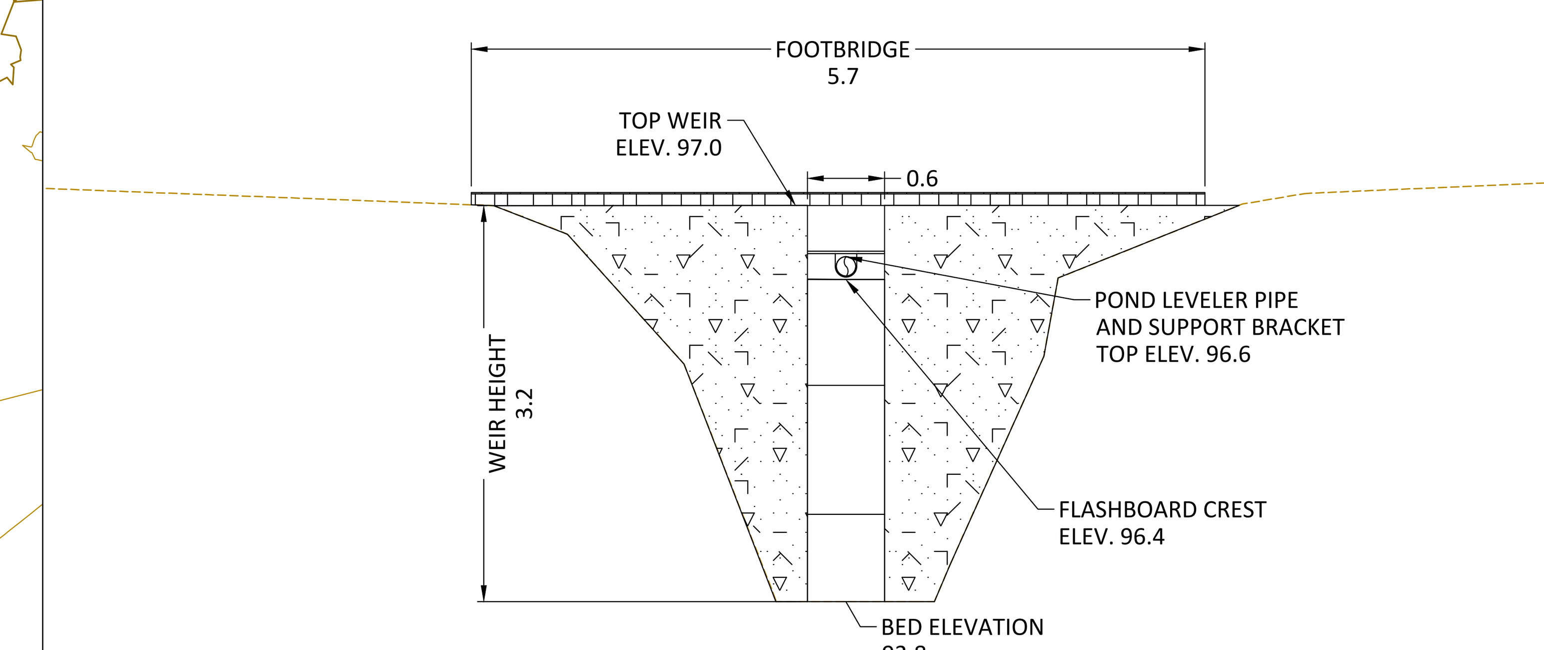


SITE MAP
SCALE 1:2,500



SECTION 1 EXISTING WEIR
SCALE 1:50

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PROPERTY BOUNDARY
- ESTIMATED HIGH SEASONAL WATER LEVEL
- ESTIMATED LOW SEASONAL WATER LEVEL
- SURVEYED EDGE OF WATER (2022-09-19)
- TRAIL EDGE
- 2010 BATHYMETRIC SURVEY POINTS PROVIDED BY RDN
- CONCRETE
- WOOD

1. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR, 2022 CNES DISTRIBUTION AIRBUS DS
2. NHC TOPO SURVEY COMPLETED 2022-09-19 (RTK AND TOTAL STATION), SUPPLEMENTED BY 2019 PROVINCIAL LIDAR AND 2010 BATHYMETRIC SURVEY FROM RDN. THE 2010 BATHYMETRIC DATA HAS LIMITED COVERAGE AND UNKNOWN HORIZONTAL AND VERTICAL ACCURACY; THE ESTIMATED MARSH INUNDATION EXTENTS ASSOCIATED WITH EACH DESIGN CONCEPT ARE SUBJECT TO UNCERTAINTY AND HAVE NOT BEEN CONFIRMED BY ADDITIONAL BATHYMETRIC SURVEY.
3. PROPERTY BOUNDARIES WERE DERIVED FROM PROVINCIAL CADASTRAL MAPPING AND HAVE NOT BEEN VERIFIED ON THE GROUND BY LEGAL SURVEY.
4. ALL DIMENSIONS IN METERS
5. COORDINATE SYSTEM | UTM 10N WGS84,CGVD2013
6. CONTOUR INTERVAL
   MAJOR: 1.0m
   MINOR: 0.2m

CLIENT:

REGIONAL DISTRICT OF NANAIMO
6300 HAMMOND BAY ROAD
NANAIMO, BC
V9T 6N2

REV.	DATE	DESCRIPTION
0	2023-02-09	ISSUED FOR DISCUSSION

nhc northwest hydraulic consultants

SEAL:

COATS MARSH WEIR REPLACEMENT

2022 EXISTING CONDITIONS

FOR DISCUSSION ONLY

DESIGNED:	EJA	SHEET ID:	3007584-PROD-IFR-COATSMARSH-EXISTING-R0F-100 R0	SHEET No: 100
DRAFTED:	RWC	STATUS:	ISSUED FOR DISCUSSION	
CHECKED:	NAV	SCALE:	AS SHOWN WHEN PLOTTED D SIZE	
APPROVED:	----	DATE:	9 FEB 2023	REV No: R0

SUPERSEDES ALL REVISIONS WITH NUMBER PRECEDING

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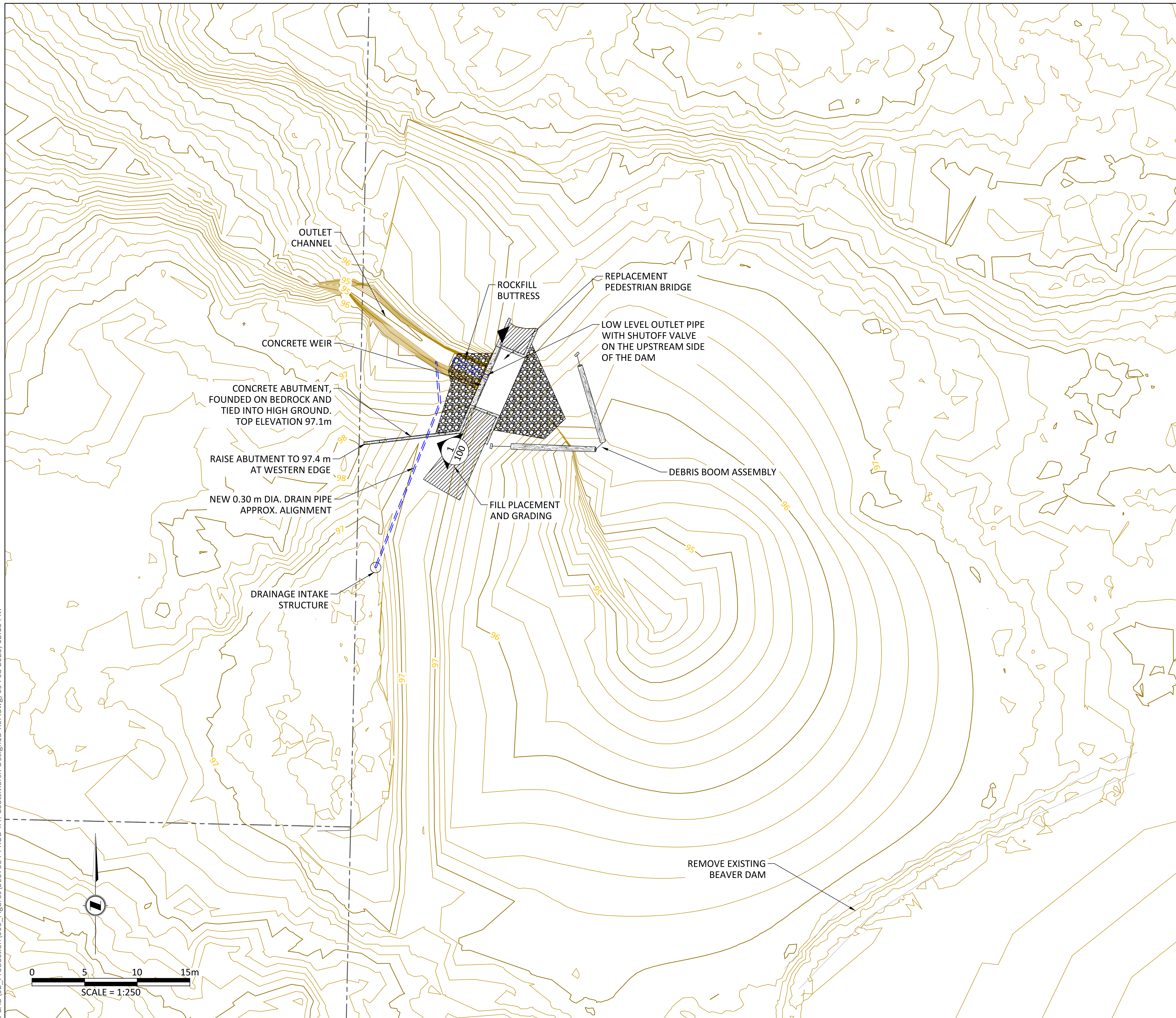

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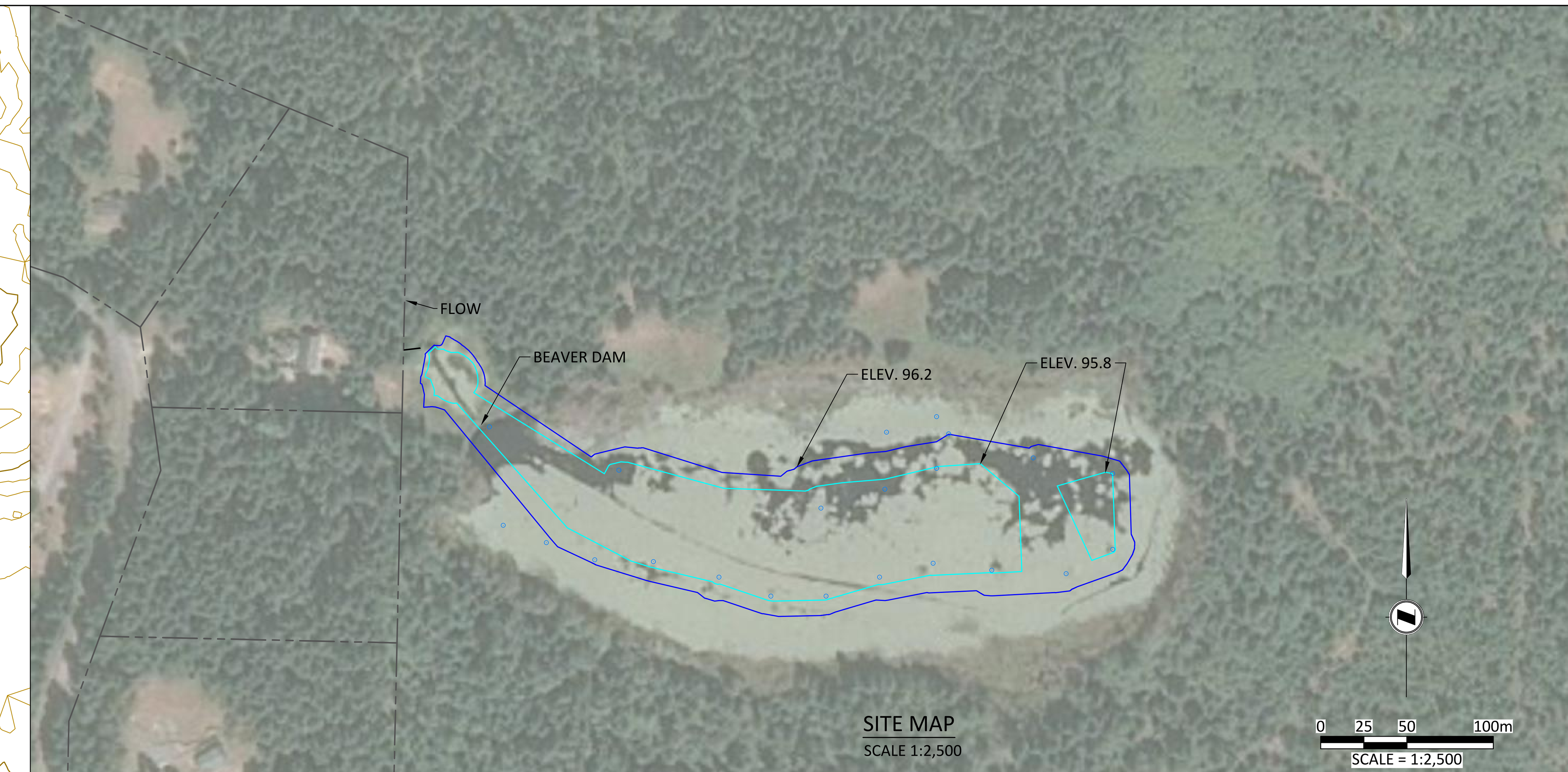
SCALE 1:250



SITE MAP
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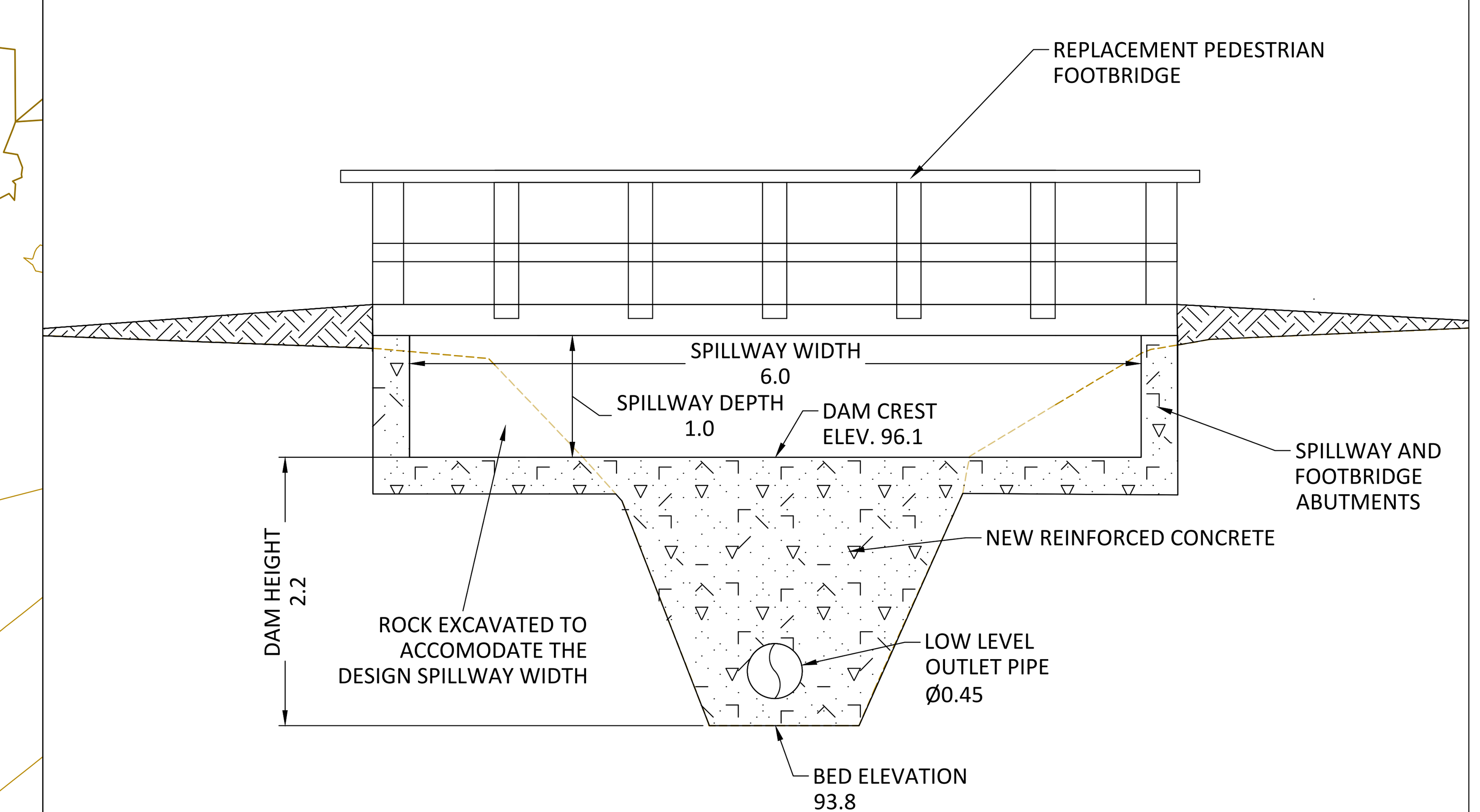

SECTION 1 | DAM
SCALE 1:50

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PROPERTY BOUNDARY
- ESTIMATED HIGH SEASONAL WATER LEVEL
- ESTIMATED LOW SEASONAL WATER LEVEL
- TRAIL EDGE
- 2010 BATHYMETRIC POINTS PROVIDED BY RDN
- CONCRETE
- WOOD
- FILL
- ROCK FILL

1. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR, 2022 CNES DISTRIBUTION AIRBUS DS
2. NHC TOPO SURVEY COMPLETED 2022-09-19 (RTK AND TOTAL STATION), SUPPLEMENTED BY 2019 PROVINCIAL LIDAR AND 2010 BATHYMETRIC SURVEY FROM RDN. THE 2010 BATHYMETRIC DATA HAS LIMITED COVERAGE AND UNKNOWN HORIZONTAL AND VERTICAL ACCURACY; THE ESTIMATED MARSH INUNDATION EXTENTS ASSOCIATED WITH EACH DESIGN CONCEPT ARE SUBJECT TO UNCERTAINTY AND HAVE NOT BEEN CONFIRMED BY ADDITIONAL BATHYMETRIC SURVEY.
3. PROPERTY BOUNDARIES WERE DERIVED FROM PROVINCIAL CADASTRAL MAPPING AND HAVE NOT BEEN VERIFIED ON THE GROUND BY LEGAL SURVEY.
4. ALL DIMENSIONS IN METERS
5. COORDINATE SYSTEM | UTM 10N WGS84,CGVD2013
6. CONTOUR INTERVAL
   MAJOR: 1.0m
   MINOR: 0.2m

CLIENT:

REGIONAL DISTRICT OF NANAIMO
6300 HAMMOND BAY ROAD
NANAIMO, BC
V9T 6N2

REGIONAL DISTRICT OF NANAIMO

REV.	DATE	DESCRIPTION
0	2023-02-09	ISSUED FOR DISCUSSION

nhc northwest hydraulic consultants

SEAL:

COATS MARSH WEIR REPLACEMENT

CONCEPTUAL DESIGN 1

FOR DISCUSSION ONLY

DESIGNED:	EJA	SHEET ID:	3007584-PROD-IFR-COATSMARSH-DESIGN1B-R0F-100 R0	SHEET No:
DRAFTED:	RWC	STATUS:	ISSUED FOR DISCUSSION	100
CHECKED:	NAV	SCALE:	AS SHOWN WHEN PLOTTED D SIZE	
APPROVED:	----	DATE:	9 FEB 2023	REV No: R0

SUPERSEDES ALL REVISIONS WITH NUMBER PRECEDING

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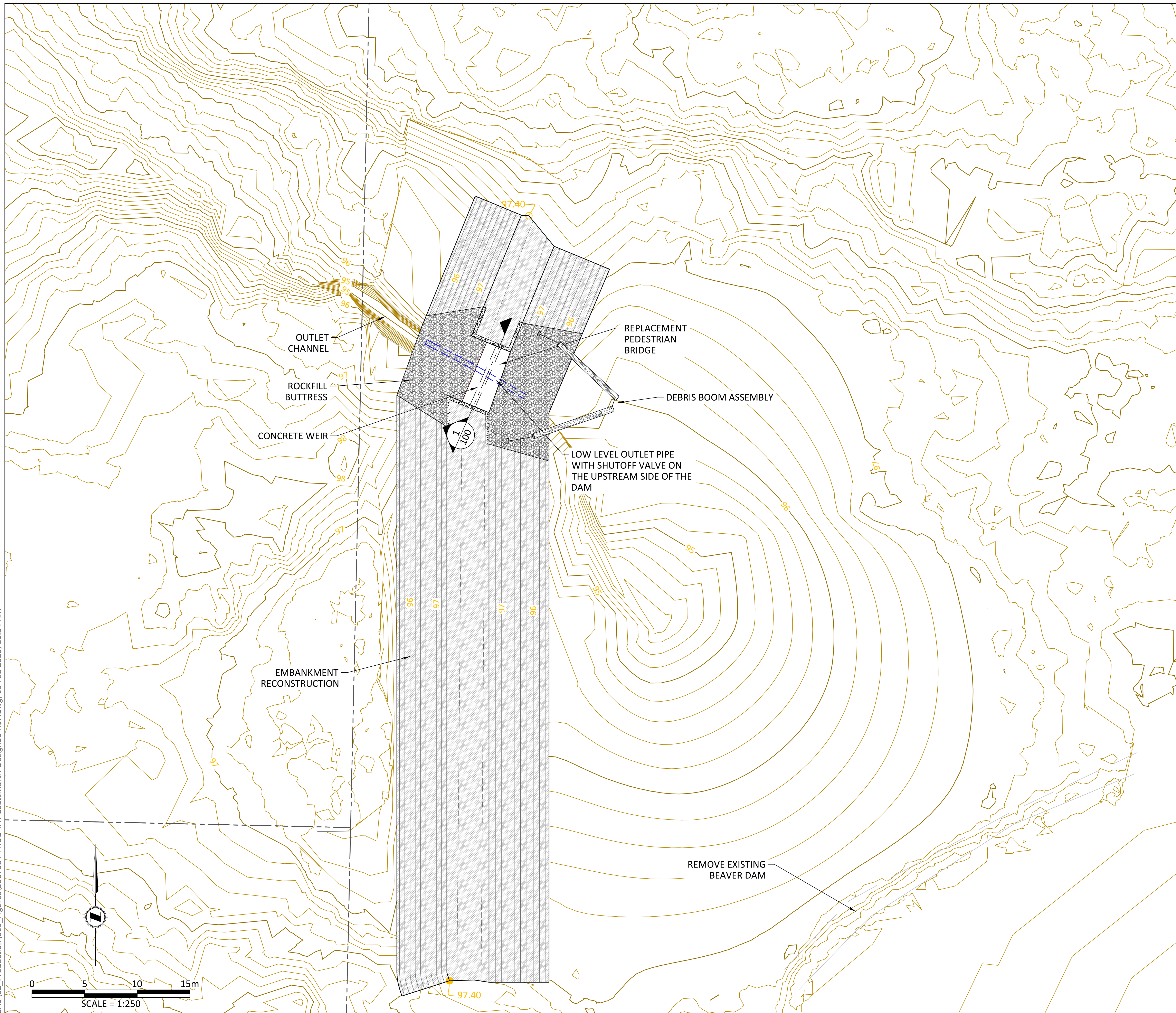

PLAN VIEW
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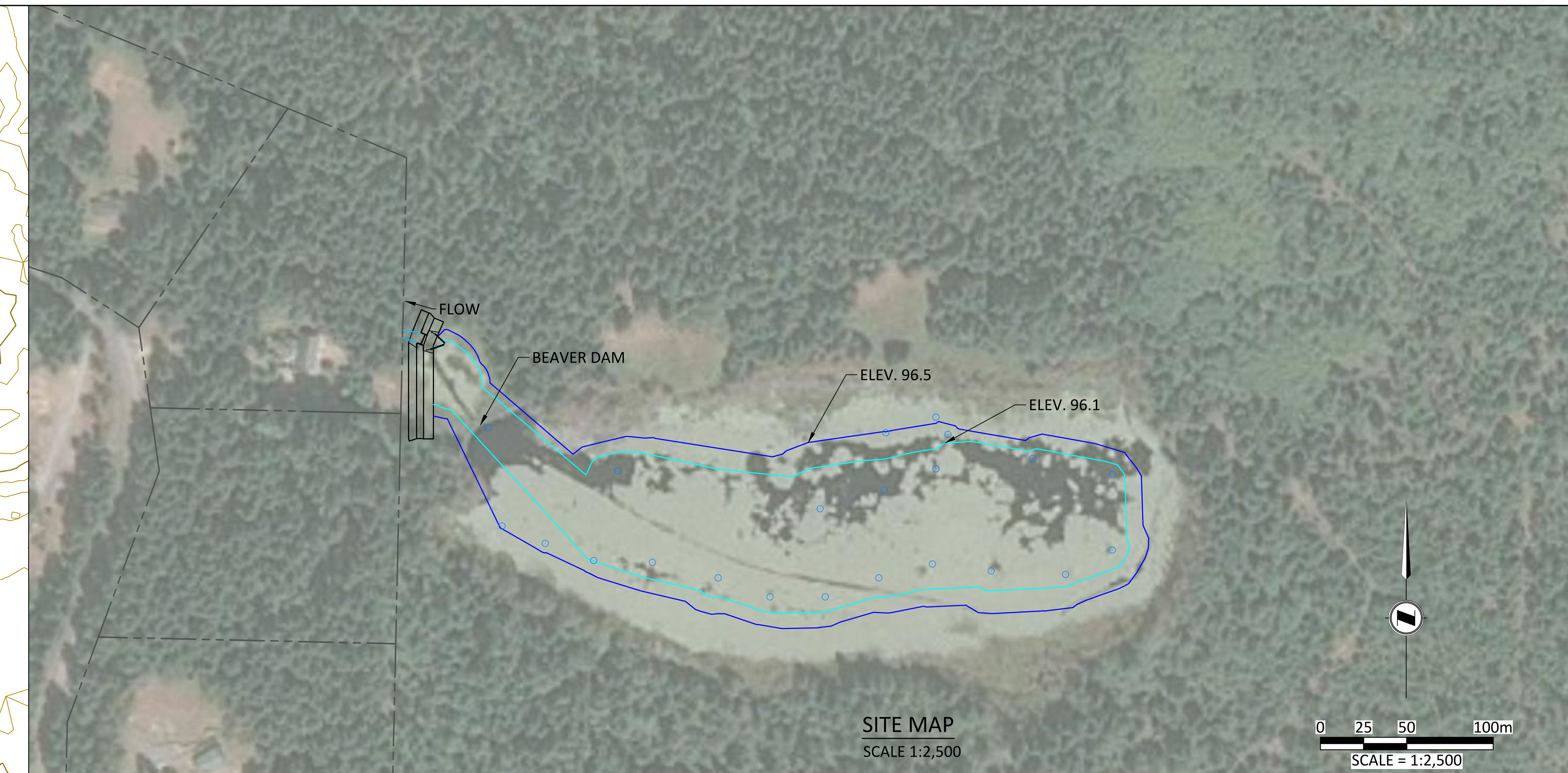
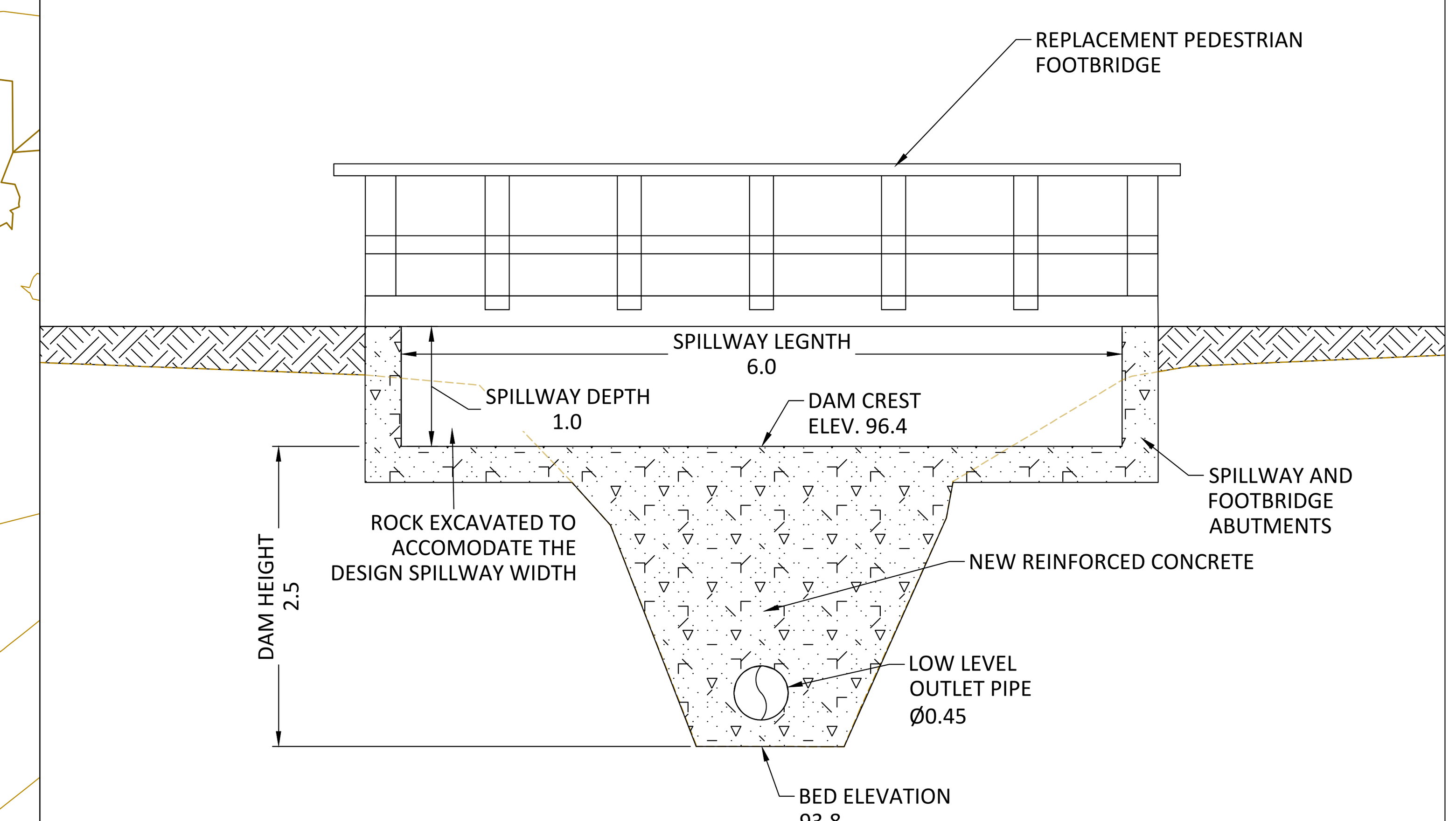


SITE MAP
SCALE 1:2,500



SECTION 1 | DAM
SCALE 1:50

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PROPERTY BOUNDARY
- ESTIMATED HIGH SEASONAL WATER LEVEL
- ESTIMATED LOW SEASONAL WATER LEVEL
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- FILL
- ROCK FILL

1. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR, 2022 CNES DISTRIBUTION AIRBUS DS
2. NHC TOPO SURVEY COMPLETED 2022-09-19 (RTK AND TOTAL STATION), SUPPLEMENTED BY 2019 PROVINCIAL LIDAR AND 2010 BATHYMETRIC SURVEY FROM RDN. THE 2010 BATHYMETRIC DATA HAS LIMITED COVERAGE AND UNKNOWN HORIZONTAL AND VERTICAL ACCURACY; THE ESTIMATED MARSH INUNDATION EXTENTS ASSOCIATED WITH EACH DESIGN CONCEPT ARE SUBJECT TO UNCERTAINTY AND HAVE NOT BEEN CONFIRMED BY ADDITIONAL BATHYMETRIC SURVEY.
3. PROPERTY BOUNDARIES WERE DERIVED FROM PROVINCIAL CADASTRAL MAPPING AND HAVE NOT BEEN VERIFIED ON THE GROUND BY LEGAL SURVEY.
4. ALL DIMENSIONS IN METERS
5. COORDINATE SYSTEM | UTM 10N WGS84,CGVD2013
6. CONTOUR INTERVAL
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   MINOR: 0.2m

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CLIENT:

REGIONAL DISTRICT OF NANAIMO
6300 HAMMOND BAY ROAD
NANAIMO, BC
V9T 6N2

REV.	DATE	DESCRIPTION
0	2023-02-09	ISSUED FOR DISCUSSION

northwest hydraulic consultants

SEAL:

COATS MARSH WEIR REPLACEMENT

CONCEPTUAL DESIGN 2

FOR DISCUSSION ONLY

DESIGNED:	EAJ	SHEET ID:	3007584-PROD-IFR-COATSMARSH-DESIGN2B-R0F-100 R0	SHEET No:
DRAFTED:	RWC	STATUS:	ISSUED FOR DISCUSSION	100
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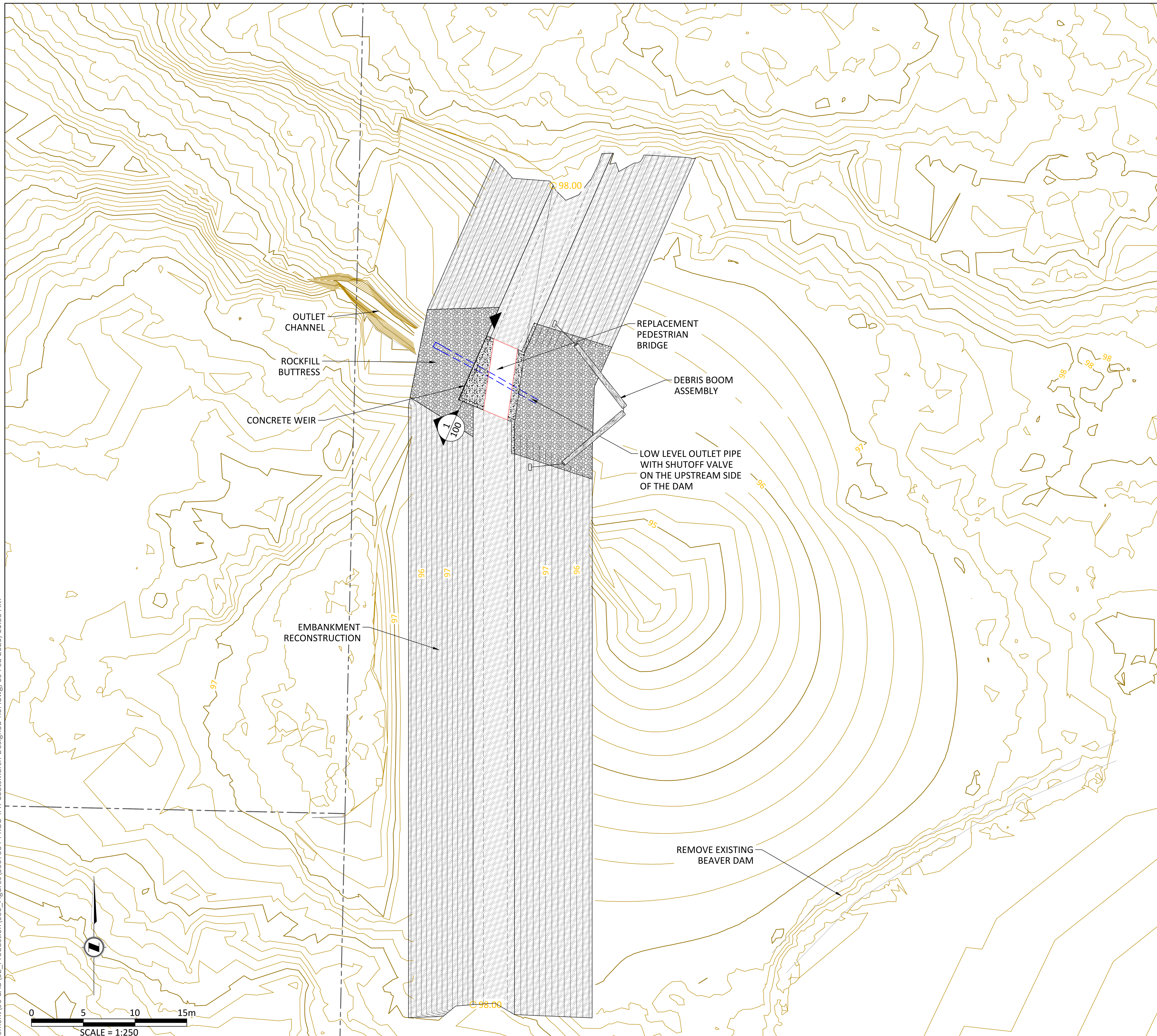
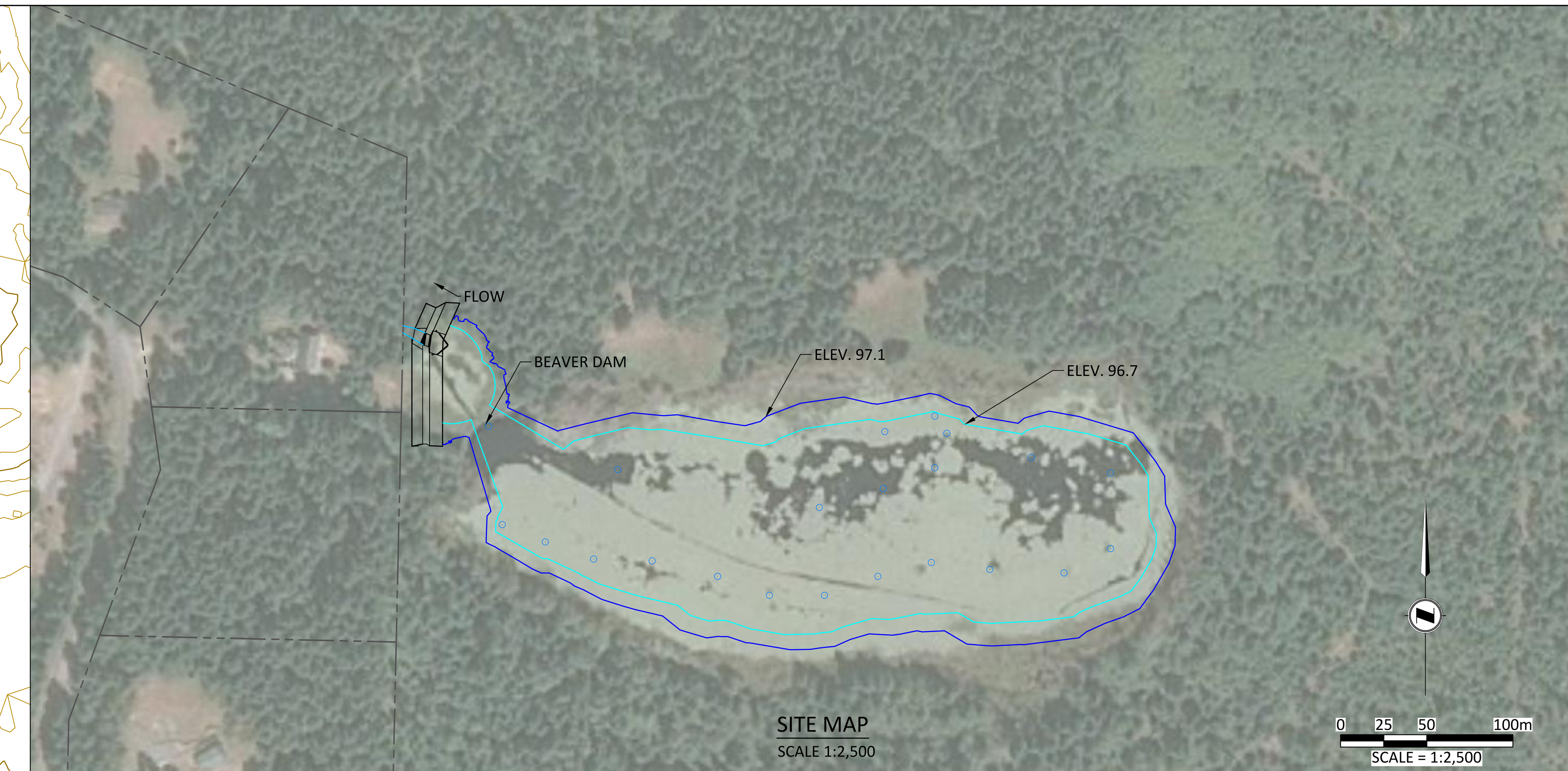


PLAN VIEW

SCALE 1:250



SITE MAP

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6. CONTOUR INTERVAL
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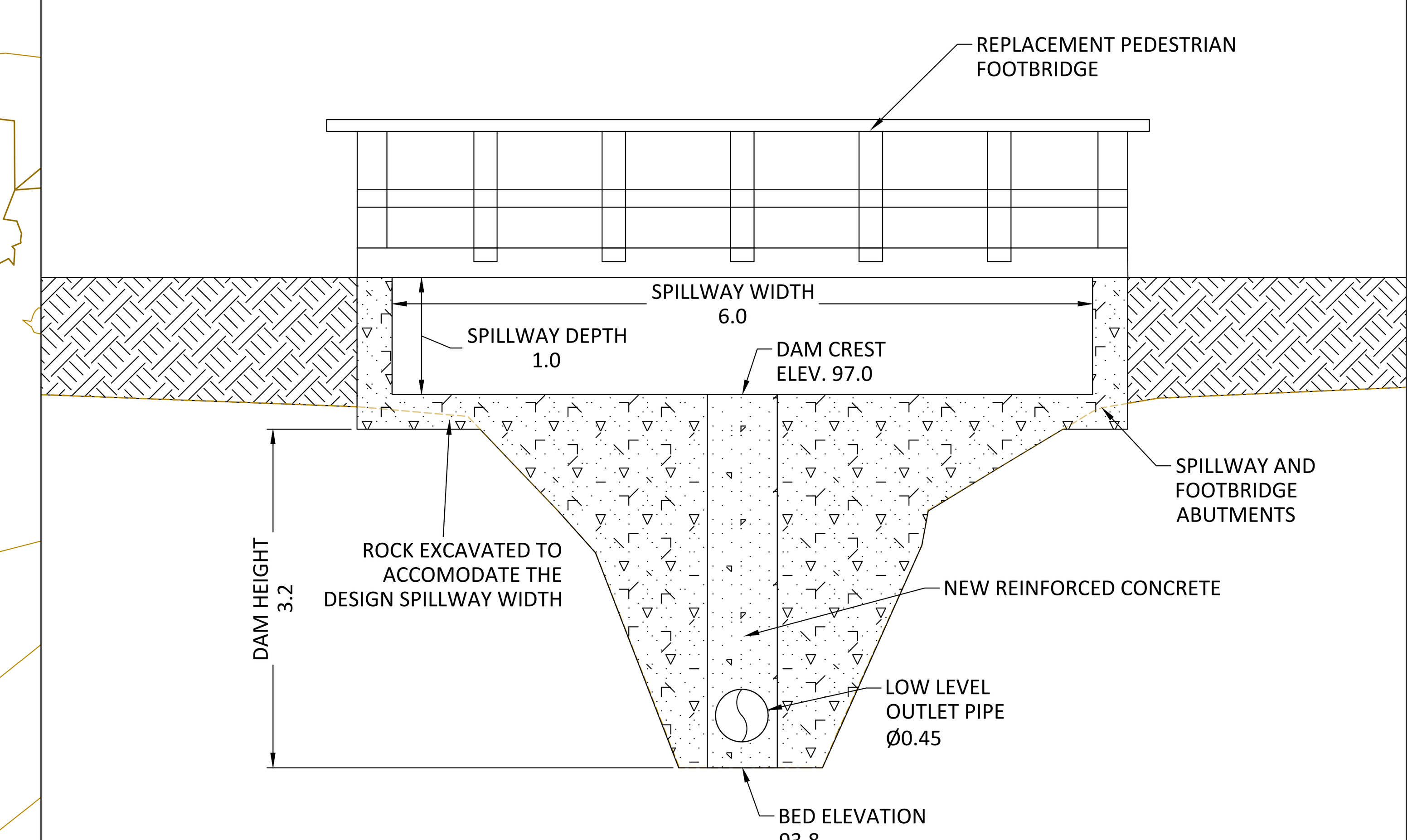
   MINOR: 0.2m



SECTION 1 | DAM

SCALE 1:50

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PROPERTY BOUNDARY
- ESTIMATED HIGH SEASONAL WATER LEVEL
- ESTIMATED LOW SEASONAL WATER LEVEL
- TRAIL EDGE
- 2010 BATHYMETRIC POINTS PROVIDED BY RDN
- CONCRETE
- WOOD
- FILL
- ROCK FILL

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6300 HAMMOND BAY ROAD
NANAIMO, BC
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SEAL:

COATS MARSH WEIR REPLACEMENT

CONCEPTUAL DESIGN 3

FOR DISCUSSION ONLY

DESIGNED:	EJA	SHEET ID:	3007584-PROD-IFR-COATSMARSH-DESIGN3B-R0F-100 R0	SHEET No:
DRAFTED:	RWC	STATUS:	ISSUED FOR DISCUSSION	100
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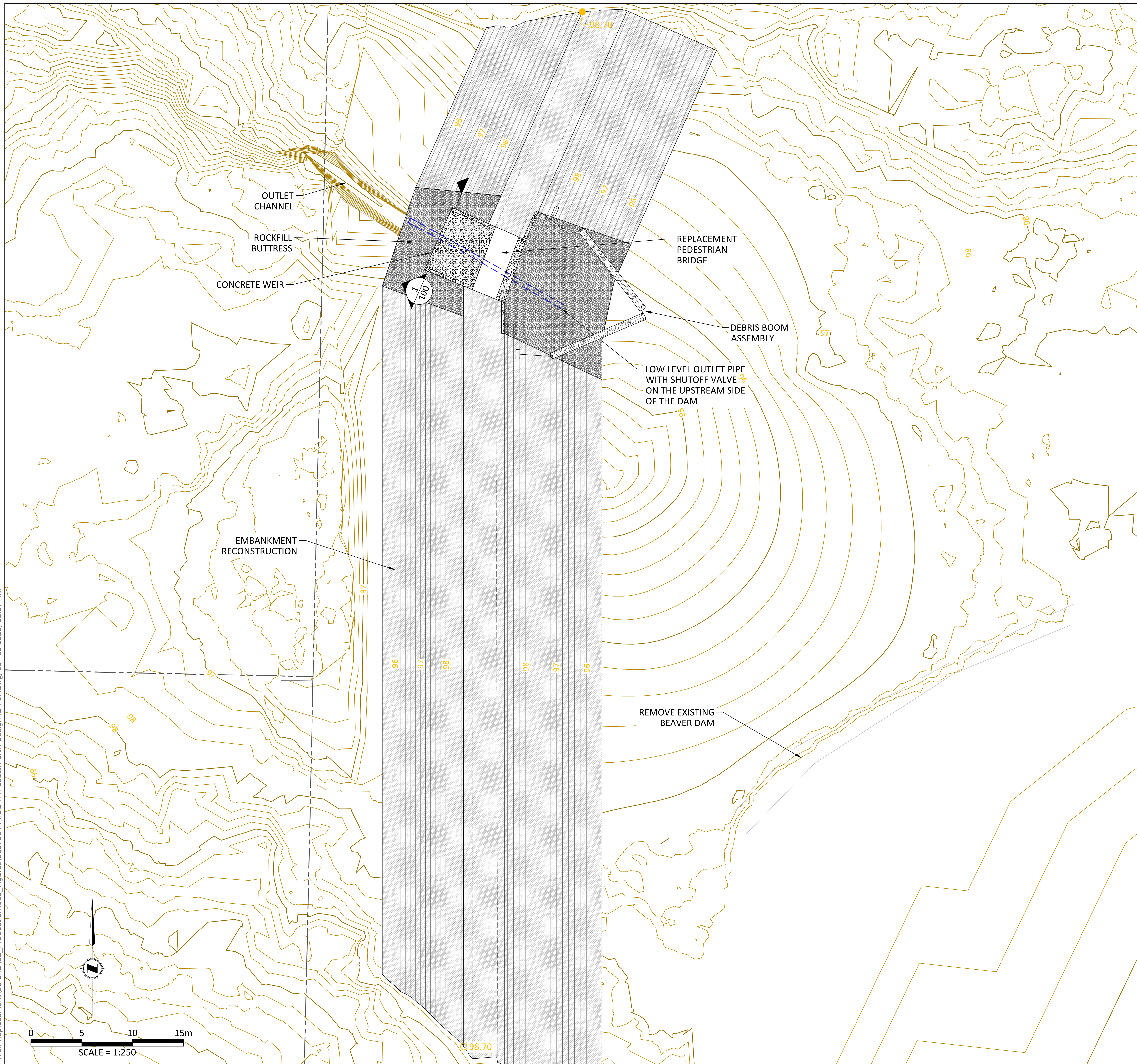
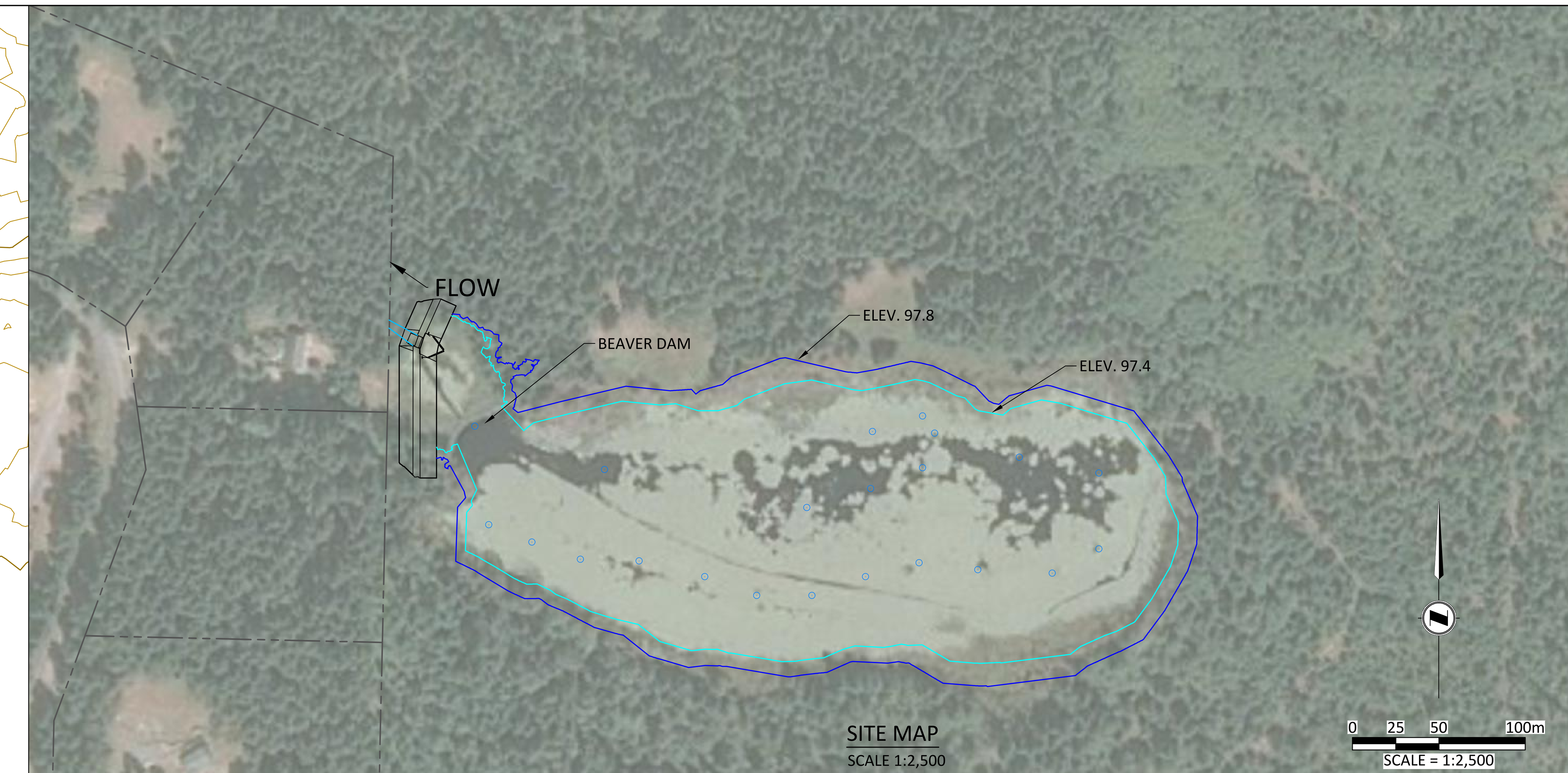


PLAN VIEW

SCALE 1:250



SITE MAP

SCALE 1:2,500

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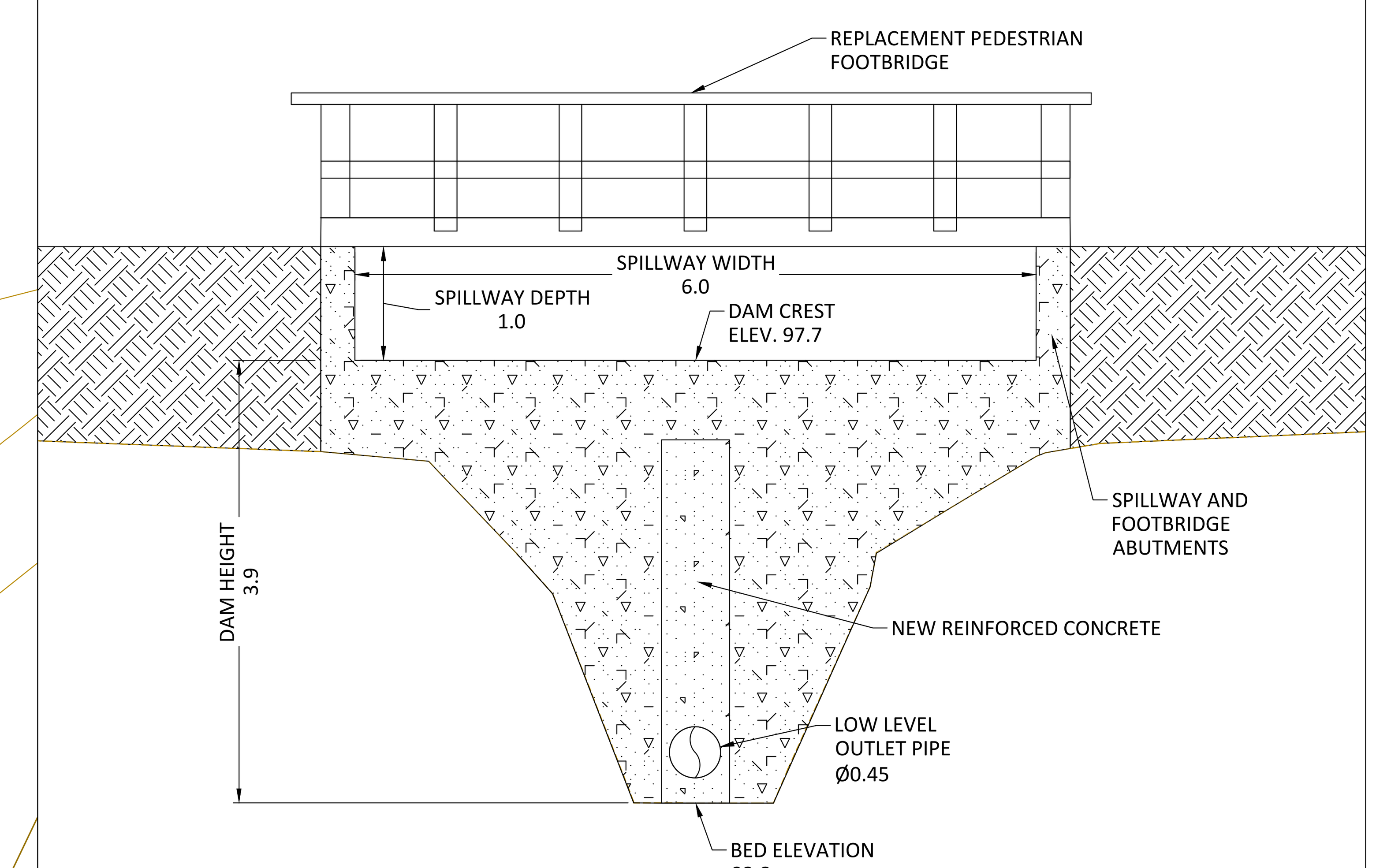

SECTION 1 | DAM

SCALE 1:50

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PROPERTY BOUNDARY
- ESTIMATED HIGH SEASONAL WATER LEVEL
- ESTIMATED LOW SEASONAL WATER LEVEL
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REGIONAL DISTRICT OF NANAIMO

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SEAL:

COATS MARSH WEIR REPLACEMENT

CONCEPTUAL DESIGN 4

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DESIGNED:	EJA	SHEET ID:	3007584-PROD-IFR-COATSMARSH-DESIGN4B-R0F-100 R0	SHEET No:
DRAFTED:	RWC	STATUS:	ISSUED FOR DISCUSSION	100
CHECKED:	NAV	SCALE:	AS SHOWN WHEN PLOTTED D SIZE	
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APPENDIX D

DETAILED HYDROLOGIC AND HYDRAULIC CALCULATIONS

FLOOD FLOW HYDROLOGY COMPUTATIONS

The Rational Method was used to estimate peak flood flows into Coats Marsh, excluding attenuation effects. The Rational Method formula is stated as follows, with inputs and results summarized in Table D1.

$$Q_p = 0.28CPA/T_c$$

Where Q_p is the peak stream discharge (m^3/s), *C* is the runoff coefficient, *P* is the uniform precipitation depth corresponding to the watershed's time of concentration (mm), *A* is the watershed area (km^2), and T_c is the watershed's time of concentration (h).

Table D1 Summary of Rational Method inputs and results.

Parameter	Value	Notes
Time of concentration	2.6 hours	Estimated using watershed slope/area curves available from the Province (BC MOE, Water Management Division, 1991).
Watershed area	1.454 km^2	Calculated from 2019 LiDAR data available from the Province (Government of British Columbia, 2021).
Rainfall depths	1/10-year = 26.3 mm 1/100-year = 37.6 mm 1/500-year = 46.2 mm 1/1000-year = 49.8 mm	Obtained from the average of Nanaimo Airport, Nanaimo City Yard, and Nanaimo Departure Bay IDF curves (Environment and Climate Change Canada, 2022). Return periods beyond the maximum published 100-year period were extrapolated.
Runoff coefficient	0.70	Corresponds to moderately sloped, wooded terrain with an adjustment for increased runoff potential during severe storms (BC MOE, Water Management Division, 1991).
Peak stream discharge	1/10-year = 2.8 m^3/s 1/100-year = 4.1 m^3/s 1/500-year = 5.1 m^3/s 1/1000-year = 5.5 m^3/s	Calculated using the Rational Method formula

The Rational Method results were first checked by comparing the 1/10-year peak flow estimate to the November 2021 flood event, during which 24-hour rainfall in Nanaimo had a return period of approximately 10 years. Field observations by local Gabriola Resident Mr. Nick Doe indicate that peak flows at the weir reached approximately 0.13 m deep over a 6 m length (Doe, 2021). Assuming flow velocities between 1 and 2 m/s, the peak discharge would have been approximately 0.8 to 1.6 m^3/s. This range is less than the Rational Method estimate of 2.8 m^3/s but remains within reasonable bounds when considering peak flow attenuation through the marsh.

The Rational Method results at higher flows were then checked against available flood flow estimates for three regional Water Survey Canada (WSC) stream gauges (Table D2.) The gauges were selected based on proximity to Coats Marsh and similarity in basin characteristics (i.e., area, elevations, and mean annual precipitation). 1/100-year peak discharges at the gauges were scaled to Coats Marsh using the following formula (NHC, 2021):

$$Q_{ungauged} = Q_{gauged} * \left(\frac{Area_{ungauged}}{Area_{gauged}}\right)^{b}$$

Where *Q* and *A* correspond to the discharges and watershed areas for the gauged and ungauged streams, and *b* is a scaling exponent. For daily average discharge, flows on Vancouver Island scale with a *b* value of 1.0 (NHC, 2021). For instantaneous peak flows, a *b* value less than 1.0 provides a more realistic representation of the "flashy" characteristics of small watersheds when compared to larger watersheds. A *b* value of 0.85 was adopted for assessing Coats Marsh.

Sandhill Creek does not have significant lake areas, so its scaled discharge value is a reasonable proxy for flows into Coats Marsh when peak flow attenuation is not accounted for. The 1/100-year scaled peak discharge at Sandhill Creek (3.7 m^3/s) is comparable to the Rational Method estimate of 4.1 m^3/s. The Enos Creek and Cusheon Creek gauges are both located at the outlets of lakes, so attenuation effects reduce their peak flows compared to Sandhill Creek. Scaled peak flows at the two gauges are 30% to 40% of those at Sandhill Creek; similar peak flow attenuation could be expected at Coats Marsh. A peak flow attenuation factor of 50% is recommended for initial spillway sizing and should be refined during detailed design based on reservoir routing analysis.

Table D2 Summary of proxy gauges used for regional streamflow scaling.

WSC ID	Name	Area (km^2)	1/100-Year Peak Discharge (m^3/s)	
			Gauge FFA[1] Value	Scaled FFA for Coats Marsh
08HB030	Enos Creek	1.6	1.6	1.5
08HA060	Sandhill Creek	3.1	6.5	3.4
08HA026	Cusheon Creek	7.8	4.1	1.0

4. Flood frequency analysis (FFA) values for maximum daily discharge were extracted at each stream from the reference study (NHC, 2021). Peak instantaneous discharges were obtained by multiplying the daily discharge values by average peak/daily ratios at each gauge.

Local PMP estimates indicate that the 24-hour duration PMP at Coats Marsh is approximately 80% greater than the 24-hour duration 1/1000-year precipitation depth (DTN and MGS Engineering, 2020). Assuming that this ratio is consistent for shorter duration storms, the PMF inflow to Coats Marsh would be 80% greater than the 1/1000-year inflow when computed using the Rational Method. This approach yields an initial PMF peak flow estimate of 9.9 m^3/s. If the final dam consequence classification is High, we recommend detailed hydrologic modelling during future design phases to confirm the PMF value.

Table D3 Summary of IDF peak flow estimates.

Design Case	Peak Flood Flow at Stated Return Period (m^3/s)			
	1/100-Year	1/1000-Year	PMF	1/3 Between 1/1000-Year and PMF
Unattenuated inflow, from Rational Method	4.1	5.5	9.9	7.0

Design Case	Peak Flood Flow at Stated Return Period (m^3/s)			
	1/100-Year	1/1000-Year	PMF	1/3 Between 1/1000-Year and PMF
Unattenuated inflow, plus a 30% climate change factor	5.4	7.1	12.9	9.0
Design flow, considering peak flow attenuation at 50%	2.7	3.5	6.5	4.5

CLIMATE CHANGE IMPACTS ON FLOOD FLOW HYDROLOGY

Climate change is expected to impact the severity of rainfall-driven flood events on Vancouver Island (CVRD, 2017). Climate change can be factored into flood flow estimates using several methods, ranging from simple percentage-based increases on peak flows or precipitation to detailed watershed hydrologic modelling.

For the present study, NHC has carried out an overview-level climate change assessment based on existing literature and readily available climate projections. The objective of the assessment is to compile several estimates of extreme precipitation increases, such that a reasonable climate change factor (i.e., percentage increase) can be included in the design flows. The following summarizes our review findings. Note that all projections reviewed are median values under the SSP 5-85 or RCP8.5 climate scenarios, both of which correspond to roughly "business as usual" for emissions and warming. Note also that all climate change projections are subject to significant uncertainty, particularly when projecting to the year 2100.

- Cowichan Valley Regional District completed a detailed climate projections and impacts analysis in 2017. For extreme precipitation, the report findings are similar to what could be expected on nearby Gabriola Island. Annual maximum 24-hour precipitation was projected to increase by 17% by the 2050s and 30% by the 2080s.
- Environment and Climate Change Canada[1] provide a simplified method for estimating future precipitation increases, based on the relationship between temperature and the moisture capacity of the atmosphere (i.e., the Clausius-Clapeyron relation). On Gabriola Island, mean annual temperatures are projected to increase by 4.4°C by the year 2100; this corresponds to an extreme precipitation increase of 35%.
- The University of Western Ontario IDF_CC tool (UWO, 2022) provides estimates of IDF curve values under future climate change conditions. NHC reviewed climate change projections for the Nanaimo Airport climate station at various return periods and storm durations. For 24-hour duration, 100-year return period precipitation, the design precipitation value increases by 31%. For 1-hour duration, 100-year return period precipitation, the design precipitation value increases by 22%. The hydrologically critical design storm for Coats Marsh is likely between 1

[1] Climate Data Canada, available at: https://climatedata.ca/resource/idf-data-and-climate-change/

and 24 hours in duration; therefore, the climate change factor for this storm would be on the order of 20%-30%.

Based on the foregoing, NHC recommends applying a 30% increase on design flows to account for the potential future impacts of climate change. This recommendation is provided as a reasonably conservative design value in light of available information.

SEASONAL WATER BALANCE COMPUTATIONS

After review of available data, the source chosen for determining a seasonal water balance for Gabriola Island is Burgess and Allen's (2016) Groundwater Recharge Model for Gabriola Island, which was presented in a report for the Regional District of Nanaimo. This source considers groundwater recharge and conditions specific to Gabriola Island, however the authors acknowledge that geologic conditions on even finer scales can be important. This source aggregates some components of seasonal water balance that would otherwise be cumbersome to compute independently. The methodology and results of that work are further presented in Burgess (2017). Burgess and Allen (2016) developed a MIKE SHE model for surface and groundwater hydrology, including monthly outputs. Major water balance components from that work are summarized graphically in Figure D1.

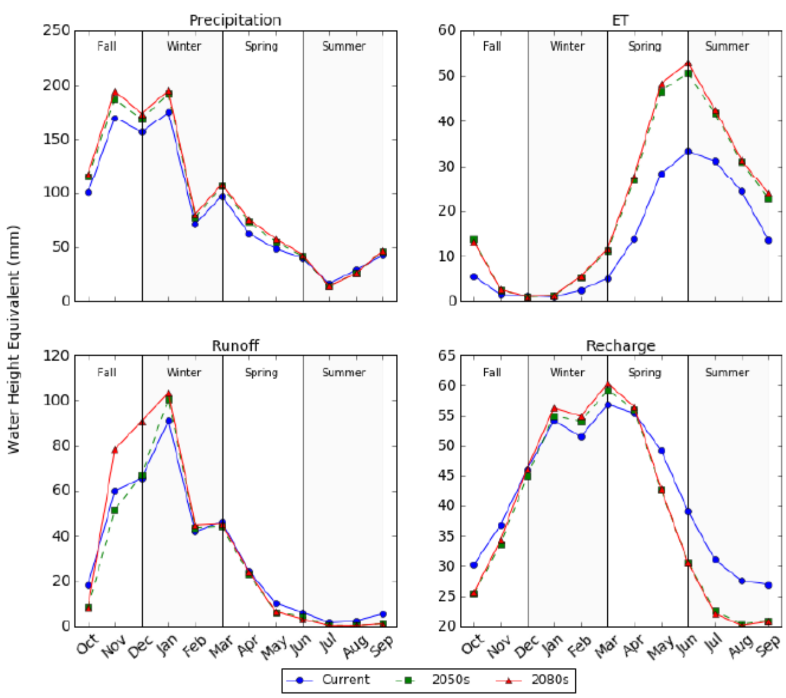

Figure 29. Model water balance under current and future climate conditions. Water balance components are average monthly totals. The calibration period was used as the dataset for averaging.

Figure D1 Water balance for Gabriola Island from Burgess and Allen (2016).

NHC has updated the precipitation values used for this seasonal water balance with mean precipitation over a longer time horizon to be consistent with typical climate data sources that would usually be used for this type of work. Values for precipitation and runoff were read from Figure D1 determine a derived percent of runoff from Burgess and Allen (2016). We then apply this percentage to the 1981 to 2010 monthly precipitation normals at the Gabriola Island ECCC station instead of using the same precipitation as Burgess and Allen (2016). The amount of precipitation that is converted to runoff is highest toward the end of the winter, as groundwater stores have been partially recharged and precipitation remains high. All precipitation is accounted for within the month it falls: mean annual snowfall amounts to about 34.7 cm, which on Gabriola Island usually melts within a few days or weeks; we therefore treat snow as snow water equivalent within the month it falls. Deriving runoff from Burgess and Allen (2016) allows for simplification of groundwater interactions and evapotranspiration components of the water balance into total runoff over land within the watershed. However, we adjust water balances to consider open water evaporation and precipitation over the surface of Coats Marsh in the summer months. Open water evaporation is based on normals from the ECCC climate station at Saanichton over the 1981 to 2010 period. This is the closest representative station with evaporation data available; it is located about 65 km southeast of Coats Marsh at a slightly lower elevation of 61 m above sea level, although it is a more exposed location than Coats Marsh considering the surrounding area is more agricultural than the forested area around Coats Marsh. Table D4 provides open water evaporation in mm/day, neglecting December to March, when evaporation is negligible.

Table D4 Saanichton open water evaporation normals (mm/day), 1981-2020 (Environment and Climate Change Canada).

April	May	June	July	August	September	October	November
2.0	2.7	3.3	3.7	3.3	2.1	1.1	1

The seasonal water balance for Coats Marsh is conducted in two components: for all land area within the watershed supplying the marsh and for the surface area of open water at the marsh itself. Based on the mapping conducted for the watershed, a surface area of 55,000 m^2 is chosen for the surface area of the open water. While this value is not consistent over the course of the year as the marsh is drawn down over the summer, the results of the water balance are not very sensitive to the fluctuations in water levels, so this effect is neglected. Further, any runoff over land to the marsh during the months of May to September are neglected: if they were included, these 5 summer months would together account for only 7.3% of annual runoff. This is done to provide a conservative estimate regarding summer drawdowns because it assumes that no water is added to the pond except precipitation falling directly on the open water surface, and accounts for the effect of lower summer precipitation resulting in localized ponding under relatively stronger evaporation conditions that would convey less runoff arriving at the marsh. Based on this methodology, the derived runoff over the land area in the watershed is summarized in Table D5.

Table D5 Derived runoff over watershed land area.

Month	Percent Runoff (derived from Burgess and Allen 2016)	Precipitation (climate normals for Gabriola, 1981 to 2020, in mm)	Derived Runoff Over Land (in mm, * indicates neglected surface runoff)
January	49.32%	147.3	72.7
February	55.44%	95.6	53.0
March	46.08%	92.1	42.4

Month	Percent Runoff (derived from Burgess and Allen 2016)	Precipitation (climate normals for Gabriola, 1981 to 2020, in mm)	Derived Runoff Over Land (in mm, * indicates neglected surface runoff)
April	40%	62.8	24.8
May	20%	47.9	*
June	15%	43.2	*
July	11%	24.5	*
August	7%	26.6	*
September	14%	33.9	*
October	18%	86.3	15.4
November	34%	156.9	52.8
December	39%	140.5	55.4
Total	36%	957.6	316.5

The water balance for both components is then conducted on a volume basis (accounting for the number of days in each month, with February assumed to have 28 days). A monthly water balance is computed by combining runoff over the land area, as well as the precipitation and evaporation over the surface of the marsh. The final value is reported as "flow through weir," as it represents the sum of all water balance components at that location; negative values indicate a net loss of water in the system and therefore that drawdown is occurring in the months of May to September. These values are shown in Table D6. If this analysis were conducted dynamically for each scenario accounting for varying sizes of marsh surface area, slightly lower flows would be seen at the weir for smaller marsh sizes because of less direct precipitation on water surface; however, the results are not very sensitive given the relatively small size of the marsh to the watershed area. For example, considering the surface area of the marsh to be 20,000 m^3 would result in about a 2.4% reduction in flow for the month of January.

Table D6 Seasonal water balance, by monthly volume.

Month	Surface runoff over land (m^3)	Precipitation directly on marsh (m^3)	Open water evaporation (m^3)	Flow through weir (m^3)
January	101,642	8,102	*	109,743
February	74,149	5,258	*	79,407
March	59,373	5,066	*	64,439
April	34,709	3,454	-3,300	34,863
May	*	2,635	-4,604	-1,969
June	*	2,376	-5,445	-3,069
July	*	1,348	-6,309	-4,961
August	*	1,463	-5,627	-4,164

Month	Surface runoff over land (m^3)	Precipitation directly on marsh (m^3)	Open water evaporation (m^3)	Flow through weir (m^3)
September	*	1,865	-3,465	-1,601
October	21,560	4,747	-1,876	24,431
November	73,890	8,630	-1,650	80,869
December	77,523	7,728	*	82,250
Total	442,845	52,668	-32,274	463,239

Some important monthly outputs from the seasonal water balance are reported in Table D7. The months of July and August undergo the highest drawdowns in pond levels; the pond can be expected achieve its lowest water surface elevation some time near mid to late September, when rains typically begin to replenish the volume that was lost over the summer.

Table D7 Important output from seasonal water balance (* indicates no drawdown).

Month	Average flow through weir (L/s)	Drawdown (m)
January	41.0	*
February	32.8	*
March	24.1	*
April	13.5	*
May	0	0.036
June	0	0.056
July	0	0.090
August	0	0.076
September	0	0.029
October	9.1	*
November	31.2	*
December	31.8	*
Total	*	**0.287**

From Table D7, a typical summer/dry season would result in 0.287 m of evaporation. This is rounded to the 0.3 m assumed in the main body of the report for typical summer drawdown. This value is not dependent on assumed marsh area and is therefore the same for all dam elevation scenarios. The monthly average flows through the weir are much lower than instantaneous flows that would be experienced during winter storm events, as these values would fluctuate drastically to match the hydrograph of flow over the watershed.

CLIMATE CHANGE IMPACTS ON SEASONAL WATER BALANCE

Outlooks for climate change are also based on those from Burgess and Allen (2016). They provide monthly values for estimated change in precipitation for the 2050s and the 2080s. We apply these values to determine new derived percent runoffs, assuming that any additional precipitation is converted directly into runoff (i.e. that groundwater cannot be recharged any faster than it is in their data). They also supply predicted estimates for change in reference evapotranspiration (RET), which we use as a multiplication factor to adjust open water evaporation (as influenced by warmer average temperatures). This method does not independently adjust for changes in evapotranspiration over the land surface, but these changes are negligible in what would continue to be very wet winters. However, in the summer, we may be using percent runoff values higher than would be achieved with increased evapotranspiration, but we assume zero land surface runoff in the months of May to September, so higher evapotranspiration during these months does not affect our calculated drawdown results. Table D8 provides the climate change effects on precipitation and RET from Burgess and Allen (2016).

Table D8 Predicted climate change impacts on monthly water balance components, from Burgess and Allen (2016).

Table 8. Changes to RET and precipitation under forecast future climate conditions.

	RET (% change)		Precipitation (% change)	
	2050s	2080s	2050s	2080s
January	5	8	10	11
February	7	10	9	13
March	5	8	9	11
April	3	5	16	21
May	4	6	12	19
June	6	9	2	6
July	11	16	-9	-13
August	13	18	-11	-10
September	9	13	8	10
October	5	8	15	17
November	4	7	12	15
December	5	8	7	11

Table D9 provides a summary of some important water balance outputs after applying climate change adjustments for the 2050s and 2080s. This analysis yields that by the 2080s, summer drawdown levels in Coats Marsh are likely to increase by 4.97 cm, or 17.3% more than present drawdowns would be.

Table D9 Outputs from seasonal water balance, with climate change considerations for the 2050s and 2080s (* indicates no drawdown).

	2050s		2080s	
Month	Average Flow through weir (L/s)	Drawdown (m)	Average Flow through weir (L/s)	Drawdown (m)
January	54.1	*	56.0	*
February	41.1	*	43.9	*
March	30.0	*	31.6	*
April	18.9	*	20.3	*
May	0	0.033	0	0.032
June	0	0.061	0	0.062
July	0	0.105	0	0.112
August	0	0.092	0	0.097
September	0	0.032	0	0.034
October	12.1	*	12.3	*
November	42.7	*	45.0	*
December	43.9	*	47.1	*
Total		**0.323**		**0.336**

DAM BREACH OUTFLOW COMPUTATIONS

Dam breach outflow computations are typically the first step in a dam breach inundation and downstream consequences assessment. For the present study, NHC's scope does not include detailed dam breach modelling and downstream inundation mapping. Instead, the objective of the dam breach assessment is to estimate the peak outflows that could be expected from the existing dam and any future replacement structures. This information can be used to assess the relative dam breach hazards posed by each scenario and supports a qualitative assessment of downstream consequences.

Peak outflows during a dam failure depend on several factors such as the location of the breach (i.e., at the berm vs. at the weir structure), the breach geometry and formation time, and antecedent water level and flow conditions. The most critical location for a breach is likely at the weir, due to the height of the structure above the downstream channel.

NHC has estimated peak dam breach outflows using the following methodology, assuming a sudden catastrophic failure across the full width of the concrete structure. Peak outflows would be less than these values if the failure occurred slowly, if only a portion of the structure failed, or if a portion of the structure became wedged downstream and re-blocked the outflow channel. The peak outflow estimates do not include baseline streamflow; additional discharge would be present if the failure occurred during the IDF.

- The breach geometry was characterized by a 2 m width and a height equal to the height of the weir crest above the downstream channel.
- Peak breach outflows were calculated using three methods:
  - Steady-state energy balance between the static pond level and critical depth control in the downstream channel (i.e., Bernoulli equation). This approach is overly conservative because it doesn't account for head losses through the breach or the decrease in pond levels as the breach flows ramp up; it is suitable as an upper-bound check on the other approaches.
  - Ritter's solution to the 1-D Saint Venant equations for unsteady flow (Castro-Orgaz and Chanson, 2017). This approach is typically applied to concrete dams whose width is equal to the full width of the reservoir; the approach is an improvement over the Bernoulli equation in that it represents unsteady hydraulic effects. In the case of Coats Marsh, Ritter's approach will tend to underestimate peak flows because the width of the reservoir is much greater than the width of the weir; this approach has been used as a lower-bound check on the other approaches.
  - Schoklitsch's equation for full-depth, unsteady, partial-width breaches in a rectangular channel (Pilotti et al., 2010). This equation is an improvement on Ritter's approach in that it explicitly accounts for the ratio of breach width to reservoir width, which is an important factor for dam breach flows at Coats Marsh. This equation has been used for final peak flow estimation.

Table D10 summarizes the dam breach outflow estimates.

Table D10 Summary of dam breach outflow estimates.

Scenario	Dam Breach Peak Outflow Estimates (m^3/s)		
	Lower Bound Check (Ritter)	Design Estimate (Schoklitsch)	Upper Bound Check (Bernoulli)
1	6	9	12
2		11	
3		15	
4	14	20	25