ADDENDUM

SPECIAL OPEN COMMITTEE OF THE WHOLE MEETING
SHAW AUDITORIUM, 80 COMMERCIAL STREET, NANAIMO, BC
MONDAY, 2015-JUL-06, AT 4:30 P.M.

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4. **CORPORATE SERVICES:** **PAGES**

(a) Reorder Property Expropriation to Agenda Item 4 (b) and Add Colliery Dam Update and the following delegations: *2-93*

1. Mr. Jeff Solomon
2. Mr. Matthew O'Donnell
3. Mr. Leon Cake
4. Ms. Geraldine Collins
5. Ms. Sandi Blankenship
6. Mr. Ronald Stead
7. Ms. Louise Gilfoy

Purpose: To provide an update on options for the Colliery Dam remediation; provide a review of the recent letters received from the Provincial Comptroller of Water Rights; and provide recommendations to remediate the Lower and Middle Colliery Dams.

Staff Recommendation: That Council direct Staff to undertake design and installation of an Auxiliary Spillway (Labyrinth/Box Culvert, Open Channel alternative) for the Lower Colliery Dam and prepare a conceptual plan for the Middle Colliery Dam that complies with the Dam Safety regulations.

5. **COMMUNITY SERVICES:**

(a) Reorder Automation of Sanitation Fleet Presentation to Agenda Item 5 (a) and Asset Management Presentation to Agenda Item 5 (b).

City of Nanaimo

REPORT TO COUNCIL

DATE OF MEETING: 2015-JUL-06

AUTHORED BY: TOBY SEWARD, ACTING GENERAL MANAGER
COMMUNITY DEVELOPMENT & PROTECTIVE SERVICES

RE: COLLIERY DAM UPDATE

STAFF RECOMMENDATION:

That Council direct staff to undertake design and installation of an Auxiliary Spillway (Labyrinth/Box Culvert, Open Channel alternative) for the Lower Colliery Dam and prepare a conceptual plan for the Middle Colliery Dam that complies with the Dam Safety regulations.

PURPOSE:

To provide an update on options for the Colliery Dam remediation; provide a review of the recent letters received from the Provincial Comptroller of Water Rights; and provide recommendations to remediate the Lower and Middle Colliery Dams.

BACKGROUND:

2015-APR-29

- Revised Order received from Comptroller, granting consideration of third option and 30-day extensions (Attachment A)

2015-MAY-11

- Council meeting
- Approval to sole-source slope stabilization portion of Lower Dam remediation to GeoStabilization International (GSI), pending approval from Council, Comptroller, and DSS

2015-MAY-12

- Site meeting with engineers from GSI, Golder, and Herold Engineering

2015-MAY-15

- GSI elects not to provide design for overtopping portion of the remediation

2015-MAY-18

- Council meeting
- Council receives input from City solicitor in Open Meeting and directs staff to make application for an appeal and stay
- Council seeks meeting with Deputy Minister and Comptroller

2015-MAY-21

- City solicitor makes application to the Environmental Appeal Board (EAB), appealing Comptroller's Order of 2015-APR-29.

☐ Council
☑ Committee: special open COW
☑ Open Meeting
☐ In-Camera Meeting
Meeting Date: 2015-JUL-06

2015-MAY-26	• City solicitor makes application for a stay • Engineers not previously involved in the project are contacted about possibly undertaking a peer review of work undertaken to date
2015-JUN-01	• Council Meeting • Council approves an 11-point summary of issues that will form the basis of the discussion 2015-JUN-04 with the Deputy Minister of Forests and Lands and the Comptroller of Water Rights
2015-JUN-04	• Six members of Council meet with the Deputy Minister of Forests, Lands & Natural Resource Operations, Tim Sheldan, and the Comptroller of Water Rights, Glen Davidson
2015-JUN-22	• Council Meeting • Council passes a motion to write to the Comptroller, requesting that an alternate course of action be granted by the Comptroller
2015-JUN-24	• The lawyer for the Comptroller responds that Council's proposal approved 2015-JUN-22 is rejected and the Comptroller's lawyer suggests that if the City has another remediation option that meets standards, that a meeting could be arranged prior to the decision of the EAB on the application for a stay, if Council wishes to pursue this option
2015-JUN-30	The City receives correspondence from the EAB that the City's stay application has been denied
2015-JUN-30	The Comptroller's lawyer advises the City solicitor that the Order issued 2015-APR-29 stands and the dates for submission of a selected option and design drawings are revised to 2015-JUL-24

DISCUSSION:

Option to Address Colliery Dam Remediation

Following are options for Council's consideration regarding remediation of the Colliery Dams (outlined in comparison table below):

1. Auxiliary Spillway: Three alternatives have been generated by Golder Associates/Herold Engineering for construction of a new Auxiliary Spillway. Estimated costs of these options include construction cost and contingency plus costs for engineering, permitting, access, etc. Designs and images of these alternatives are included in the Golder report (Attachment B), labelled 6.a to 9.b and D-1 to D-11:

    i. Anchored channel ($3.3-$5.5 million);
    ii. Labyrinth/box culvert, open channel ($2.8-$4.6 million);
    iii. Labyrinth/box culvert and cover ($3.3-$5.5 million).

These three options have been developed in concept and drawings have been developed (Golder report Attachment B, submitted in draft, as report is not fully completed and signed) outlining the three alternatives. As these alternatives have only been developed in concept stage, actual costs have not been fully determined, however, are estimated in the range of $2.8-$5.5 million (including construction cost, contingency, engineering, permits, access, landscaping).

If direction is provided to pursue the proposed Auxiliary Spillway alternative, ground conditions (soil/rock) will be determined through drilling, allowing for more refined cost estimates.

2. <u>Labyrinth Spillway</u>: This alternative was originally developed in the spring of 2014 as part of the Technical Committee review. Drawings for this option are attached as Attachment C. Three-dimensional drawings of this option have not been delivered as it is the most expensive and most intrusive option, plus there is large public opposition to this proposal. Estimated cost is $8.1 million.

Remediation Options

	Labyrinth Spillway	Auxiliary Spillway
Estimated Cost	* $8.1 million ±	* $2.8-5.5 million
Invasiveness	* Requires major excavation, substantial tree/vegetation removal, substantial cofferdam or drawing down reservoir	* Requires 15-20 metre-wide construction corridor, 5-metre deep excavation, tree/vegetation removal * Design, permits, secure contractor, construction
Schedule	* 6-9 months minimum (including design, permits, secure contractor, construction)	* 5-8 months minimum (including design, permits, secure contractor, construction)
Advantages	* New long-term solution in place * Allows for low-level outlet	* Second spillway allows for redundancy, if either spillway requires maintenance * Allows for tree and vegetation replacement in construction corridor * Allows for low-level outlet
Disadvantages	* Large public opposition * Most expensive option * Loss of heritage structure and bridge * Lower Dam access closed for 3-4 months * Fencing required * Equipment access challenges	* Concern regarding tree removal and wide construction corridor * Lower Dam access closed for 1-2 months * Fencing required * Equipment access challenges

Overtopping Protection

Though GSI did not provide a design for hardening the dam embankment, the original proposal for overtopping by Golder still exists, however there is insufficient time to prepare a design and submit proposal to a technical expert prior to the 2015-JUL-24 deadline. The overtopping proposal by Golder was originally estimated at $7.3 million and would involve re-contouring the dam embankment; hardening the embankment with a soil/cement mixture; addressing the overland flow of water at the base of the embankment; removing trees on the embankment; raising the spillway walls by approximately 1.5 m, which would include trees/vegetation removal along each side of the spillway; and would require a new bridge and fill material to raise the grade to allow pedestrian traffic over the raised spillway walls.

Schedule

As noted in previous reports, the revised dates proposed in the Comptroller's Order 2015-APR-29 (revised 2015-JUN-30 requiring a selected option and design report by 2015-JUL-24) will be extremely difficult to achieve as detailed design, permits, referrals, tendering, and construction would have to take place between July and November 2015. It would be very difficult to complete the work within this timeframe. Once Council provides direction on which option to pursue, staff will direct Golder to commence detailed designs and staff will review options to sole source the work.

Snuneymuxw First Nation (SFN)

The Dam Safety Section has advised they would be seeking SFN input in the referral process that would take place during the application approval of various permits needed prior to undertaking the work. The SFN has previously endorsed the labyrinth spillway as a remediation option. Staff have communicated with SFN staff and are sending the SFN copies of the Golder report to determine if the SFN would consider endorsing the auxiliary spillway if that option is chosen.

Permits

Permits will be required to address environmental, archaeological, fishery, water management, and other issues that may arise depending on the option chosen. City staff will also be involved in permitting any tree removal required.

Budget

In 2014, Council directed staff to allocate $2.5 million from reserves (2012 surplus) to the Colliery Dams project. Up until the Colliery Dams Technical Committee was established in October 2013, approximately $1 million was spent on costs for the project. Costs from October 2013 to date are approximately $1.60 million; therefore the $2.5 million originally reserved for the project has now been spent, plus an additional $100,000.

Currently the estimated costs range from $2.8 million (least expensive auxiliary spillway option) to $8.1 million (labyrinth spillway). Previously $3 million was accrued in 2012 for Colliery Dams remediation. Any additional costs for remediation work will be funded from reserves.

Once Council direction is provided regarding the preferred remediation option, a report will be generated recommending sources of funds.

SUMMARY:

During the past number of months, the City has taken a number of steps to have the Comptroller's Order to remediate the dam set aside, delayed, or reviewed and has been unsuccessful in all of these attempts. The EAB has now ruled that they are not prepared to consider a stay of the Comptroller's Order; therefore, the City is in a position that they must move ahead with remediation of the dams.

Failure to proceed immediately with remediation as per the Comptroller's Order will put the City in non-compliance with the Order thus exposing the City, and potentially individuals, to enforcement under the *Water Act* or otherwise.

Staff recommend proceeding with the auxiliary spillway (labyrinth/box culvert open channel alternative), which is the least expensive option and will allow the work to commence later this year. If Council directs staff to proceed with the auxiliary spillway, a rock drill will be scheduled immediately to determine subsurface conditions.

Respectfully submitted,

TOBY SEWARD
ACTING GENERAL MANAGER
COMMUNITY DEVELOPMENT & PROTECTIVE SERVICES

CITY MANAGER COMMENT:

I concur with the staff recommendation.

Drafted: 2015-JUN-29
G:/DEVBLDG/COUNCIL REPORTS/2015
TS/kb/mjl

ATTACHMENT A

BRITISH COLUMBIA

April 29, 2015

File: 76915-20/D720001-00 & D720002-00

E.C. (Ted) Swabey
City Manager
City of Nanaimo
455 Wallace St
Nanaimo BC V9R 5J6

Dear Mr. Swabey:

Re: Middle Chase River Dam and Lower Chase River Dam – Replacement Order

On April 9, 2015, the City of Nanaimo (the City) was issued an order to correct the potential safety hazard of Lower Dam by selecting one of two remediation options acceptable to our office, by providing a plan for the selected option and by implementing that plan no later than the end of 2015, and, thereafter, to take actions to correct the potential safety hazard of Middle Dam.

At a meeting with this office on April 22, 2015, a third potential remediation option, which would involve an overtopping protection approach along with other features, was proposed to us by the City. On April 28, 2015 our office received a request from the City to amend the April 9, 2015 order to allow time for the City to further develop the proposal for a third option for the potential remediation of Lower Dam and to extend the timeframes in the April 9, 2015 order by 30 days.

Please find attached a new order, issued pursuant to Section 87 and Section 88(1)(d) of the *Water Act*, revoking my April 9, 2015 order and replacing it with the attached order directing the City of Nanaimo to correct the potential safety hazard of Middle Dam and Lower Dam by implementing an approach acceptable to this office. Please be reminded that should the proposed third option be the City's remediation option of choice, the City must retain an independent expert, satisfactory to the Comptroller, with qualifications and experience as described in the order, and provide their report on the issue to me in accordance with Section 12, BC Dam Safety Regulation, *Water Act*.

.../2

Ministry of Forests, Lands & Natural Resource Operations
Resource Stewardship Division
Office of the Comptroller of Water Rights
Water Management Branch
Dam Safety Section
Mailing Address:
PO Box 9340 Stn Prov Govt
Victoria BC V8W 9M1
Location:
3rd Floor, 395 Waterfront Cres
Victoria BC V8T 5K7

A right of appeal to my Order lies to the Environmental Appeal Board. Notice of any appeal must (1) be in writing, (2) include grounds for the appeal, (3) be directed by registered mail or personally delivered to the Chair, Environmental Appeal Board, 4th Floor, 747 Fort Street, PO Box 9425 Stn Prov Govt, Victoria, BC V8V 9V1, (4) be delivered within 30 days of receiving this Order; and (5) be accompanied by a fee of $25, payable to the Minister of Finance.

You are also reminded that Section 92(9) of the *Water Act* states that: "An appeal does not act as a stay or suspend to operation of the Order being appealed unless the appeal board orders otherwise".

Yours truly,

Glen Davidson, P.Eng.
Comptroller of Water Rights

pc: John Baldwin, Dam Safety Officer, Regional Operations, FLNR, Nanaimo
Toby Seward, A/City Manager, City of Nanaimo

ORDER
Sections 87 and 88
Water Act of British Columbia

Dam File No.: 76915-20/D720001-00 & D720002-00
Water Licence File No.: 0355097 & 0355174

IN THE MATTER OF Conditional Water Licences C061424 and C061423, held by the City of Nanaimo (the City), which authorize the storage of 75 acre feet of water behind the Middle Chase River Dam (Middle Dam) and 140 acre feet of water behind Lower Chase River Dam (Lower Dam), as part of the Colliery Dam system on Chase River.

WHEREAS engineering consultant, Golder Associates (Golder), was retained by the City to be technical advisor to the City's Colliery Dam Technical Committee (TC). The TC's mandate was to identify an environmentally minimally invasive, cost and time effective remediation solution for the Colliery (Middle and Lower) Dam system that meets safety standards, among other things. The mandate also included the development of a permanent solution to be put in place in 2014 if possible, but not later than 2015, with shorter term mitigation put in place, if required, in 2014;

WHEREAS the focus was primarily on the remediation of Lower Dam as Golder had determined that Middle and Lower Dams act together as a system, with Lower Dam largely controlling downstream consequences. For this reason, Golder determined that the remediation of Lower Dam would provide greatest reduction in risk to those living downstream of the dams, and remediation of this dam should be given highest priority. Golder indicated, in its report, Dam Remediation Options (August 29, 2014), that the remediation of the Middle Dam would be addressed separately at a later date;

WHEREAS Golder undertook a number of studies and produced several reports including their Hydrology, Hydraulics and Middle Dam Breach Analysis (July 25, 2014) which determined that Middle and Lower Dam's spillways both have inadequate flood routing capacity to pass the design flood event which could result in the dams overtopping. The report states (pg i, Executive Summary):

> *"These calculations have determined that the spillway for the Middle Dam has the capacity to convey the flows associated with approximately the 50-year (2% annual exceedance probability) rainfall event. Storms larger than the 50-year overtop the dam embankment. The spillway for the Lower Dam has the capacity to convey the flows associated with approximately the 25-year (4% annual exceedance probability) rainfall event. Storms larger than the 25-year overtop the dam embankment."*

WHEREAS Golder calculated the existing flood routing capacity of Lower Dam to be 55.0 cubic meters per second (cms), equivalent to a 1 in 25 year flood event;

WHEREAS Golder reviewed the failure consequence classification for Lower Dam and concluded that a *very high* classification was appropriate;

WHEREAS in Canada, current practice for selection of the design flood event for dam safety is suggested in Table 6-1B in the Canadian Dam Association's (CDA) Dam Safety Guidelines (2013);

WHEREAS, with respect to flood routing capacity for Lower Dam, Golder states (pg. 17, Colliery Dams, Nanaimo, BC, Report on Dam Remediation Options, Golder, August 29, 2014):

> *"...the risk of dam collapse due to flood events is significant and must be addressed by dam remediation to improve flood routing characteristics of the dam. The required flood routing capacity is given by the Table 6.1 CDA Guidelines, and is based on the Consequence Classification of the dam. For a Very High consequence dam, the dam must be able to pass a flood at least the equivalent of 2/3 of the way between a 1000 year and a PMF flood..."*

WHEREAS in accordance with CDA Table 6-1B Golder calculated the design flood event of Lower Dam, a *very high* consequence dam, to be a total peak outflow of 144.0 cms. A total peak outflow of 144.0 cms is 2.6 times greater than the calculated 55.0 cms flood routing capacity of Lower Dam's current spillway;

WHEREAS insufficient flood routing capacity is considered a *potential safety hazard* as it may lead to overtopping and possible failure of the dams;

WHEREAS the City has completed numerous studies and evaluated several options to address the dam safety issues at Lower Dam and Middle Dam, two of which options for Lower Dam are conceptually acceptable to this office: the (a) labyrinth spillway design and the (b) auxiliary spillway design;

WHEREAS on February 25, 2015, under Section 7.1 of the B.C. Dam Safety Regulation, the City was requested to undertake certain steps by no later than March 27, 2015 but did not comply with the requested steps and therefore is not in compliance with the B.C. Dam Safety Regulation, *Water Act*;

WHEREAS the City was issued an order on April 9, 2015 to correct the potential safety hazard of Middle Dam and Lower Dam by:

1. Immediately undertaking the necessary steps to increase the flood routing capacity of Lower Dam to 144.0 cms, as calculated by Golder, in order to meet an annual exceedance probability design flood event level that is 2/3 of the way between a 1 in 1000 year flood and the Probable Maximum Flood (PMF) in respect of Lower Dam, by:
   a. Selecting one of the two following Lower Dam remediation options (as described by Golder) in order to address the potential safety hazard of Lower Dam:
      i. the Labyrinth Spillway Design (Report on Dam Remediation Options, Golder, August 29, 2014); or
      ii. the Auxiliary Spillway Design (Auxiliary Spillway - Conceptual Design, Golder, January 16, 2015);
   b. Notifying this office of the selected option **by May 1, 2015**;
   c. Preparing and submitting a design report and construction plans, for approval under Section 4 of the B.C. Dam Safety Regulation **by May 22, 2015**;
   d. Substantially completing the chosen remediation option **by October 15, 2015**; and
2. Once the chosen remediation option for Lower Dam has been completed (as required by Section 1 of this Order), the City must undertake the following actions:
   a. Prepare and submit to this office **by the end of 2015**, a revised conceptual plan that identifies and prioritizes any actions required to correct the potential safety hazard with Middle Dam, along with a timeline for taking those actions within a reasonably expeditious time frame, timed to follow after completion of actions to correct the potential safety hazard with Lower Dam; and,
   b. Implement the revised plan, based on the priorities identified in the plan, within a reasonably expeditious time frame **but no later than the end of 2017**, and in accordance with Section 4 of the B.C. Dam Safety Regulation, as applicable to any alteration, improvement or replacement to all or any part of the dam intended to correct a potential safety hazard and which must be implemented in a timely manner.

WHEREAS, at the request of the City, this office met with City officials on April 22, 2015 to discuss requirements for a proposal with respect to a possible third option;

WHEREAS, on April 28, 2015, the City requested an additional 30 days to retain professional engineering consultants to prepare a proposal with respect to a possible third option which would involve the installation of overtopping protection to these dams, as well as other features, to address the potential safety hazards;

WHEREAS, this office is prepared to accede to the request for additional time in order to allow the City to prepare such a proposal for submission to this office.

NOW THEREFORE, I, Glen Davidson, Comptroller of Water Rights, pursuant to Section 87 and Section 88(1)(d) of the *Water Act*, revoke my April 9, 2015 order and replace it with the following order to the City of Nanaimo, and hereby direct the City to correct the potential safety hazard of Middle Dam and Lower Dam:

1. By immediately undertaking the necessary steps to increase the flood routing capacity of Lower Dam to 144.0 cms, as calculated by Golder, in order to meet an annual exceedance probability design flood event level that is 2/3 of the way between a 1 in 1000 year flood and the Probable Maximum Flood (PMF) in respect of Lower Dam (the "flood routing capacity"), by:

    a) selecting one of the following Lower Dam remediation options in order to address the potential safety hazard of Lower Dam:

        i. the labyrinth spillway design (Report on Dam Remediation Options, Golder, August 29, 2014),

        ii. the auxiliary spillway design (Auxiliary Spillway - Conceptual Design, Golder, January 16, 2015, or

        iii. an overtopping protection approach which, combined with other features as may be required (together the "overtopping protection approach"), would provide a level of protection comparable to that provided by the other two options, the technical details for which approach to be set out in an acceptable alternative proposal as described in paragraph b), below;

    b) notifying this office of the selected remediation option **by June 1, 2015** and, if proceeding with the overtopping protection approach, the notification must be accompanied by a report from an independent expert, satisfactory to this office, with the following qualifications and experience, in accordance with Section 12 of the BC Dam Safety Regulation:

        i. in dam design, construction and analysis, and
        ii. in hydraulic, hydrological, geological, geotechnical and structural engineering, and
        iii. in the design, construction and performance of overtopping protection alternatives for embankment dams;

    The report of the independent expert must confirm the technical feasibility of the proposal to meet the flood routing capacity at Lower Dam and that the proposal meets recognized dam safety guidelines (e.g. CDA Dam Safety Guidelines, 2013), as well as current best practice for the design and construction of overtopping protection for dams (e.g., US FEMA Technical Manual: Overtopping Protection for Dams, 2014);

    c) preparing a design report and construction plans for the selected remediation option and submitting them to this office, for approval under Sections 4 and 7.1 of the BC Dam Safety Regulation **by June 22, 2015**;

    d) substantially completing the selected remediation option **by November 15, 2015**; and

2. The City must undertake the following actions in relation to Middle Dam:

   a) Prepare and submit to this office **by the end of 2015**, a revised conceptual plan that identifies and prioritizes any actions required to correct the potential safety hazard with Middle Dam, along with a timeline for taking those actions within a reasonably expeditious time frame, timed to follow after completion of actions to correct the potential safety hazard with Lower Dam; and,

   b) Implement the revised plan for Middle Dam, based on the priorities identified in the plan, within a reasonably expeditious time frame but **no later than the end of 2017**, and in accordance with Section 4 and 7.1 of the B.C. Dam Safety Regulation, as applicable to any alteration, improvement or replacement to all or any part of the dam intended to correct a potential safety hazard and which must be implemented in a timely manner.

Dated at Victoria, British Columbia this 29th day of April, 2015.

Glen Davidson, P. Eng.
Comptroller of Water Rights

ATTACHMENT B

Golder Associates

July 3, 2015 Reference No. 1314470516-025-L-RevA

Toby Seward, Community Development and Protective Services
City of Nanaimo
455 Wallace Street
Nanaimo, BC
V9R 5J6

COLLIERY DAMS, NANAIMO BC
LOWER DAM – DEVELOPMENT OF DESIGN ALTERNATIVES

1.0 INTRODUCTION

This memorandum summarizes the findings of studies carried out by Golder Associates Ltd.(Golder) for the City of Nanaimo (City) on the Lower Colliery Dam in Nanaimo BC. These studies, carried out principally in May 2015, were primarily related to further development of flood routing remediation options for the Lower Dam. The remediation options that were to be evaluated were drawn from a list of options identified by the Province of BC, which formed part of the basis of an Order for remediation of the Colliery Dams (BC, 2015). This report documents additional work that has been carried out on two of the options identified in the Province of BC letter, namely, the Overtopping option, and the Auxiliary Spillway Option. A general arrangement of the Lower Dam, the existing spillway and the proposed auxiliary spillway location are shown on Figure 1.

The work undertaken on these remediation options is of a preliminary nature (not detailed design), and is intended to improve the understanding of the scope and cost of the options. It is understood that this improved understanding is to be used to form the basis for the City to select one of the options, which would then be submitted to the Province of BC for review and approval, and ultimately taken forward to final design and construction.

2.0 OVERTOPPING PROTECTION OPTION

2.1 Description

Overtopping protection involves strengthening an embankment dam to allow the dam to be safely overtopped during rare (or long return period) storm events. Such approaches provide a distinct alternative to larger spillways as a means to convey floods through reservoirs, and for some projects this approach may be preferable to conventional approaches such as increasing the spillway capacity. While overtopping protection options have become increasingly prevalent in recent years, there is limited experience with overtopping protection in Canada, and limited experience with this approach on a dam of the height of the Lower Dam.

In the remediation order (BC 2015), the Province of BC indicated that an overtopping protection approach would be acceptable, provided that the design was accompanied by a review report from a qualified independent expert, indicating the design to be acceptable.

Overtopping protection has been previously evaluated for this project (Golder 2014a). For the current stage of study, the City wished to evaluate alternative approaches to the previous design. Any alternative designs would be required to meet certain minimum design requirements, which are described in this memorandum.

As stated above, the objective of overtopping protection is to safely convey the design flood over the dam. In the event of a flood, the increased reservoir level will result in a release of water over the dam as well as any other potential low points around the reservoir rim. The resultant distribution of water flows from the reservoir is described in previous reports (Golder 2015). To safely convey the flows over the dam, it is necessary to direct the flows in a controlled manner to minimize damage to the dam and abutments. For the Lower Dam, the overtopping flows are anticipated to be directed either over the crest of the dam, or down the existing spillway. In order to direct and control the design flows, it is necessary to shape the dam crest to direct the water over the hardened portion of the dam or into the spillway. Since the maximum reservoir level is increased with this option, it is necessary to increase the existing spillway wall height and capacity to safely convey the increased spillway flows in the design flood event.

These two major components of the overtopping protection option (spillway capacity improvements and dam hardening requirements) are described in the following sections. A conceptual plan and profile showing the overtopping protection option for the Lower Dam are shown on Figure 2. Note that the concept presented on Figure 2 represents the shaped dam surface which formed part of the previously developed overtopping concept (Golder 2014). Alternative designs may involve a variation to the shaped dam surface shown on this figure.

2.2 Existing Spillway Improvements

2.2.1 Description

During the design flood event, the spillway would be subject to a peak flow of approximately 100 m3/sec. Note that the peak flow is dependent on the final configuration of the modifications to the existing spillway bridge as well as the final re-shaping of the dam crest associated with directing the overtopping flows. Varying these parameters within the anticipated practical limits yields a possible range of peak flows through the modified spillway from 90 to 110 m3/sec with the remaining portion overtopping the hardened dam embankment. In order to achieve this additional flow capacity, an increase in the height of the spillway walls is required. This section describes the scope of these spillway improvements.

Spillway flow characteristics were modelled using HEC-RAS (Hydrologic Engineering Center's (HEC) River Analysis System (HEC-RAS)) software. Additional freeboard was calculated using the methodology described for Channel Freeboard in *Design of Small Dams, third edition, by the United States Department of the Interior Bureau of Reclamation.* This methodology uses the flow velocities and flow depths to calculate addition freeboard to contain the "...surface roughness, wave action, air bulking, splash, and spray..." The results of the spillway wall freeboard analysis are presented on Table 1 below.

Table 1: Spillway design requirements

Location	Velocity (105 m^3/sec flow)	Depth (m)	Freeboard (m)
Downstream of Bridge to the beginning of taper	3.2	2.7	0.8
Beginning of taper to the increase in channel slope	4.6	2.1	0.8
Increase in channel slope to the decrease in channel slope	5.7	2.7	0.9
Decrease in channel slope to the end of spillway	10.2	1.9	1.1

A profile along the spillway walls, together with the required increases to the height of the spillway walls is shown on Figure 3. The structural design for the spillway improvements were provided by Herold Engineering Ltd. (Herold). The structural drawings and corresponding memorandum are shown in Appendix A.

2.3 Existing Spillway Improvements - Construction

This section presents a summary of the proposed methods of construction for the spillway improvements, together with estimated costs and construction schedule. This section highlights access considerations, construction sequencing and methods, environmental controls and schedule. The construction described in this section is separate from the auxiliary spillway construction described later in this report.

2.3.1 Access

Access is expected to be from both the north and south sides of the existing spillway (Figure 1). The existing parking lot accessed from Sixth Street is approximately 200 m to the north of the existing spillway along an asphalt path. The Harewood Mines Road to the south of the spillway is accessed via the existing paths. It is anticipated that the bulk of construction materials and equipment can be mobilized via the parking lot to the north, however some limited access may be required via the trail network on the south side of the existing spillway.

2.3.2 Construction Sequencing

A general construction sequence for the existing spillway improvements is outlined below.

1. Mobilization
    a. Set up of small site trailer at north parking lot;
    b. Survey the existing spillway and bridge location; and
    c. Installation of temporary fencing and signage to deter public access during construction.
2. Site and access preparation – channel alignment
    a. Sediment and erosion control implementation along the existing spillway;
    b. Tree removal, clearing and grubbing (minor);
    c. Build access path with small excavator along the outside of the existing spillway walls; and
    d. Stripping and disposal of excess soil along the existing spillway walls.
3. Spillway rehabilitation
    a. Foundation preparation; and
    b. Forming, pouring and stripping.
    c. Backfill.
4. Bridge construction
    a. Bridge removal;

   b. Foundation preparation; and
   c. Forming, pouring and stripping.
5. Aesthetics
   a. Cleanup.
6. Demobilization

2.3.3 Methods

Consideration was given to the construction method for each stage of the work. The list below highlights construction methods that can be implemented to have overall advantages to the project in terms of budget, safety and/ or impact to the park.

- Laydown area and site offices located at the existing parking lot off Wakesiah Avenue and Sixth Street;
- Temporary safety fencing of work area to exclude public from the worksite;
- General purpose labourers/ flaggers when required will be onsite during working hours to ensure the excavator and trucks do not interact with pedestrians;
- 7 tonne excavator (ie. Hitachi 70X) to carry out excavation and access preparation work, with some assistance from a backhoe and/or bobcat;
- Small crane to swing forms across existing spillway channel may be required; and
- Asphalt removal and reinstatement where the path abuts the existing bridge.

2.3.4 Construction Schedule

A preliminary construction schedule was contemplated at the time the cost estimate was developed. The work is anticipated to take approximately 2 months to complete. The ideal construction window is during the drier season from mid-July to mid-September.

2.3.5 Estimated Constructions Costs

An estimate of construction costs has been carried out based on the preliminary design information. The estimate has been developed using a resource-based (bottoms-up) method. The cost for the spillway improvement, including building a new bridge, is estimated to be in the range of **$0.8 M to $1.5M**. This estimate has been prepared on the assumptions listed in the Basis of Estimate in Appendix B. The uncertainty underlying this estimated cost is principally related to the unknown ground conditions as the location of the existing spillway. The cost estimate for any related dam hardening work is not included.

This estimate represents the construction cost (ie cost to a contractor, including overhead and profit, assuming a design-bid-build approach), but does not include design (including site investigations), permitting, construction management or related costs.

2.4 Dam Hardening

As described above, the City wished to receive an alternate approach for the hardening of the dam, and therefore engaged Golder to assist in developing the technical requirements for a design-build submission, and to assist with City with the independent expert review procedure. This section describes the basis for development of the design-build performance requirements that were prepared for the dam hardening.

Preliminary design requirements were developed to outline the general performance requirements and requirements for submittal of documentation by the design-build contractor. It is noted that these preliminary requirements were developed in Draft, for review and comment by those involved in the review process (the City, the independent expert and the design-builder).

The requirements make reference to current design and construction practices for dam hardening. Overtopping protection systems have been the subject of a recently issued technical manual from the Federal Emergency Management Agency (FEMA 2014). This manual, which was developed by FEMA in conjunction with the US Bureau of Reclamation (USBR), is considered to represent the current practice in the design of overtopping protection and was therefore the principal reference in these performance requirements. The technical manual discusses best practices for design, construction, problem identification and evaluation, inspection, maintenance, renovation, and repair.

The FEMA manual, and the Canadian Dam Association (CDA) Dam Safety Guidelines were also referenced in the Province of BC Order (BC 2015).

The Draft design-build performance requirements are presented in Appendix C and consist of the following principal components:

- Scope. This section describes the scope of the work to be undertaken.
- Reference Documents. Relevant technical guidelines are referenced in this section, and provide the basis for carrying out project design and construction. These include the above mentioned FEMA and CDA guidelines, as well as relevant specifications from ASTM (American Society for Testing and Materials).
- Project Data. This section provides relevant data from previously issued reports which may be useful in preparing the project design, and includes site information as well as findings from previous analyses.
- Design Principles. This section describes the overall design objective and individual design requirements.
- Other requirements. Objectives related to other aspects of the project, including environmental protection, protection of park amenities/aesthetics and minimization of construction impacts are addressed in the design-build requirements.
- Submittals. This section describes the documentation which is required to be submitted in order to demonstrate conformance with the project requirements.

The Draft design-build performance requirements were issued on May 11, 2015. A site visit to the dam with the proposed design-builder (GeoStabilization Inc (GSI)) was carried out on May 12, 2015.

3.0 AUXILIARY SPILLWAY

3.1 Description

The auxiliary spillway concept was developed as it provides a means to generate additional spillway capacity without impacting the existing spillway. With this approach, the existing spillway would remain in place and serve as the primary spillway, while a second spillway (the Auxiliary Spillway) would be constructed to provide the additional required capacity. As it is preferable that the existing spillway, and the existing river channel downstream of the spillway, serve as the primary flow channel, the auxiliary spillway would only be activated in the event of a storm. The following sections expand on the previous design (Golder 2015) and present four variations on the auxiliary spillway design concept previously presented (Golder 2015).

The key factors considered in developing the auxiliary spillway concept are as follows:

- Spillway Capacity - The required capacity of the auxiliary spillway is 89 m3/sec, based on the design requirement of 144 m3/sec, and on the existing spillway capacity of 55 m3/sec.
- Spillway Crest Elevation - The spillway crest elevation has been set at 72.1 m, which is 0.5 m above that of the existing spillway. Based on the hydrology model, at this elevation the spillway is anticipated to be engaged once per year, on average.
- Location - As shown on Figure 1, the spillway entrance is located about 10 m to the south of the existing spillway and is set back 10 to 15 m from the perimeter of the reservoir. (This is an increase of approximately 7 m from the location proposed previously (Golder 2015)). The location has been selected based on minimizing the length of spillway channel and has been set back into the abutment to reduce its visibility from the dam crest, and to ease the requirements for cofferdam construction, as discussed later in this report.
- Spillway conceptual design.
  - Spillway Channel. There are four variations on the spillway channel, as discussed in Section 3.3.
  - Entrance structure (weir). The key component of the spillway design is the design of the entrance (or weir) structure. The preferred weir structure is required to satisfy the conflicting requirements of; 1) providing the required design capacity; 2) minimizing the footprint and meeting aesthetic requirements; 3) providing a cost effective solution and 4) being acceptable from an environmental and public safety standpoint.
    - Following an evaluation of different weir types (Golder 2015), a labyrinth weir was selected as the recommended type based on the above considerations. Preliminary analyses indicate a weir of 13.8 m (l) x 13 m (w) and 3 m in height would be sufficient to pass the design flow.

3.2 Site Description

3.2.1 May 2015 Site Visit

A site visit to the Lower Colliery Dam was carried out by representatives from Golder and the City on May 12, 2015. The purpose of this site visit was to investigate possible methods of reducing the construction footprint and the cost of the auxiliary spillway. The key findings from this site visit are:

- Setting back the spillway inlet by approximately 7 m could allow the use of a native 'plug' and remove the requirement to construct a cofferdam or lower the lake level for construction (depending on the subsurface conditions encountered);
- Significant upgrades to Harewood Creek are not expected to be required, as the auxiliary spillway channel could be curved to tie-in with existing bedrock along the alignment of the creek channel (again, depending on actual conditions encountered);
- Design modifications could be made to better incorporate the spillway structure and channel into the existing parkland landscape, including the use of covered box-culverts and a narrower spillway channel;
- No evidence of bedrock was identified along the alignment of the proposed auxiliary spillway, although bedrock was observed at the proposed tie-in location to Harewood Creek (Figure 4); and
- Construction access could be provided along an existing trail heading south towards Seventh Street, with a material laydown area in the lay-by just off the road. The access route crosses over a small bridge over Harewood Creek, which would require temporary removal during construction.

Photos from the site visit are included below.

Photo 1: Proposed location of auxiliary spillway.

Photo 2: Proposed tie-in to Harewood Creek.

3.2.2 Geotechnical Understanding

As there is no subsurface geotechnical information along the proposed alignment of the auxiliary spillway, a review of available information was carried out in order to provide a basis for conceptual design and costing. The geotechnical understanding for the auxiliary spillway is based on observations noted during the site visit, available data from boreholes and test pits in the vicinity (approx. 50 to 120 m distant from the proposed auxiliary spillway location, as shown on Figure 4) and regional geology information (BC MEM, 1998), as shown on Figure 5.

Bedrock Conditions

Available information on bedrock conditions (rock type and depth to bedrock) includes the following:

- Subsurface information from nearby boreholes (see Figure 4). Bedrock was encountered in all boreholes drilled in 2014 and generally comprises massive, dark grey to grey, medium strong, clast supported conglomerate.
- Surface information (nearby rock exposures), see Figure 4 and Photos 3 and 4. The nearest rock exposures are located to the east and southeast of the proposed spillway, at elevations ranging between 65 to 70 m.
- Regional surficial bedrock geological mapping. Based on available geological maps (BC MEM, 1998), the Lower Dam and auxiliary spillway are located within the Upper Cretaceous, Millstream Member of the Nanaimo Group, as shown on Figure 5. The Millstream Member comprises conglomerate and gritstone, minor sandstone, siltstone and carbonaceous shale and coal. The bedding in the area dips to the northeast. A normal fault dipping to the southeast is shown running through the Lower dam where it appears to terminate on the downstream side. The Chase River Fault (a normal fault) runs northeast – southwest and is approximately 400 m north of the dam. A geological boundary is shown approximately 100 m to the east of the dam, striking northwest – southeast.
  - These descriptions of the rock types in the Millstream Member are consistent with the observations from the boreholes drilled in the dam to the north of the auxiliary spillway, which encountered predominantly strong conglomerate.

The above information suggests the auxiliary spillway is likely to encounter bedrock at the depth of the base of the spillway channel, and that bedrock is likely to consist predominantly of strong conglomerate and gritstone (sandstone).

Soil Conditions

The borehole and test pit locations from previous investigations carried out by Golder and others at the Lower Dam are shown in Figure 4. A review of this information shows that glacial till generally overlies bedrock in the area.

Photo 3: View of bedrock outcrop looking southwest near proposed auxiliary spillway discharge location into Harewood Creek

Photo 4: View of north side of existing spillway chute from discharge pool at base looking upstream.

Summary of Geological Assumptions

Based on the above information, it is assumed that strong conglomerate bedrock will be encountered in the invert of the auxiliary spillway, and form the foundation for the weir. Dense glacial till is anticipated to overlie the bedrock and form the bulk of the material to be excavated for the auxiliary spillway.

A geotechnical drilling investigation is recommended in the proposed location of the auxiliary spillway to confirm the ground conditions.

3.3 Auxiliary Spillway Options

3.3.1 Description

Based on discussions with the City, including during the May site visit, the following auxiliary spillway alternative designs have been developed from the previously submitted option (Golder 2015):

- Option 1 (Anchored Channel Option) – This option consists of a 13.8 m wide labyrinth weir set back into the abutment, as shown on Figure 6a and 6b. Water flows over the labyrinth weir then through a covered box culvert structure. Downstream of the box culvert the water flows through a 10 m long tapered, anchor supported open channel into a 6.0 m wide anchor supported open channel before discharging into Harewood Creek. The anchor supported section will require safety fencing along the crest of the slope. Some advantages of this revised design over that proposed previously (Golder 2015), include:
  - The weir has been moved further into the abutment – this is expected to eliminate the need for an artificial cofferdam (the bedrock elevation will first need to be confirmed with a geotechnical investigation). This is described in further detail later in this report.
  - A 10 m long box culvert has been included downstream of the weir (improved visual characteristics).
  - The channel downstream of the weir is designed as an anchored cut, which minimizes both the construction stage disturbance (top-down construction), as well as the permanent land take. The feasibility of this is to be confirmed based on future geotechnical investigations.

- Option 1A (Anchored Channel Option 1A) – This option is similar to Option 1, however the covered box culvert section is 20 m long and includes a 10 m covered tapered section, as shown on Figure 7a and 7b. Water flows from the weir, through the extended box culvert and into the 6.0 m wide steep, anchor supported open channel before discharging into Harewood Creek. This option has similar advantages to Option 1 with the additional improvement of a 20 m long box culvert downstream of the weir (improved visual characteristics).
- Option 2 (Open Channel Option) - This option is similar to Option 1, however water flows from the weir, through the 10 m long box culvert and into an open channel swale before discharging into Harewood Creek. The open channel will be wider than Option 1 and will therefore require no anchor support or safety fencing, as shown on Figures 8a and 8b. To prevent erosion, the channel will be armoured or cut into bedrock (if encountered).
- Option 3 (Buried Option) – This option is similar to Option 1A, however water flows from the weir through an approximately 31 m long box culvert which tapers from 13.8 m to 6 m wide, as shown on Figures 9a and 9b. The water exits the box culvert and discharges into Harewood Creek from a short open channel.

Note that the excavation footprint of the box culvert will be greater than for the anchored cut – the temporary excavated slopes (for the box culvert) will be flatter than the anchored slopes.

3.3.2 Design

Preliminary structural designs for the labyrinth weir and box culverts are presented in Appendix A of this report. As indicated previously, it has been assumed that these structures will be founded on bedrock. A cast-in-place box culvert design has been adopted, rather than a pre-cast box culvert option (or bridge option), as this will reduce the size of equipment needed for the project (a large crane would be required to transport and place the heavy pre-cast box culvert sections).

As indicated previously in this report, the weir has been moved further into the right abutment, as a means to isolate the weir from the reservoir and thereby facilitate construction and avoid the need for a substantial cofferdam to be constructed. Assuming that rock is present between the reservoir and the weir location, a two stage weir construction procedure is envisaged,

- Stage 1 excavation. Excavation for the weir would be carried out below reservoir level, with a "rock plug" providing containment of the reservoir and avoiding the need for a cofferdam to be constructed. If good quality rock does not comprise the full depth of this "plug", it may be possible to develop a "soil plug", however, this will likely require a greater separation from the reservoir and may require an artificial cut-off to be constructed to limit seepage and piping.
- Stage 2 Excavation. Once the weir (and downstream channel work) is complete, the rock plug would be removed. This would be carried out using underwater excavation methods, and would utilize accepted methods to limit impact to the aquatic environment, as discussed in subsequent sections of this report.

As the auxiliary spillway will be inactive most of the time, there may be a tendency for the public to attempt to access the spillway area during dry periods – an activity which is hazardous, as the spillway (which is uncontrolled) may be activated at any time in the event of a storm. Therefore, it will be necessary to consider public safety features during the development of this design, which could include:

- Safety boom. As shown on the Figures, a barrier is required to limit public access to the weir. An upstream boom could perform the dual function of limiting access and capturing debris (and preventing it from impacting weir operation).
- Fencing. Fencing would be required around all openings and steepened slopes adjacent to the weir and downstream channel. A barrier may also be required to restrict access into the box culvert, although any such barrier would need to be appropriately designed so as not to restrict flow in the event of spillway activation.
- Signage and warnings.

As indicated in previous reports, the weir structure will be used as a means to "draw down" the reservoir in the event of a major earthquake which results in damage to the Lower Dam. The weir could also be provided with a low level outlet to supplement dry season water flows in the Chase River. Options include the use of stop logs (which could be an effective means of lowering the reservoir level, but less effective for supplementing low season flows), large diameter valves or sluice gates (the figures in Appendix A show a concept for the use of stop logs in the labyrinth weir). A detailed review of means to provide these flows has not been developed at this stage, but should be carried out in the detailed design stage of the project.

3.4 Hydraulics

3.4.1 Labyrinth Spillway Activation

Based on the conceptual design spillway crest elevations, the labyrinth spillway will convey discharge during flood events where the inflow to the Lower Colliery Reservoir exceeds approximately 7 m^3/s. The discharge from the labyrinth spillway for a range of flood events is presented below in Table 2.

Table 2: Labyrinth Spillway Discharge

Event return period (24-hour)	Peak inflow to Lower Colliery Dam (m^3/s)	Auxiliary spillway discharge (m^3/s)	Flow depth over labyrinth weir (m)
1:2-year	23.4	12	0.2
1:10-year	44.9	28	0.4
1:50-year	64.9	42	0.6
1:100-year	74.5	48	0.7
1:1000-year	107.2	69	1.0

A preliminary hydraulic analysis of the auxiliary spillway channel has been completed for each conceptual option. Manning's Equation was used for these analyses, under the assumption that uniform flow has established at the upstream and downstream ends of the spillway channel. The results of these calculations, based on a labyrinth spillway discharge during the IDF equal to 89 m^3/s, are presented in Table 3 and Table 4.

Table 3: Channel Hydraulics – Directly Downstream of the Labyrinth Weir

Option	Flow depth (m)	Flow velocity (m/s)
All options (box culvert design shared among all options)	0.8	8.9

Table 4: Channel Hydraulics – Channel Outlet to Harewood Creek

Option	Flow depth (m)	Flow velocity (m/s)
Option 1 and Option 1A – Anchored Channel	1.5	9.4
Option 2 – Open Channel	1.7	5.8
Option 3 – Box Culvert	1.2	12.9

A detailed hydraulic analysis of the selected auxiliary spillway channel will be completed during the detailed design phase.

3.5 Aesthetics and Park Recreation

The Colliery Dam auxiliary spillway is located in a highly valued public park with many visitors concerned about potential aesthetic and functional impacts to the park user and the character of the place, in particular: shoreline, vegetation, pathways, and public use / safety. Using digital terrain modelling and computer visualization techniques, the auxiliary spillway alternatives were examined to help illustrate how each would fit into the Colliery Dam Park.

The visualization series (attached as Appendix D) begin with a Context Plan (Appendix D, Figure D-1) to orient the viewer to the location of the existing dam and spillway, with proposed auxiliary spillway and connection to the Harewood Creek and Chase River system superimposed on an ortho photograph of the Park and adjacent neighbourhoods. A key map (Appendix D, Figure D-2) is also provided that illustrates the viewpoints from which the model illustrations are represented. Viewpoints were selected to illustrate the spillway from several angles and elevations ranging from bird's eye perspectives to shoreline vistas, to views from the lake from approximately the existing floating dock. The intent of the images is to show the relative size and scale of the constructed options in the context of the existing park, highlight the key similarities and differences between the options, and approximate the impact to trees and vegetation after approximately ten to fifteen years of post-construction growth.

For each of the options, a visual digital model was constructed according to design schematics, with accurate water and structure elevations consistent with the design concepts. The visual digital models represent materials, such as concrete, guardrails, stone armoring, etc. that depict general design concepts factored into the cost estimates. The structures were then placed in a 3D terrain model derived from the same LiDAR data being used by the project team. For each alternative, tree images were placed in the models to approximate the size and character of existing trees in the park. In the absence of accurate survey data, the project landscape architects used best judgement from site visits, photography, and Google Earth to approximate path locations, bridge structure, shoreline conditions, trees retained or removed and replaced for each of the options in an attempt to portray approximate post-construction conditions.

Each of the alternatives illustrates a similar labyrinth weir on the west side of the spillway structure (meeting the lake). The bird's eye views from the east depict the key differences related to the spillway connection to the Harewood Creek and Chase River system.

Anchored Channel Option 1 (Appendix D, Figures D3-D7) illustrates a wide concrete bridge incorporating pathway and low plantings, with perpendicular walkway connections for viewing and interpretive opportunities. This alternative has a narrow open channel to the east, with excavations to bedrock, and anchored steep sides. The narrow channel of this alternative would reduce tree removal, but due to the high steep slopes of the channel requires a durable fence system to protect the public from falls. This option may also pose a barrier to wildlife movement. The aesthetics of the anchored channel slopes also requires care so that the slopes will eventually support vegetative growth. Without the long term vegetation establishment, the channel would have on-going visual impact with hard-edge treatment out of character with the natural environment of this part of the park.

Open Channel – Option 2 (Appendix D, Figure D8 and D9) illustrates the same labyrinth, concrete bridge and spillway as Option 1, but with a wider open channel connecting to the Harewood Creek and Chase River system. Due to shallower sideslopes, this option does not require the extensive fences at the crest of the channel as does Option 1 but because of the wider cut, Option 2 requires the removal and replacement of more trees. Initially, this option would have a higher visual and aesthetic impact than Option 1 due to tree removals and wider exposed bedrock channel with potential rock armouring. However, over time, this option, with vegetation restored, would present less of an aesthetic impact that Option 1 due to shallower channel side slopes with vegetative cover, and the absence of guardrail structures.

Buried Option 3 (Appendix D, Figure D10 and D11) incorporates the same labyrinth structure as the Options 1 and 2, but instead uses underground concrete box culverts to convey flows, backfilled and covered with growing medium and vegetation to more closely restore original park conditions. The illustrations show the establishment of younger trees growing into the covered portion of the underground channel. This option has a small portion exposed to daylight at the eastern end of the channel as it connects to the Harewood Creek and Chase River system. As in the other options, the bottom of the channel is expected to be exposed bedrock. This option presents the least visual impact of the three options but requires planting and vegetation establishment efforts to gain the aesthetic benefits this configuration provides. This option also provides more flexibility and smoother trail transitions than the other options. The illustrations indicate a secondary path that follows the approximate alignment of the existing shoreline granular path, but relocated to run adjacent to the labyrinth guardrail for viewing opportunities.

3.6 Construction of the Auxiliary Spillway

Based on the design assumptions discussed above, key aspects related to the construction of the auxiliary spillway are discussed below. This section highlights access considerations, construction sequencing and methods, environmental controls and schedule. The construction topics described in this section is separate from the existing spillway rehabilitation construction described above.

3.6.1 Access

Different access routes were considered during the May site visit. Access routes from south of the site were considered to avoid crossing the bridge over the existing spillway. The shortest route with the least impact to the trails and trees is expected to be from Harewood Mines Road via an approximately 200 m long pedestrian trail comprising 170 m of gravel path and 30 m of asphalt path (Figure 1). This will require:

- A laydown area at the existing path gate on Harewood Road;

- Removal and reinstatement of asphalt (the existing asphalt will be damaged by trucks during construction);
- Removal of the existing wooden pedestrian bridge, replacement with a temporary culvert (or bridge), and eventual reinstatement of the existing bridge; and
- Removal of approximately nine trees to facilitate trucking and equipment access along the pedestrian pathway.

3.6.2 Construction Sequencing

A general construction sequence for the auxiliary spillway is outlined below starting with the downstream channel excavation and following by the labyrinth weir.

1. Mobilization to site – set up site trailers, survey, install temporary fencing and signage.
2. Access preparation – bridge removal (temporary during construction). Tree removal along access path, asphalt removal along access path.
3. Site preparation along the auxiliary spillway channel alignment:
    a. Sediment and erosion control implementation;
    b. Clearing and grubbing; and
    c. Stripping and disposal of excess topsoil.
4. Mass earthworks – downstream of plug (natural rock plug has been assumed at entrance to auxiliary spillway location).
    a. Overburden removal and disposal of excess topsoil;
    b. Drilling, blasting and excavating of main channel;
    c. Soil stabilization and shotcreting (in parallel with excavation); and
    d. Armouring and planting of downstream channel.
5. Labyrinth weir construction
    a. Foundation preparation (suitable rock assumed at base); and
    b. Forming, pouring and stripping of concrete walls.
6. Bridge, taper and box culvert/ tunnel construction (depending on Option)
    a. Foundation preparation (suitable rock assumed at base); and
    b. Forming, pouring and stripping of concrete walls.
7. Plug Removal at entrance to labyrinth weir
    a. Final overburden removal;
    b. Bubble curtain installation; and

   c. Drilling, blasting and excavation of the rock plug.

8. Aesthetics

   a. Install fencing for public safety;

   b. Reinstate bridge across access path;

   c. Planting grass and trees as designed by landscape architect;

   d. Landscaping of site and access as designed by landscape architect; and

   e. Cleanup.

9. Demobilization from site.

3.6.3 Methods

Consideration was given to the construction method for each stage of the work. The list below highlights construction methods that can be implemented to have overall advantages to the project in terms of budget, safety and/ or impact to the park:

- Laydown area and site offices located at the intersection of the access path and Harewood Mines Road limits the footprint at the worksite in the park;
- Bridging Harewood Creek with a culvert eliminates the use of a Bailey Bridge, thus reducing cost and width of access (tree cutting) required along the footpath;
- A Commando multipurpose drill rig will be used to drill for blasting purposes and install soil anchors;
- A 30 tonne excavator (ie. Cat 330) will be used to do the bulk of the excavation work, with some assistance from a backhoe and bobcat;
- A 30 tonne crane will be used to swing forms and move the drill in and out of the spillway channel during the drilling and blasting work;
- 14 tonne tandem dump trucks will be used to access the site via path system to remove surplus material that can not be reused onsite;
- General purpose labourers/ flaggers will be onsite during working hours to ensure the excavator and trucks do not interact with pedestrians; and
- Asphalt removal and reinstatement.

3.6.4 Environmental controls

As the worksite and access are within the park, environmental considerations during construction will include at least the following:

- Standard sediment and erosion control measures;
  - Sediment fence installed where useful and practical;

- Hay bales, poly and drain rock onsite for rapid response to rain events; and
- Restrict work in topsoil or other material prone to sediment deposition during rain events.

- Concrete Works
  - Installation of small perimeter dams to protect against blow out;
  - Labourers to clean concrete trucks to higher standard; and
  - Training, supervision for staff and truck driver to ensure compliance with site rules.
- Blasting
  - Use of bubble curtain in the water to protect aquatic life against shockwaves; and
  - Use of mats on top of blast to protect against flyrock.
- Additional measures
  - Siltation curtain in lake surrounding inlet to protect during plug excavation; and,
  - Drain rock / filter fabric berms at channel outlet and any other drainage points to filter surface water from work area.

3.6.5 Construction Schedule

A preliminary construction schedule was contemplated at the time the cost estimate was developed. The ideal construction window is during the drier season from July to October. The work is anticipated to take approximately 3 months to complete (if constructed during the summer/ early fall months) plus an additional 1 month for mobilization and demobilization (2 weeks at the start and 2 weeks at the completion of construction). If constructed during the winter months, the project would likely take 6 months to complete.

3.6.6 Construction Impacts

The construction of the proposed auxiliary spillway will result in impacts on park users and nearby residents.

- There will be increased traffic, including heavy trucks and equipment accessing the site via Harewood Mines Road and path system.
- There will be potential damage to trees, pathways and greenspace from trucking and heavy equipment. Reinstatement of pathways and reseeding of impacted greenspace and landscaping will occur following construction to minimize long term visual and environmental impacts. At this stage at least 27 large trees (150 mm diameter or greater) will require removal in addition to smaller brush and shrubs in the area of the proposed auxiliary spillway footprint.
- As previously noted, the existing wooden bridge over Harewood Creek will be removed during construction and reinstated following completion of the project.
- Site fenced off and public prohibited from existing spillway to tee in path SW of spillway.

Shorter work hours of ten hours per day five days per week will be implemented to reduce construction noise disruption (heavy equipment, trucks backing up, concrete pumps, blasting).

3.7 Estimated Constructions Costs

An estimate of construction costs has been carried out based on the conceptual design information. The estimate has been developed using a resource-based (bottoms-up) method with Heavy-Bid cost estimating software. It is noted that the cost ranges for Options 1, 1A and 3 are similar, and within the accuracy of our current estimate, we have reported the same cost range below. The cost for Option 2 is lower.

- Cost range, Options 1, 1A and 3. **$2.5M to $4.7M.** A potential reason why Option 3 is not markedly greater than Options 1 and 1A is the high costs of the anchored channel. This differential may change, once there is further information on ground conditions.
- Cost range, Option 2. **$2M to $3.8M.**
- The principal uncertainties affecting the accuracy of the cost estimate are the unknown ground conditions, in particularly in the vicinity of the weir.

This estimate represents the construction cost (ie cost to a contractor, including overhead and profit, assuming a design-bid-build approach), but does not include design (including site investigations), permitting, construction management or related costs.

4.0 CLOSURE

We trust that the information provided herein meets your present requirements. Should you have any questions regarding the above, please do not hesitate to contact us.

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Attachments:
Figure 1: General Arrangement
Figure 2: Lower Dam Overtopping Protection Option – Conceptual Plan and Profiles
Figure 3: Lower Dam Overtopping Protection Concept Existing Spillway Wall Raise
Figure 4: Auxilliary Spillway Location Relative to Lower Dam, Boreholes, Test Pits and Bedrock Outcrops Plan
Figure 5: Site Geology
Figure 6a: Auxiliary Spillway to Harewood Creek Conceptual Plan Option 1 – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 6b: Auxiliary Spillway to Harewood Creek Conceptual Sections Option 1 – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 7a: Auxiliary Spillway to Harewood Creek Conceptual Plan Option 1A – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 7b: Auxiliary Spillway to Harewood Creek Conceptual Sections Option 1A – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 8a: Auxiliary Spillway to Harewood Creek Conceptual Plan Option 2 – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 8b: Auxiliary Spillway to Harewood Creek Conceptual Sections Option 2 – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 9a: Auxiliary Spillway to Harewood Creek Conceptual Plan Option 3 – Labyrinth/ Box Culvert/ Anchored Channel Option
Figure 9b: Auxiliary Spillway to Harewood Creek Conceptual Sections Option 3 – Labyrinth/ Box Culvert/ Anchored Channel Option

Appendices:
Appendix A: Structural Design – Herold Engineering
Appendix B: Raising Walls of Existing Spillway – Basis (Exclusions and Limitations)
Appendix C: Draft Design Build Performance Requirements
Appendix D: Visualizations of Auxiliary Spillway Design Concepts
Appendix E: Auxiliary Spillway – Basis (Exclusions and Limitations)

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5.0 REFERENCES

BC Ministry of Energy and Mines, 1998. "Geology of the Wellington Area, Nanaimo Coalfield, British Columbia" map (NTS 92F/1E, 8E; 92G/4W)

BC Ministry of Forest, Lands and Natural Resource Operations, 2015. Letter to the City of Nanaimo "Middle Chase River Dam and Lower Chase River Dam – Replacement Order", dated April 29, 2015.

FEMA, 2014, Technical Manual: Overtopping Protection for Dams, Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair, May 2014.

Golder Associates Ltd. 2014a. Report on "Colliery Dams– Remediation Options", August 2014.

Golder Associates Ltd. 2014b. Report on "Colliery Dams – Hydraulics, Hydrology and Dam Breach Analysis", July 2014.

Golder Associates Ltd. 2015. Letter on "Colliery Dams, Auxiliary Spillway – Conceptual Design", dated January 16, 2015.

Water Management Consultants Inc. "City of Nanaimo Middle and Lower Chase River Dams Spillway Hydrology Study", April 30, 2002.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

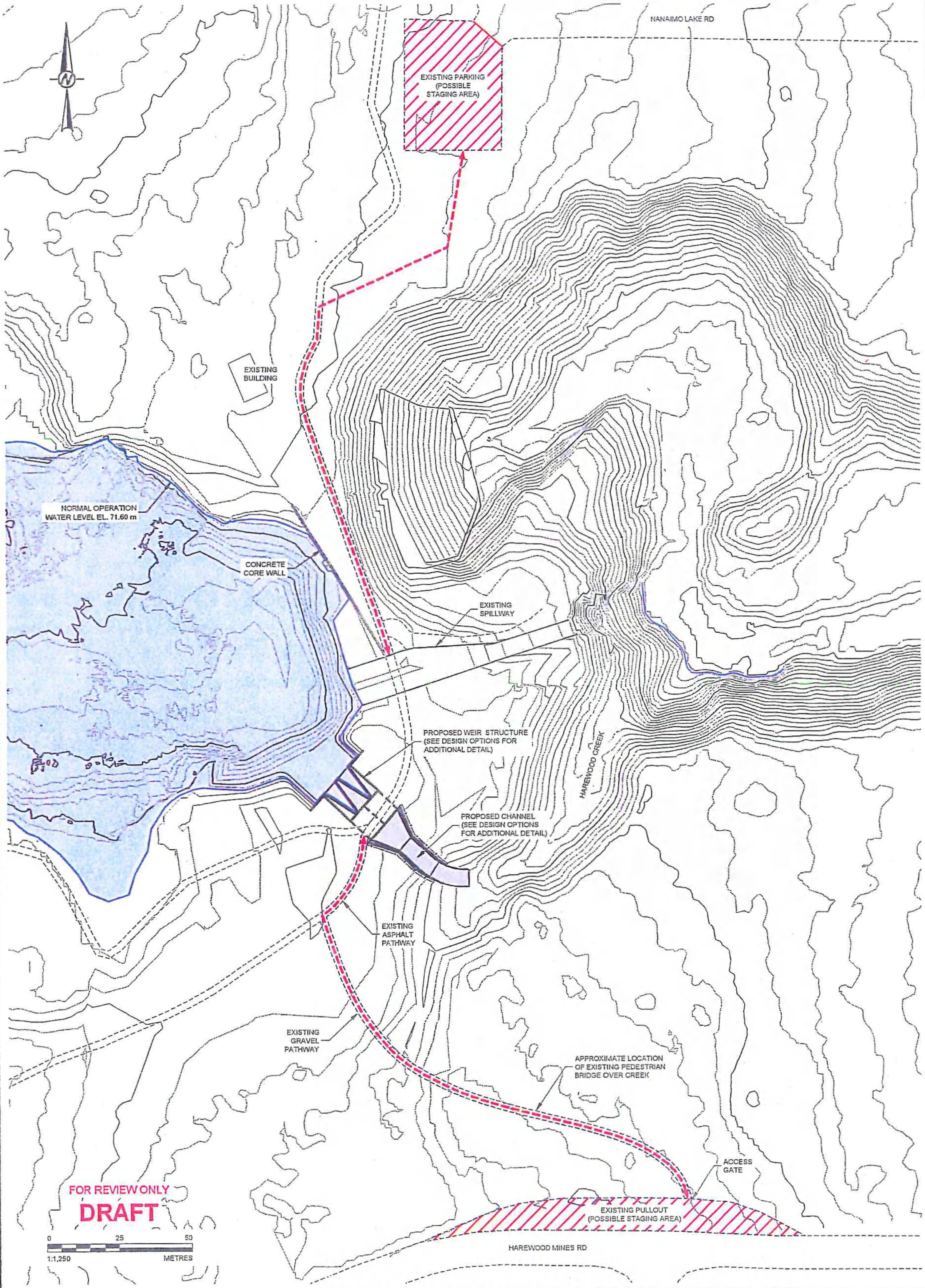
Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

File Name: 13-1447-0516_TEST HOLES 2.dwg



LEGEND

- RESERVOIR (AT REGULAR OPERATING LEVEL)
- ACCESS ROUTE
- POSSIBLE STAGING AREA

NOTE

1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.

CLIENT
CITY OF NANAIMO

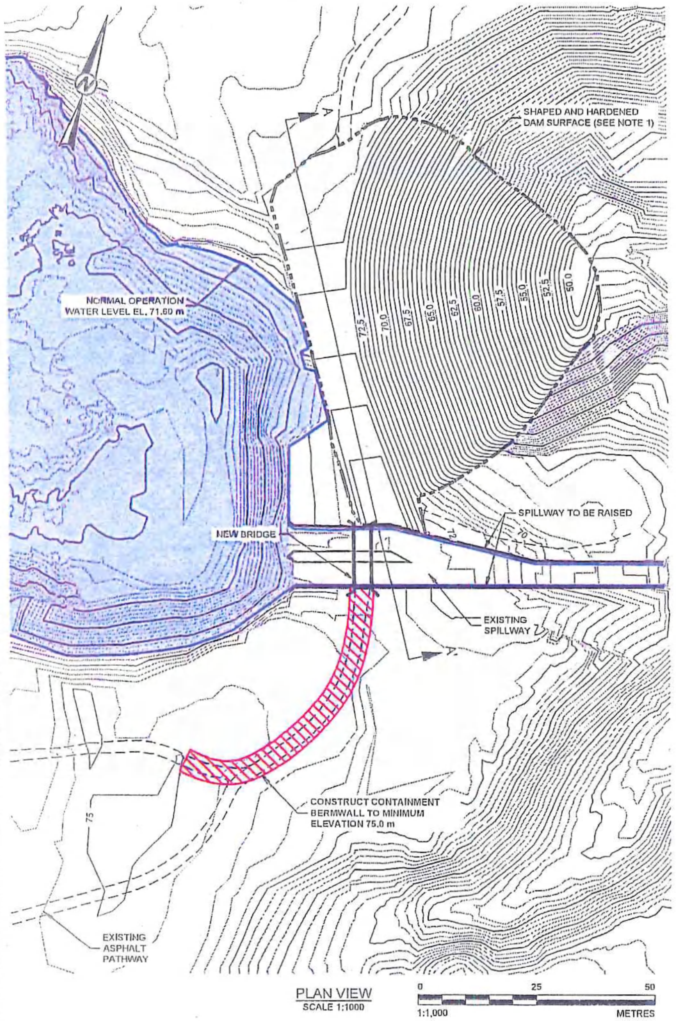
PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT
Golder Associates

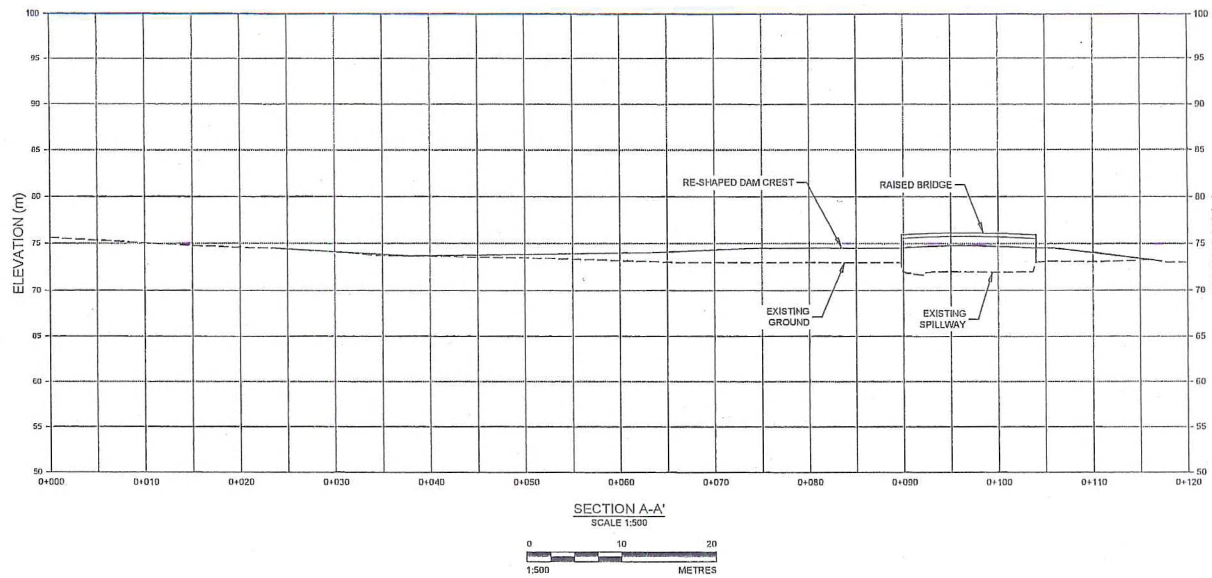
YYYY-MM-DD	2015-06-15
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

TITLE
GENERAL ARRANGEMENT

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	A	1



PLAN VIEW
SCALE 1:1000



SECTION A-A'
SCALE 1:500

PRELIMINARY
NOT FOR CONSTRUCTION

LEGEND
- RESERVOIR (AT REGULAR OPERATING LEVEL)
- CONTAINMENT BERMWALL

NOTE
1. REFERENCE CONCEPT SHOWN, ALTERNATIVE DESIGN MAY BE PROPOSED BY OTHERS.

REFERENCES
1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

CLIENT
CITY OF NANAIMO

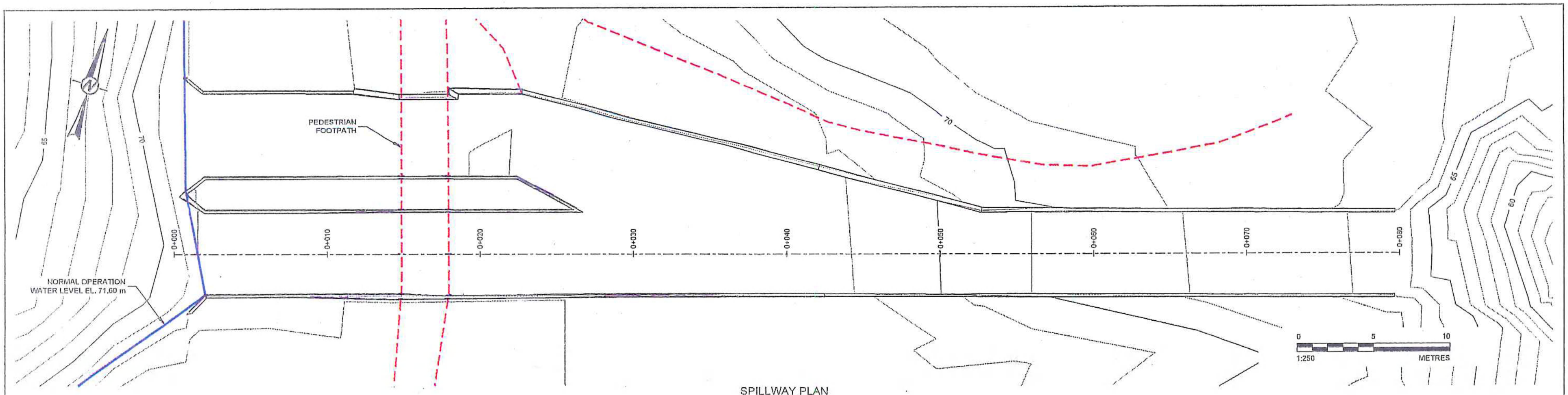
CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	SEP
REVIEW	JKM
APPROVED	BD

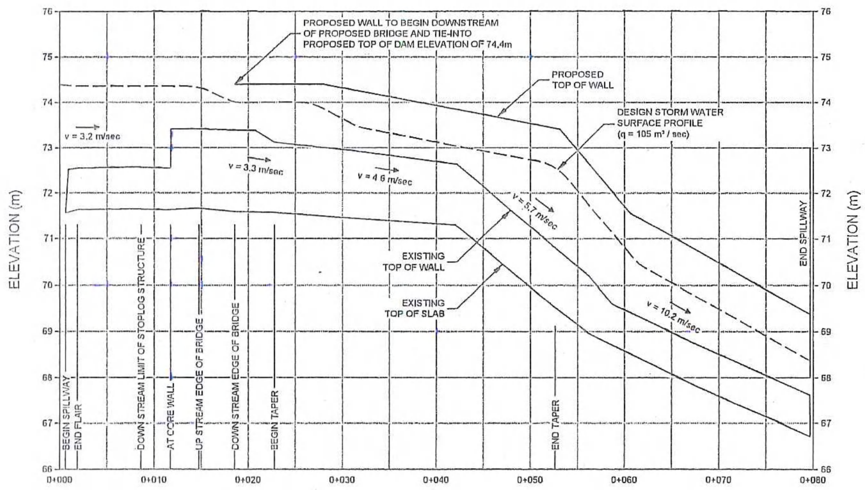
PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
LOWER DAM OVERTOPPING PROTECTION OPTION
CONCEPTUAL PLAN AND PROFILES

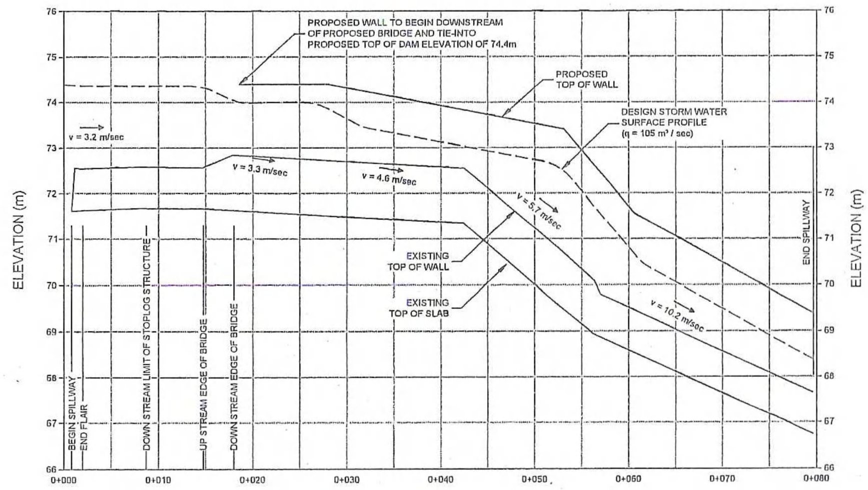
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	2



SPILLWAY PLAN
SCALE 1:250



LEFT SPILLWAY WALL (LOOKING DOWNSTREAM)
SCALE V 1:50 H 1:500



RIGHT SPILLWAY WALL (LOOKING DOWNSTREAM)
SCALE V 1:50 H 1:500

NOTE

1. PROFILES DEPICTED ARE ALONG THE STRAIGHT CENTERLINE ALIGNMENT SHOWN IN THE SPILLWAY PLAN VIEW. THE LEFT WALL'S LENGTH IS ACTUALLY LONGER DUE TO THE SPILLWAY'S TAPERING SECTION.

REFERENCES

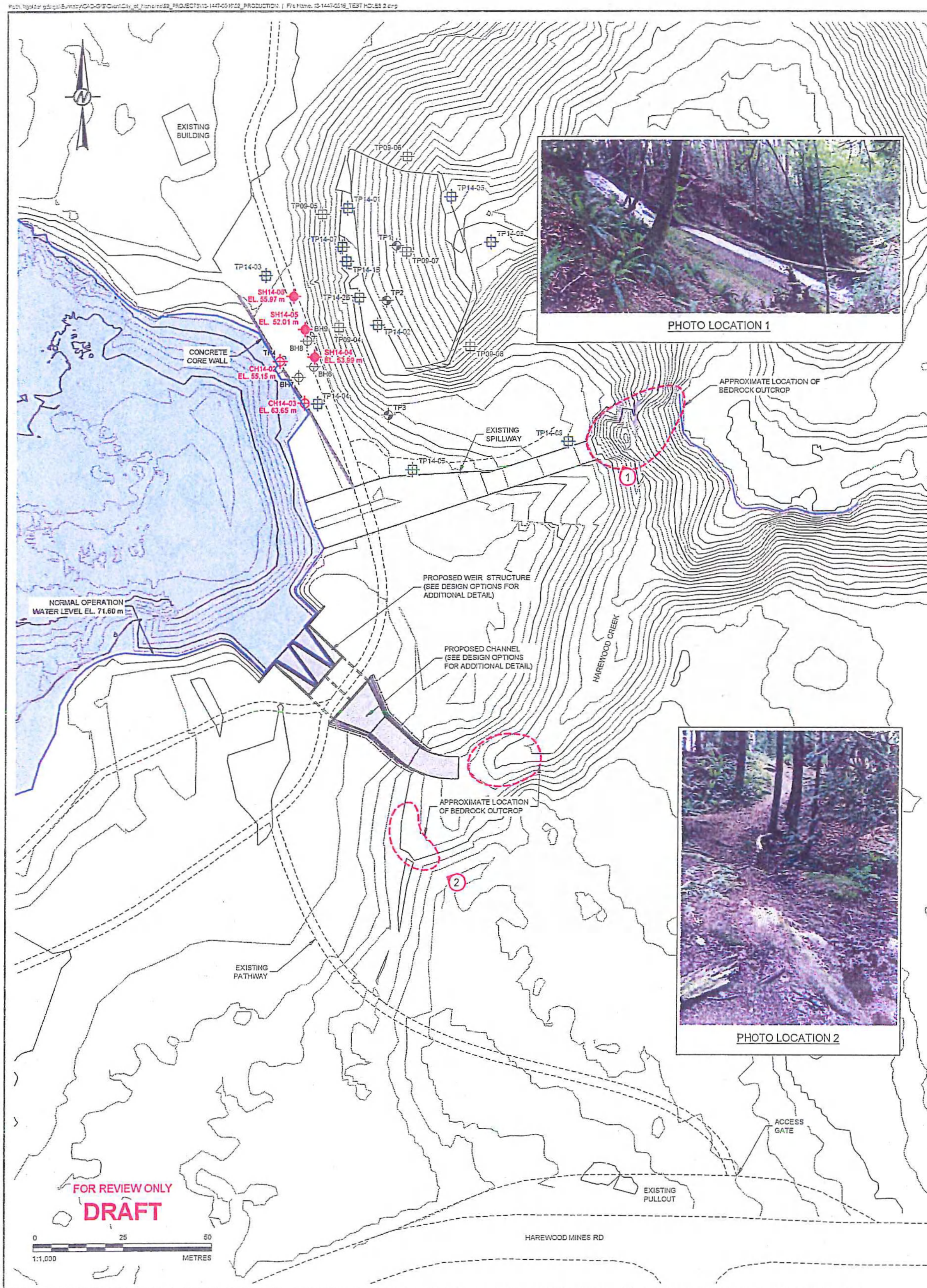
1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

PRELIMINARY
NOT FOR CONSTRUCTION

0 1 2
1:50 METRES

0 10 20
1:500 METRES

CLIENT CITY OF NANAIMO		PROJECT COLLIERY DAMS NANAIMO, BC	
CONSULTANT Golder Associates	YYYY-MM-DD: 2015-05-22 PREPARED: RP DESIGN: SEP REVIEW: JKM APPROVED: BD	TITLE LOWER DAM OVERTOPPING PROTECTION CONCEPT EXISTING SPILLWAY WALL RAISE	
		PROJECT No. 13-1447-0516	PHASE 2500 / Rev. 1 / FIGURE 3



LEGEND

- 2014 GOLDER SONIC HOLE (INCLUDING BEDROCK ELEVATION)
- 2014 GOLDER COREHOLE (INCLUDING BEDROCK ELEVATION)
- 2014 GOLDER TEST PIT (BY HAND)
- 2009 EBA TEST PIT
- 1978 GOLDER BOREHOLE
- 1978 GOLDER TEST PIT (BY EXCAVATOR)
- 1978 GOLDER TEST PIT (BY HAND)
- OUTLINE OF WALL (1.2 m THICK AT 0.6 m BELOW EXISTING GROUND)
- RESERVOIR (AT REGULAR OPERATING LEVEL)
- APPROXIMATE BEDROCK OUTCROP
- PHOTO LOCATION MARKER

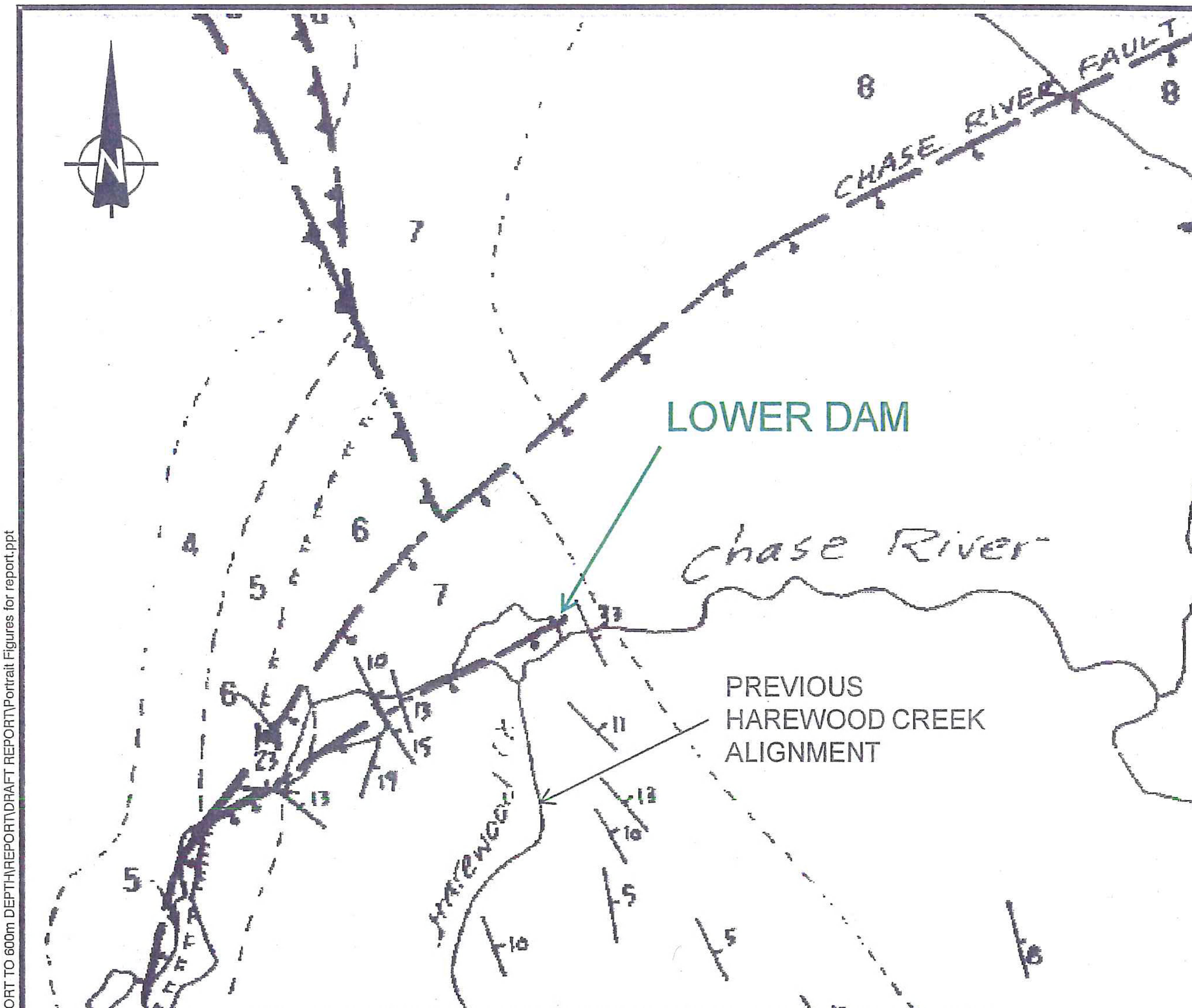
NOTE

1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lwer dam 2003.dwg, DATED: OCTOBER 20, 2003.

CLIENT CITY OF NANAIMO			PROJECT COLLIERY DAMS NANAIMO, BC
CONSULTANT Golder Associates	YYYY-MM-DD	2015-05-15	TITLE AUXILIARY SPILLWAY AVAILABLE GEOTECHNICAL INFORMATION
	PREPARED	RP	
	DESIGN	JG	
	REVIEW		PROJECT No. 13-1447-0516 · PHASE 2500 · Rev. A · FIGURE 4
	APPROVED		



STRATIGRAPHIC LEGEND

UPPER CRETACEOUS – NANAIMO GROUP

EXTENSION FORMATION:

7 MILLSTREAM MEMBER: Conglomerate and gritstone; minor sandstone, siltstone, carbonaceous shale and coal

6 NORTHFIELD MEMBER: Siltstone, carbonaceous shale and coal (Wellington Seam at base); locally contains lenses of conglomerate and sandstone

5 EAST WELLINGTON FORMATION: Sandstone; minor gritstone and siltstone

4 HASLAM FORMATION: Siltstone, with sandstone interbeds at top; grades down to black silty shale at base

SYMBOL LEGEND

NORMAL FAULT (OBSERVED, APPROXIMATE, INFERRED)

REVERSE FAIULT (OBSERVED, APPROXIMATE, INFERRED)

GEOLOGICAL BOUNDARY (OBSERVED, APPROXIMATE, INFERRED)

COAL SEAM TRACE (OBSERVED, APPROXIMATE, INFERRED)

BEDDING ORIENTATION (DIP ANGLE)

DRAFT

REFERENCE

British Columbia Ministry of Energy and Mines, Geological Survey Branch Open Fil 1998-07 (Sheet 2 of 6) Geology of the Westwood Lake Area, Nanaimo Coalfield, British Columbia, NTS 92F/1E; 92G/4W By C.G. Cathyl-Bickford (P.Go.) and G.L. Hoffman (P.Gol.)

PROJECT

COLLIERY DAMS
NANAIMO, B.C.

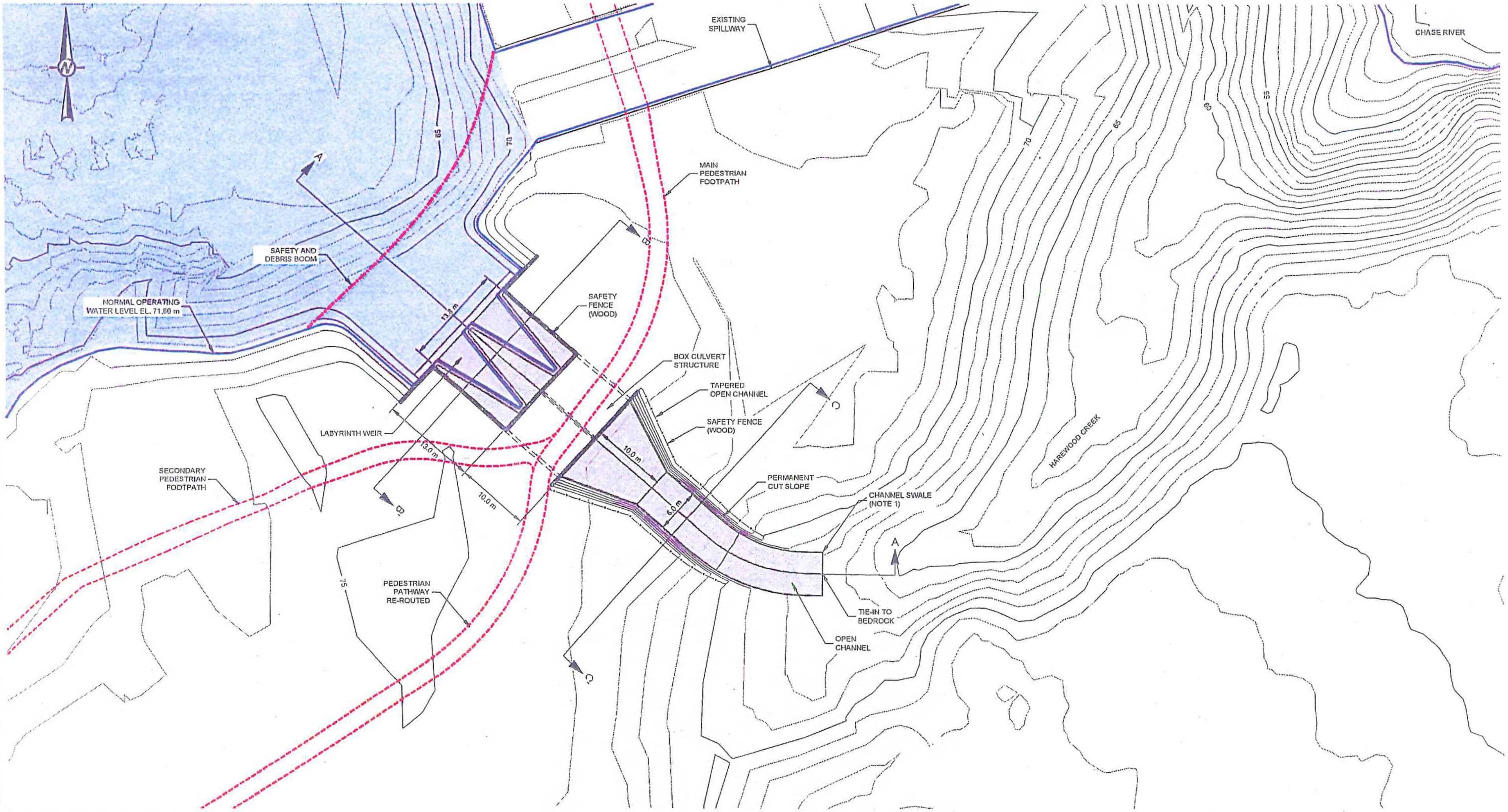
TITLE

SITE GEOLOGY

Golder Associates

PROJECT No. 13-1447-0516			PHASE No. 3000
DESIGN	JKG	19Jun15	SCALE NTS — REV.
CADD	----	19 JUN15	FIGURE 5
CHECK			
REVIEW			

O:\Active_2008\1221\08-1221-3012\4000 - Temp. Shaft Support and Liner Design\SHAFT SUPPORT TO 600m DEPTH\REPORT\DRAFT REPORT\Portrait Figures for report.ppt



NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

PRELIMINARY
NOT FOR CONSTRUCTION

0 10 20
1:500 METRES

CLIENT
CITY OF NANAIMO

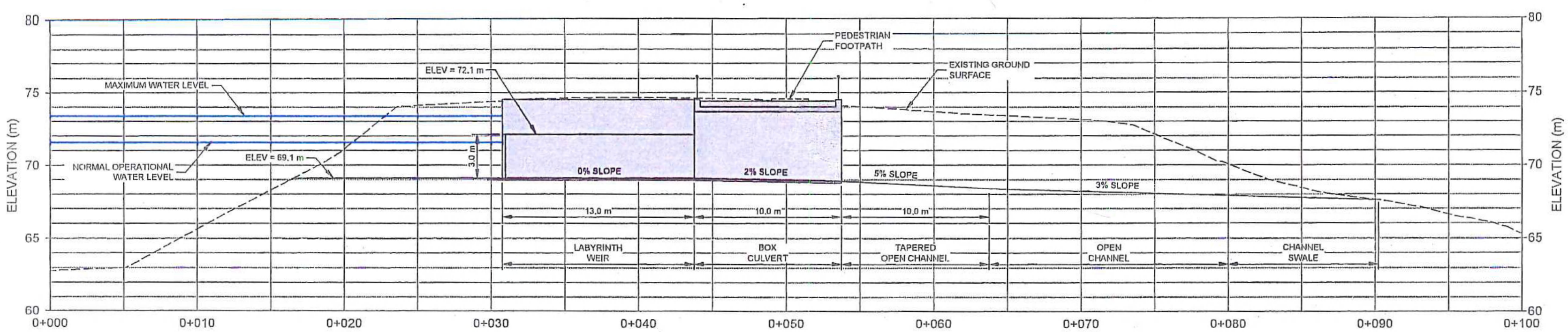
PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT
Golder Associates

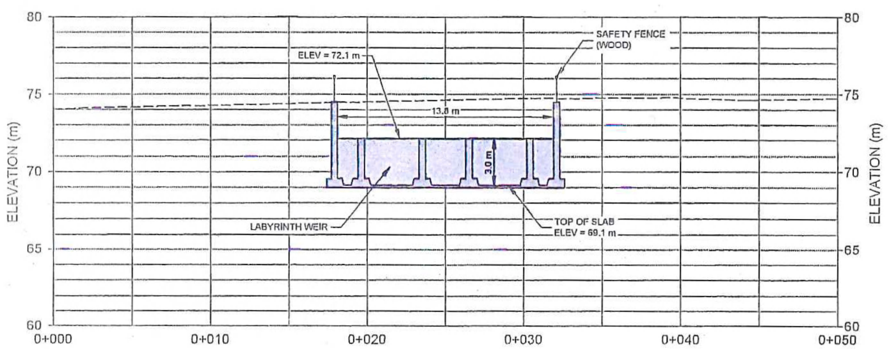
YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 1 - ANCHORED CHANNEL
CONCEPTUAL PLAN

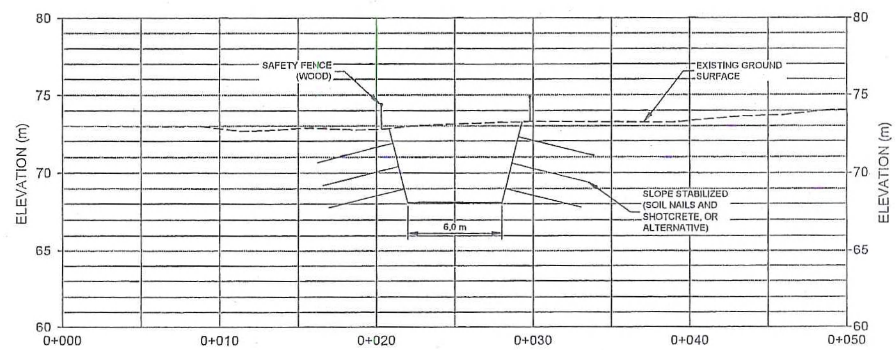
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	6a



SECTION A-A'
SCALE 1:300



SECTION B-B'
SCALE 1:300



SECTION C-C'
SCALE 1:300

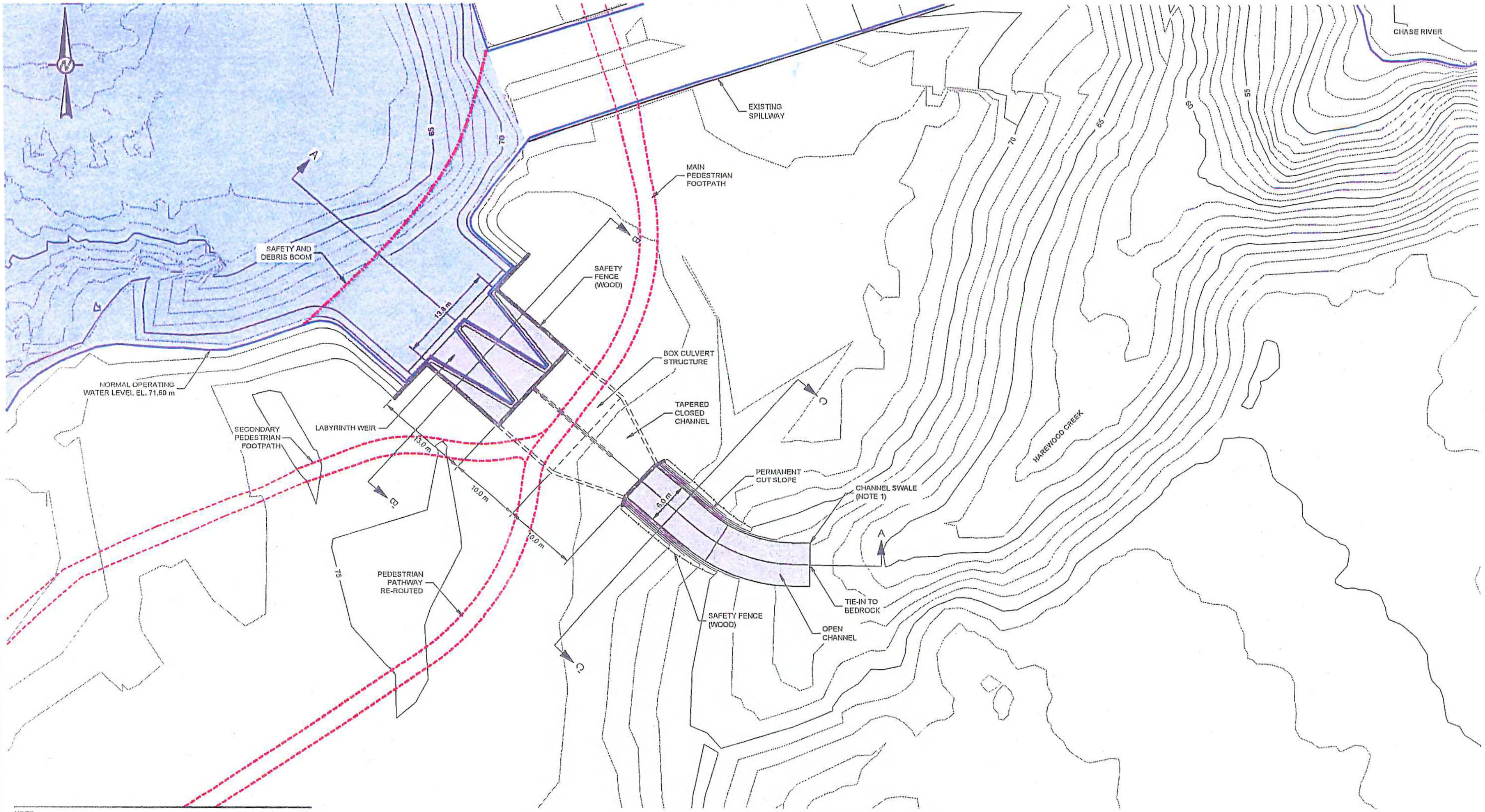
NOTE
1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES
1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bver dam 2003.dwg, DATED: OCTOBER 20, 2003.

PRELIMINARY
NOT FOR CONSTRUCTION

0 5 10
1:300 METRES

CLIENT	CITY OF NANAIMO
PROJECT	COLLIERY DAMS NANAIMO, BC
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD
TITLE	AUXILIARY SPILLWAY TO HAREWOOD CREEK OPTION 1 - ANCHORED CHANNEL CONCEPTUAL SECTIONS
PROJECT No.	13-1447-0516
PHASE	2500
Rev.	1
FIGURE	6b



NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

PRELIMINARY
NOT FOR CONSTRUCTION

0 10 20
1:500 METRES

CLIENT
CITY OF NANAIMO

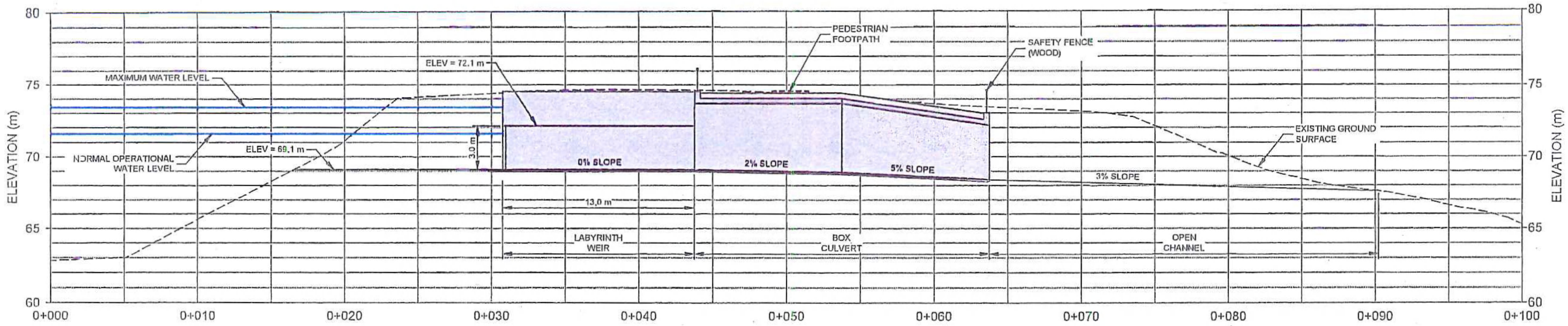
PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT
Golder Associates

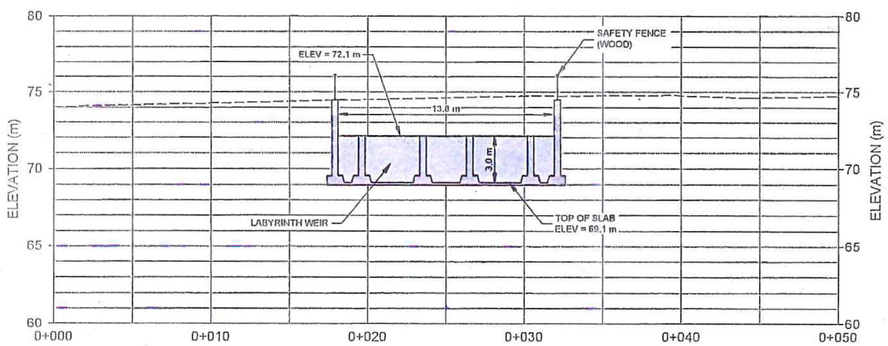
YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 1A - ANCHORED CHANNEL OPTION
CONCEPTUAL PLAN

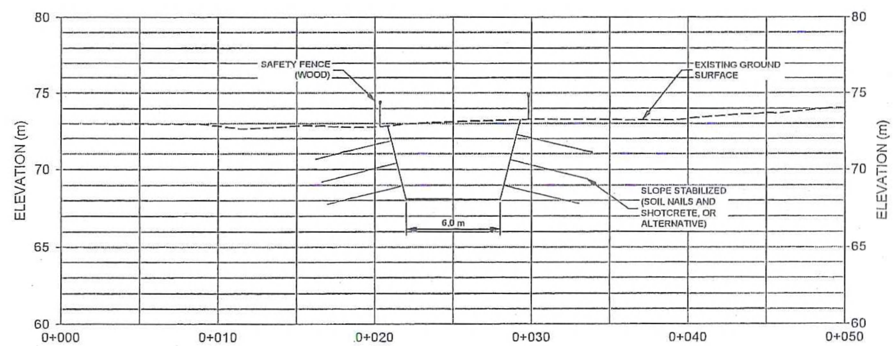
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	7a



SECTION A-A'
SCALE 1:300



SECTION B-B'
SCALE 1:300



SECTION C-C'
SCALE 1:300

NOTE
1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES
1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.

PRELIMINARY
NOT FOR CONSTRUCTION

0 5 10
1:300 METRES

CLIENT
CITY OF NANAIMO

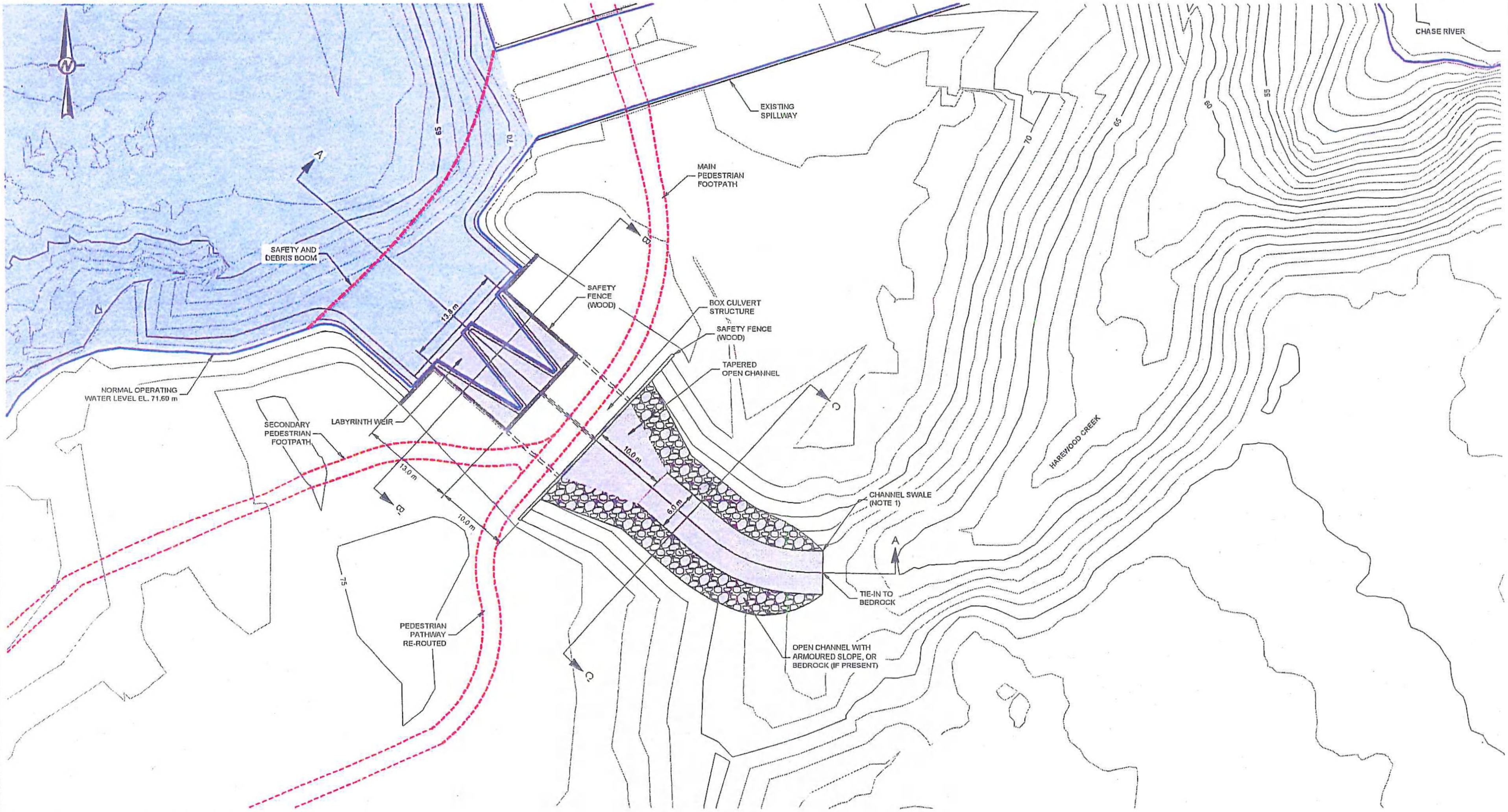
PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 1A - ANCHORED CHANNEL OPTION
CONCEPTUAL SECTIONS

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	7b



NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

PRELIMINARY
NOT FOR CONSTRUCTION

0 10 20
1:500 METRES

CLIENT
CITY OF NANAIMO

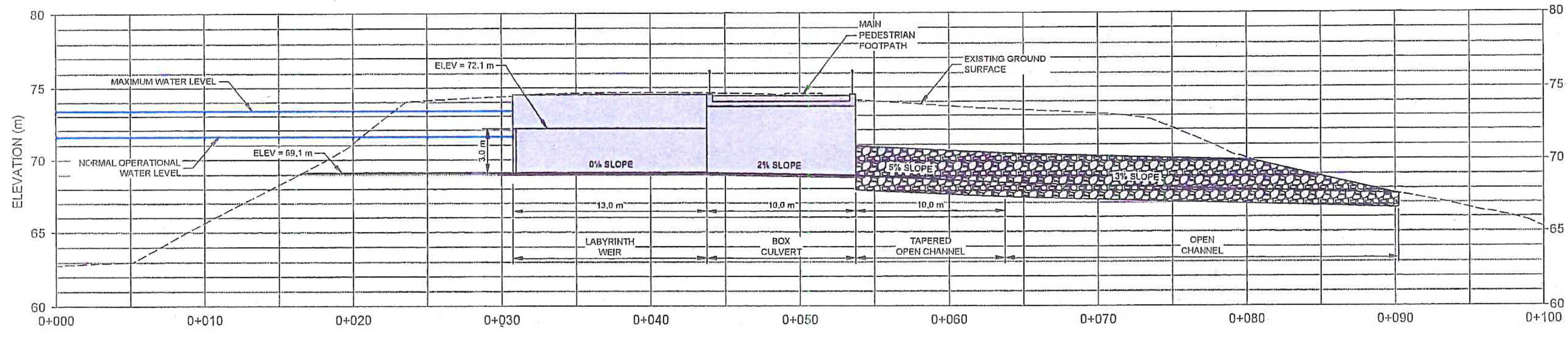
CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

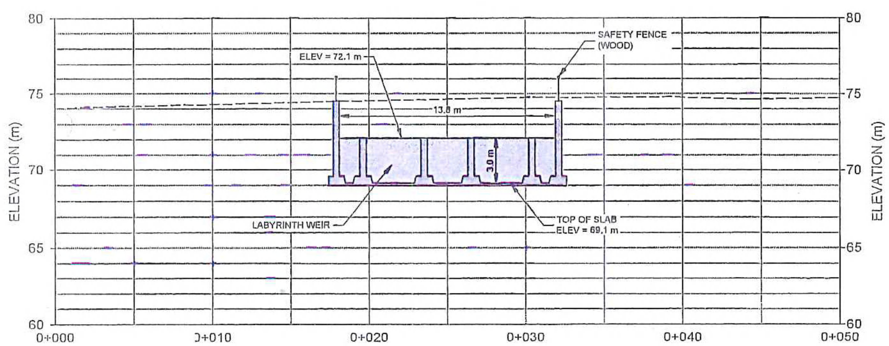
PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 2 - OPEN CHANNEL OPTION
CONCEPTUAL PLAN

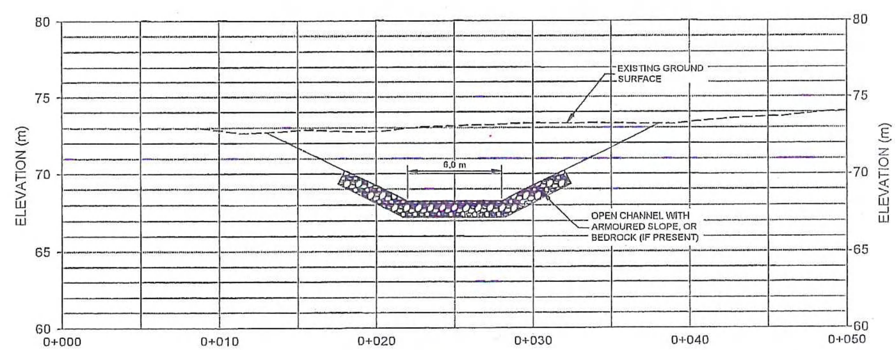
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	8a



SECTION A-A'
SCALE 1:300



SECTION B-B'
SCALE 1:300



SECTION C-C'
SCALE 1:300

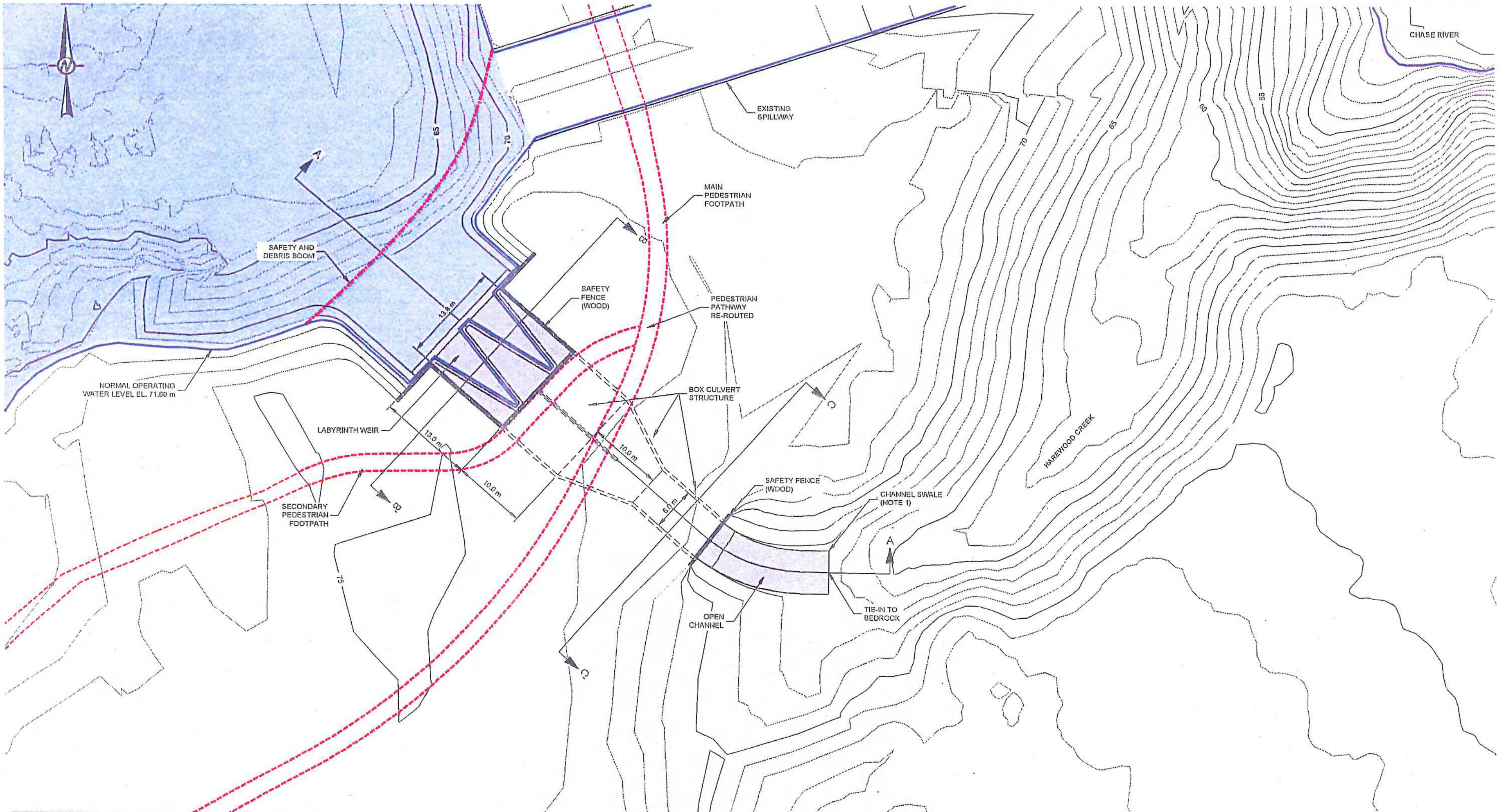
NOTE
1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES
1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg DATED: OCTOBER 20, 2003.

PRELIMINARY
NOT FOR CONSTRUCTION

0 5 10
1:300 METRES

CLIENT	CITY OF NANAIMO
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD
PROJECT	COLLIERY DAMS NANAIMO, BC
TITLE	AUXILIARY SPILLWAY TO HAREWOOD CREEK OPTION 2 - OPEN CHANNEL OPTION CONCEPTUAL SECTIONS
PROJECT No.	13-1447-0516
PHASE	2500
Rev.	1
FIGURE	8b



NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

PRELIMINARY
NOT FOR CONSTRUCTION

0 10 20
1:500 METRES

CLIENT
CITY OF NANAIMO

PROJECT
COLLIERY DAMS
NANAIMO, BC

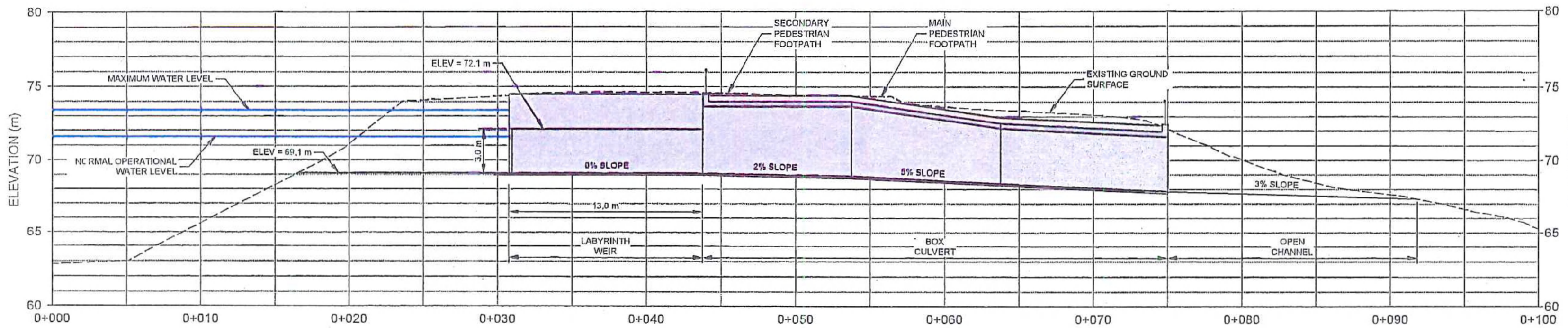
CONSULTANT

Golder Associates

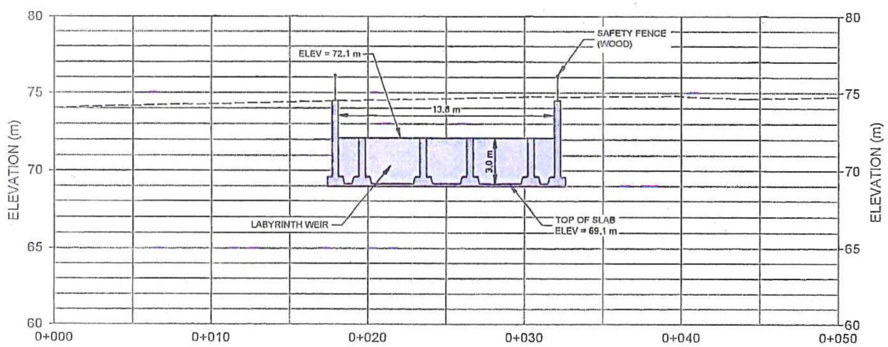
YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 3 - BURIED CHANNEL OPTION
CONCEPTUAL PLAN

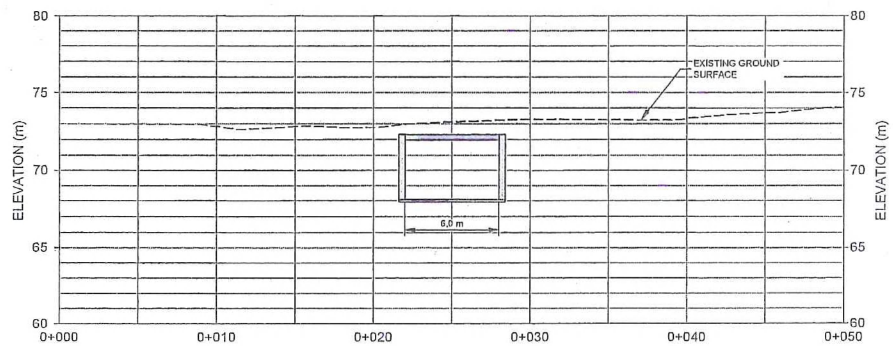
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	9a



SECTION A-A'
SCALE 1:300



SECTION B-B'
SCALE 1:300



SECTION C-C'
SCALE 1:300

NOTE

1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.

PRELIMINARY
NOT FOR CONSTRUCTION

0 5 10
1:300 METRES

CLIENT
CITY OF NANAIMO

PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-22
PREPARED	RP
DESIGN	JO
REVIEW	JO
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
OPTION 3 - BURIED CHANNEL OPTION
CONCEPTUAL SECTIONS

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	1	9b

APPENDIX A
Structural Design – Herold Engineering

City of Nanaimo – Lower Colliery Dam Remediation
Structural Design Development
June 30, 2015

Table of contents — *page*

STRUCTURAL DESIGN DEVELOPMENT

1.0 SUMMARY

The lower colliery dam has been reviewed with respect to several remediation alternatives. Analysis performed by Golder Associates produced several basic options that require structural input and design (1) enlarge the existing spillway by increasing the height of the walls and (2) provide an auxiliary spillway to augment the existing spillway.

This Design Development Report is to be considered preliminary for the purpose of conceptual review and costing. The final size and location of walls, slabs and piers are subject to change depending on final layout, alternatives confirmed and further structural analysis completed.

2.0 STRUCTURAL COMMENTARY

.1 Original Construction of the Lower Spillway

The original 1910 vintage spillway consists of a concrete entry structure, a centre island, a pedestrian bridge and a concrete slab spillway with walls approximately 1.2 m in height sloping toward the Harewood Creek. The system is believed to be founded on bedrock from reservoir entry to Harewood Creek where bedrock is visible. However, additional information is necessary to verify depth and location of bedrock.

The spillway entry structure is constructed of concrete although the reinforcing is not known. However, drilling of the internal concrete dam wall indicates that the concrete of the day (1910) was relatively homogeneous and testing indicated a compressive strength of between 17 and 20 MPa. Scouring of the apron and base slab is evident, but unknown is the condition of the entry spillway wall support mechanism, or if there is any mechanical connection to the bedrock. The lateral load retaining capacity from backfill soils, surcharge loads and seismic ground motions are not known.

The centre island is constructed of concrete walls infilled with partially visible soil and rock fill although bearing capacity is unknown. The centre pier of the pedestrian walkway is supported on the centre island. The gravity load capacity and seismic load capacity of the bridge is unknown but there is no sign of structural failure to date however, the consequence to the spillway operation of foundation or bridge failure during a seismic event is also unknown.

The spillway wall structure and spillway slab on the down-stream side appear to be in reasonable condition with some scouring but with no visible structural failure although the support mechanisms are unknown. Also, it is not known if there is a mechanical connection to the bedrock. Again, the lateral load retaining capacity from backfill soils, surcharge loads and seismic ground motions are not known.

.2 Remediation Alternatives

.2.1 Enlarge the Height of the Existing Spillway Walls (over-topping option):

See Appendix Sketches A-S200, A-S301, A-S302: this option includes keeping the existing entry structure/island, spillway base slab and walls and building on top of these elements with new reinforced concrete. This option includes raising the pedestrian entry to the bridge and provision of a new bridge to span the entire distance across (approximately 10 m). The construction along downstream walls of the spillway includes excavation behind the existing walls down to bedrock, drilling new rock anchors and constructing reinforced concrete footings and walls. The existing down-stream side walls are to be anchored to the new walls with a reinforced anchorage system to stabilize the spillway with consideration to strong seismic ground motions. Consideration towards mitigating the effects of scouring of the existing slab and walls may be included.

This alternative is only the structural concrete part of the overall strategic plan for the Overtopping Option and is not to be considered a stand-alone system.

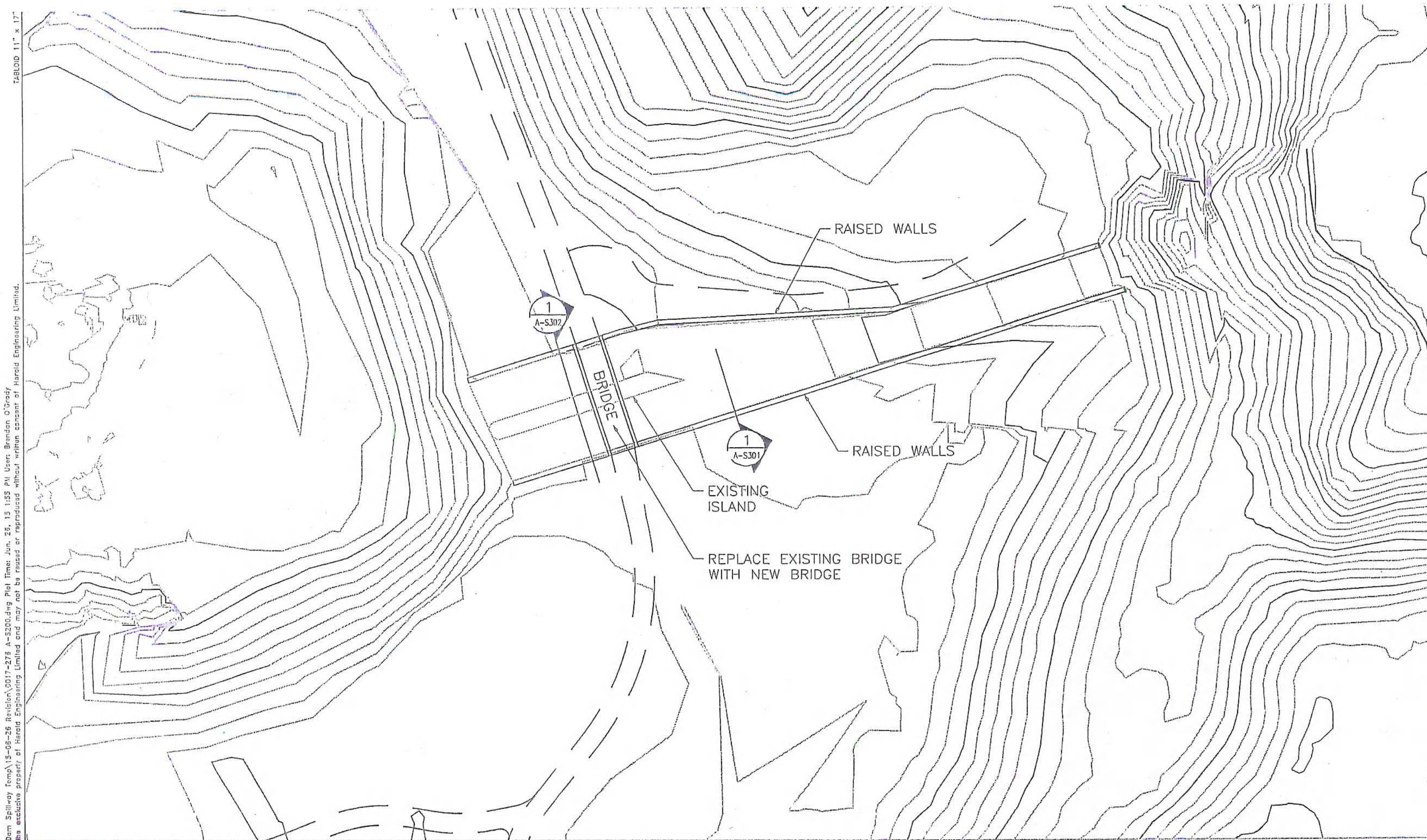
.2.2 Provide a New Auxiliary Spillway to the South of the Existing:

See Appendix Sketches B-S200, B-S201, B-S301, and B-S302: this option includes provision of a new entry apron, labyrinth weir, removable precast concrete stop logs and reinforced concrete walls and partial roof. The removable precast concrete stop logs weigh 25.92 kN (5827 lbs) each and will be designed for removal by truck crane from the south side to enable lowering of the reservoir should conditions warrant. However, considerable design is still necessary to determine the best and most feasible way of configuring and removing the logs.

There are several other options to the auxiliary alternative mainly concerning the excavation limits and channel armoring, however, from a structural standpoint the following is included:

- Reinforced concrete apron slab and wing walls to train the water into the spillway and mitigate the effects of scouring
- Reinforced concrete labyrinth weir and removable stacking precast concrete stop log system to adjust water flow levels
- Reinforced concrete box culvert style structure with a roof either at ground level or slightly below that would permit pedestrians to cross
- Walls and spillway slab on the downstream side toward Harewood Creek. The extent of structural concrete depends on the embankment configuration and channel armoring proposed.

APPENDIX 2



SITE PLAN

1:500

ISSUES		
No.	DATE	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM - STRUCTURAL 2015

411 DUNSMUIR STREET NANAIMO BC V9R 0E4

CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd, Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

SITE PLAN
RAISING WALLS OF EXISTING SPILLWAY AND NEW BRIDGE

DRAFTED BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No. 0017-276	CLIENT DRAWING No. n/a
SCALE 1 : 500	PERMIT No. n/a
HEL DRAWING No. A-S200	REVISION A

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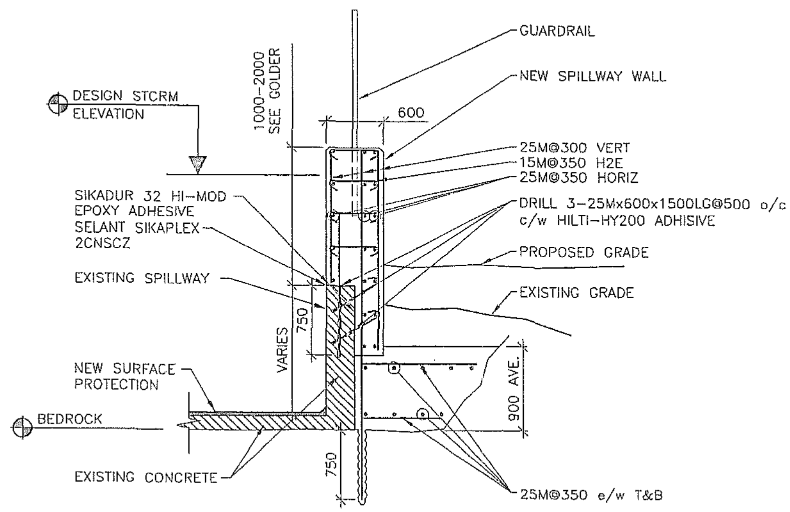

1 A-S200 SECTION
1:50

READ THIS SKETCH WITH GOLDER LOWER DAM SPILLWAY WALL RAISE PLAN

ISSUES		
No.	DATE mmm	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM - STRUCTURAL 2015

411 DUNSMUIR STREET NANAIMO BC V9R 0E4

CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd, Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

RAISING SPILLWAY WALLS OF EXISTING SPILLWAY

DRAFTED BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No. 0017-276	CLIENT DRAWING No. n/a
SCALE AS SHOWN	PERMIT No. n/a
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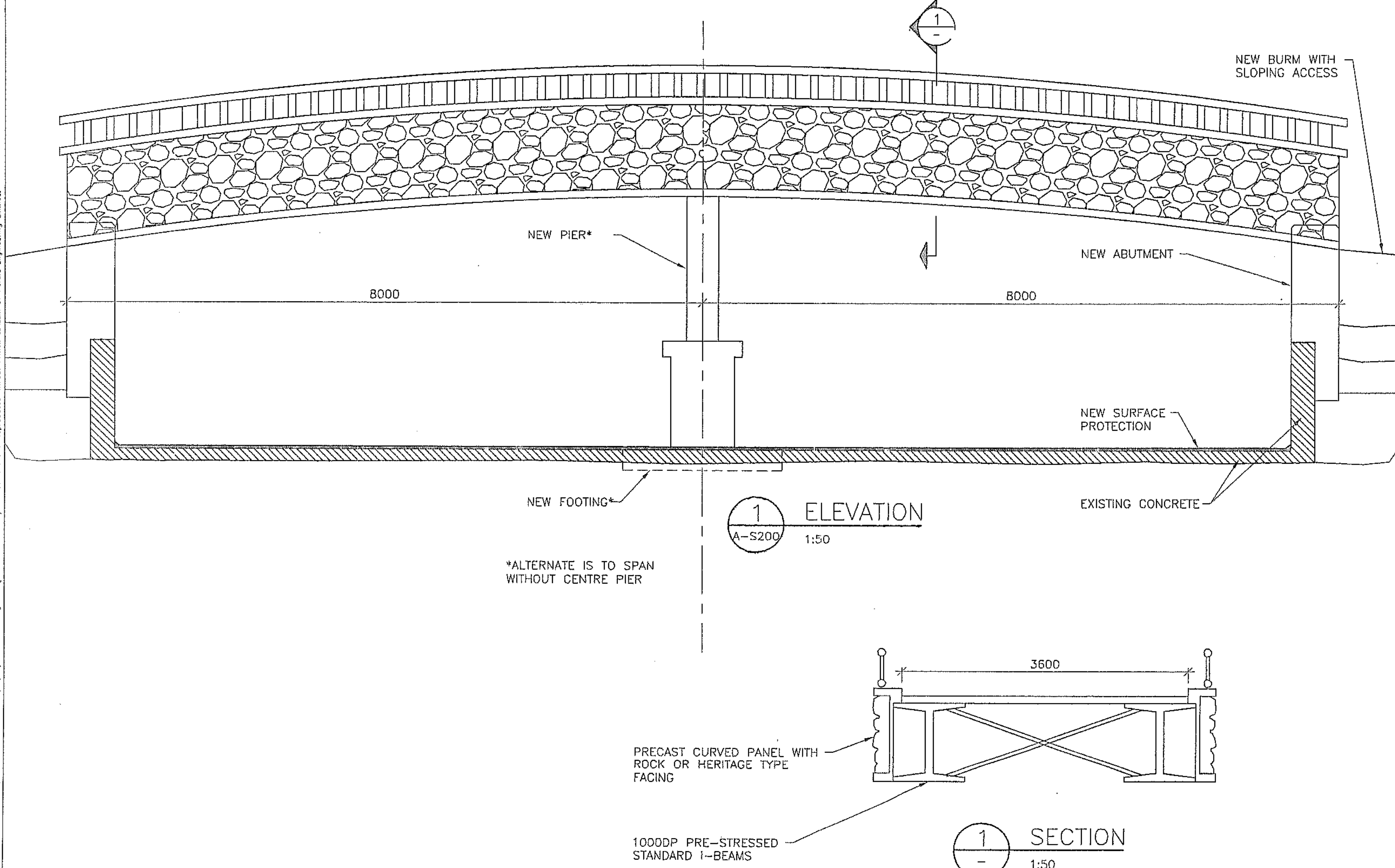

ISSUES		
No.	DATE	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM - STRUCTURAL 2015

411 DUNSMUIR STREET NANAIMO BC V9R 0E4

CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd, Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

NEW PEDESTRIAN BRIDGE OVER EXISTING SPILLWAY

DRAFTED: BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No.: 0017-276	CLIENT DRAWING No.: n/a
SCALE: AS SHOWN	PERMIT No.: n/a
HEL DRAWING No.: A-S302	REVISION: A

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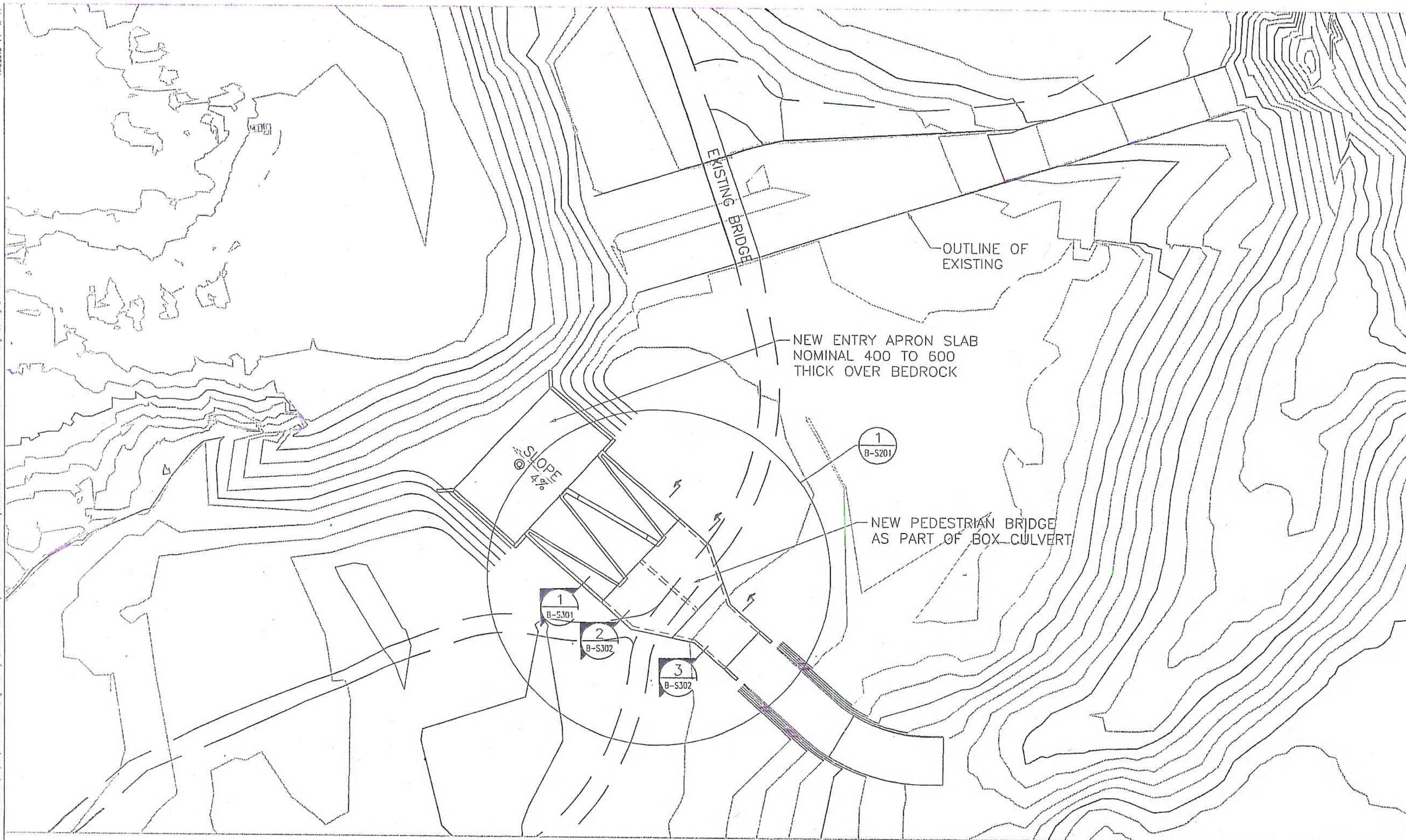

SITE PLAN
1:500

ISSUES

No.	DATE YYYY/MM/DD	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM -STRUCTURAL 2015

411 DUNSMUIR STREET NANAIMO BC V9R 0E4

CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd. Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

SITE PLAN
AUXILIARY SPILLWAY
LABYRINTH PLAN

DRAFTED: BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
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SCALE: 1 : 500	PERMIT No.: n/a
HEL DRAWING No.: B-S200	REVISION: A

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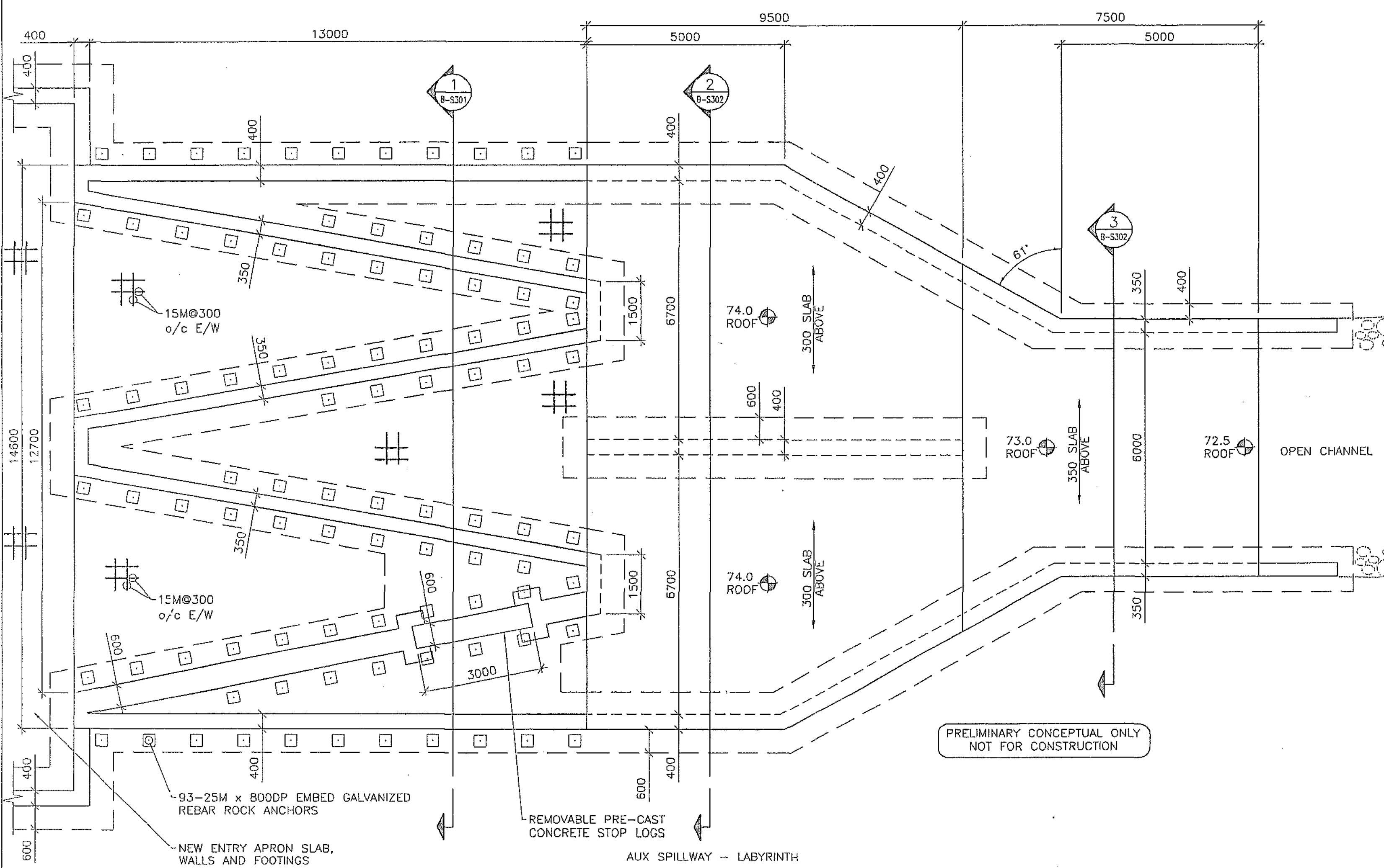

AUX SPILLWAY – LABYRINTH

FOUNDATION PLAN

1:100

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ISSUES		
No.	DATE yy-mm-dd	ISSUED FOR

SUB CONSULTANT

LOWER COLLIERY DAM AUXILLIARY SPILLWAY

HEROLD ENGINEERING
3701 Shenton Rd, Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

AUXILIARY SPILLWAY LABYRINTH PLAN

DRAFTED BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No. Work\Au	CLIENT DRAWING No. n/a
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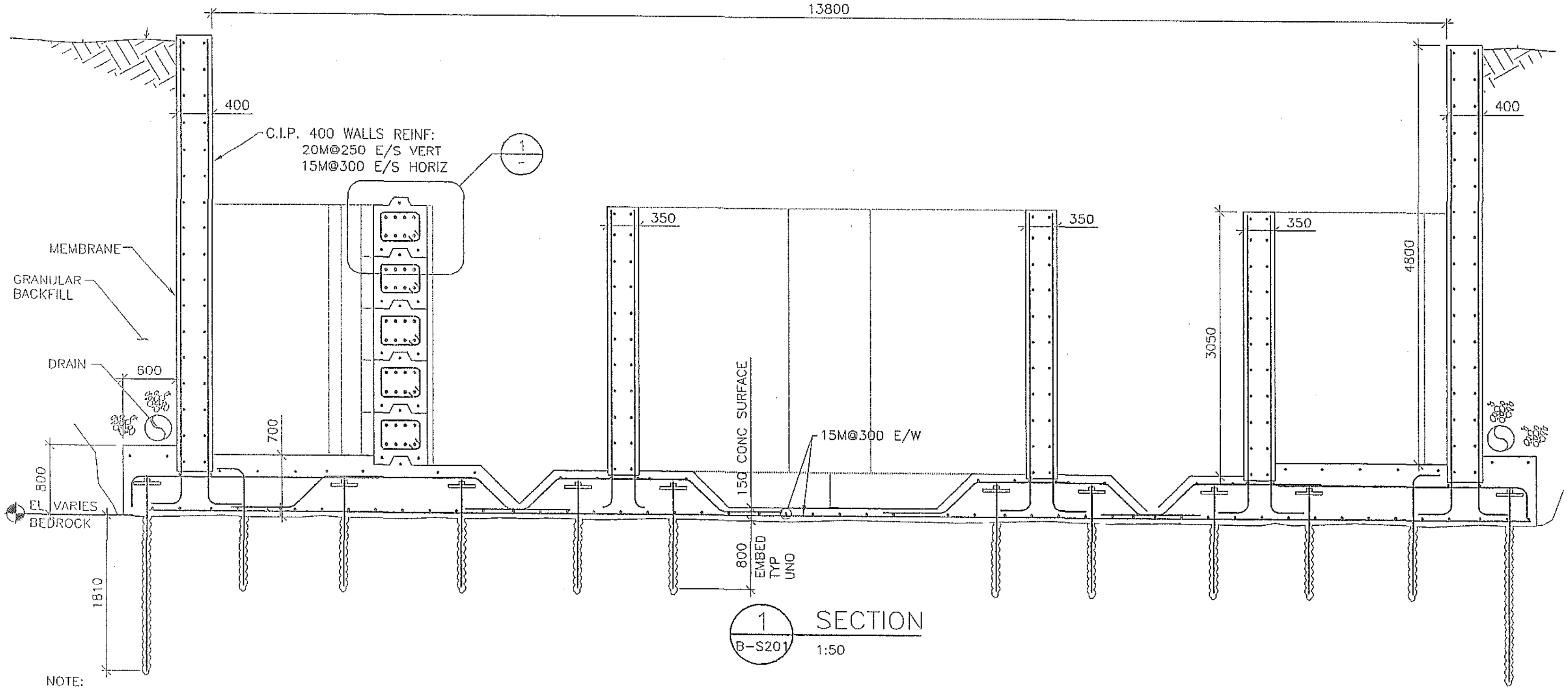
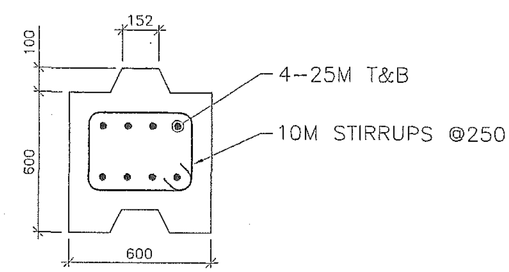


1 B-S201 SECTION 1:50

NOTE:
- CONCRETE C.I.P. WALLS : 45MPA
- CONCRETE REMOVABLE LOGS : 45MPA
- CONCRETE SLAB ON BEDROCK : 45MPA c/w WEARING SURFACE
- CONCRETE SUSPENDED SLAB : 30MPA REFER TO PLAN FOR THICKNESS AND REINFORCEMENT

PRELIMINARY CONCEPTUAL ONLY
NOT FOR CONSTRUCTION



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ISSUES		
No.	DATE	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM - STRUCTURAL 2015
411 DUNSMUIR STREET NANAIMO BC V9R 0E4
CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd. Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

AUXILIARY SPILLWAY SECTION THROUGH LABYRINTH

DRAFTED: BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No.: 0017-276	CLIENT DRAWING No.: n/a
SCALE: AS SHOWN	PERMIT No.: n/a
HEL DRAWING No.: B-S301	REVISION: A

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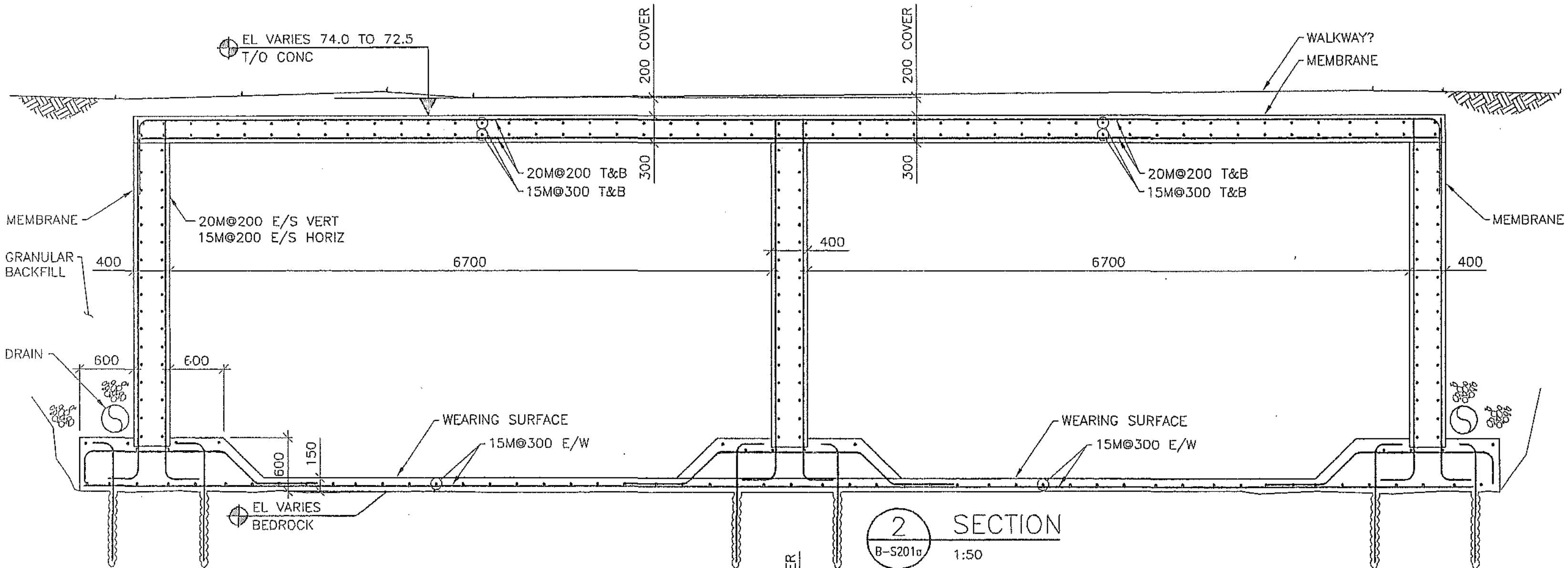

SECTION 2 (B-S201a)
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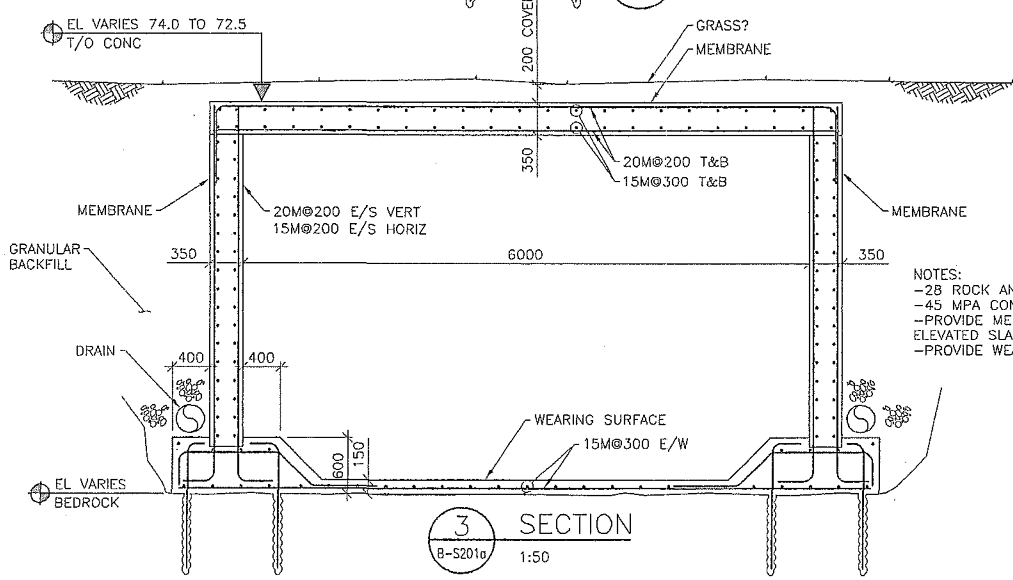

SECTION 3 (B-S201a)
1:50

NOTES:
- 28 ROCK ANCHORS
- 45 MPA CONCRETE
- PROVIDE MEMBRANE TO EXTERIOR OF WALLS AND ELEVATED SLAB
- PROVIDE WEARING SURFACE FOR SLAB ON GRADE

ISSUES		
No.	DATE	ISSUED FOR

SUB CONSULTANT

COLLIERY DAM - STRUCTURAL 2015

411 DUNSMUIR STREET NANAIMO BC V9R 0E4

CITY OF NANAIMO

HEROLD ENGINEERING
3701 Shenton Rd, Nanaimo, BC V9T 2H1
Tel: 250-751-8558 Fax: 250-751-8559
Email: mail@heroldengineering.com

AUXILIARY SPILLWAY
BOX CULVERT
DETAILS

DRAFTED BOG	DESIGNED
DRAFTING REVIEW	DESIGN REVIEW
PROJECT No. 0017-276	CLIENT DRAWING No. n/a
SCALE AS SHOWN	PERMIT No. n/a
HEL DRAWING No. B-S302	REVISION A

DESTROY ALL DRAWINGS SHOWING PREVIOUS REVISION

TABLOID 11" x 17"

File: U:\Temporary Work\0017-276 Colliery Dam Spillway Temp\15-06-25 Revision\0017-276 B-S302.dwg Plot Time: Jun. 25, 15 2:57 PM User: Brendan O'Grady

APPENDIX B
Raising Walls of Existing Spillway – Basis (Exclusions and Limitations)

1.1.1 Raising Walls of Existing Spillway - Basis (Exclusions and limitations)

1.1.1.1 Basis of Estimate

The cost estimate has been prepared based on the drawings prepared by Herold Engineering titled "Spillway Wall Remediation Option – North & South Walls", dated May 2015, and "Spillway Wall Remediation Option – Footbridge Replacement", dated May 2015 found in Appendix A.

It is noted that subsurface site conditions remain to be determined and design development is ongoing. The current concepts have been analyzed as if the designs were frozen and details have been inferred from those concepts. Assuming that the designs do not change in scope, but are merely developed into further detail, we can expect accuracy on the order of -20 / + 50%.

Given the current uncertainties, this estimate may be used for initial comparison of options but should not be used for final budgeting purposes.

The following paragraphs describe the assumptions, limitations, inclusions and exclusions of the estimate.

1.1.1.2 Available Site Information

There is no borehole or geotechnical subsurface exploration results available along the proposed auxiliary spillway alignment. Conditions have been extrapolated from site visits and information available from past studies and investigations, as discussed in Section 3.2.1 and 3.2.2. Completion of a geotechnical investigation program would be essential if the City desires to reduce the uncertainties associated with the cost of the project. Ground conditions will have some impact on the spillway channel rehabilitation and pedestrian bridge foundation construction costs.

1.1.1.3 Groundwater during Construction

Some minor seepage from the lake near the spillway inlet is not anticipated, but it is expected this can be removed from the foundation and trench with small pumps.

1.1.1.4 Vegetation

Vegetation removal adjacent to the existing spillway and pedestrian bridge will be required.

1.1.1.5 Access

Access is expected to be from both the north and south side of the existing spillway. The existing parking lot accessed from Sixth Street is approximately 200 m to the north of the existing spillway along an asphalt path. The Harewood Mines Road to the south of the spillway is accessed via a path consisting of approximately 170 m of gravel pedestrian path and approximately 90 m of asphalt path. It is anticipated that the bulk of construction materials and equipment can be mobilized via the parking lot, however some limited access may be required via the trail network on the other side of the existing spillway. This will require:

- A laydown area and small office site at the existing parking lot approximately 200 m to the north of the site;

- Removal and reinstatement of asphalt (the existing asphalt will be damaged by trucks during construction).

1.1.1.6 Disruptions

No allowances have been made to account for issues such as work stoppages and other restrictions beyond a contractor's control. The estimate contemplates unrestricted access to the site during normal working hours.

1.1.1.7 Labour Agreements

The estimate contemplates an "open site" with no restrictions on union or non-union labour.

1.1.1.8 Project Management, Construction Management and Quality Control

The estimate is provided from the perspective of a contractor bidding on the project, who will provide Site and Construction Management for the benefit of the contractor. Project Management, for the benefit of the owner, will be provided by the City and is not included in the estimate.

Standard MMCD quality control is included in the estimate. Owner-side quality assurance is not.

1.1.1.9 Environmental Protection during Construction and Permitting

Sediment fencing is included to control surface runoff only.

1.1.1.10 Overhead and Profit

The estimate assumes a competitive tendering process in the Nanaimo marketplace. It includes a 15% allowance for overhead and profit, in addition to the bare direct and indirect costs for equipment, labour and materials.

1.1.1.11 Disposal

It is expected that only minor surplus material will be generated from excavating.

1.1.1.12 Slope Treatments and Visual Enhancements

No allowance has been made for vegetated covering of the concrete walls.

1.1.1.13 Asphalt

No allowance has been made for damage to, or re-instatement of the existing asphalt pathway.

1.1.1.14 Schedule

The current schedule contemplates mobilization and completion within a two-month period, during the drier months of the summer. Working into the wetter months would incur additional costs and double the construction period. Delaying the work until 2016 would probably incur additional costs.

Work would normally occur Monday to Friday from 7 am to 5:30 pm, with occasional night or weekend work to accommodate discrete events or conditions.

Forest fire season presents a risk to the schedule, since work will occur in the forest and thus subject to any bans issued by the Ministry of Forests or local Fire Department.

1.1.1.15 Rebar

As the detailed design is not yet complete, the estimate contemplates a rebar density of 75 kg/m3.

1.1.1.16 Permanent Fencing

No allowance for fencing along the spillway walls has been included.

1.1.1.17 Value engineering and other options not contemplated in the estimate

- Vegetative slope treatments for aesthetics;

1.1.1.18 Contingency and Risk

A contingency has not been included in the estimate.

o:\final\2013\1447\13-1447-0516\1314470516-025-r-reva\appendix b\appendix b - basis of estimate ex spill.docx

APPENDIX C
Draft Design Build Performance Requirements

LOWER COLLIERY DAM, NANAIMO

OVERTOPPING PROTECTION FACILITY

PRELIMINARY DESIGN AND CONSTRUCTION SPECIFICATIONS

TABLE OF CONTENTS

1. INTERPRETATION

A. **Scope**

This document provides the design requirements for the Dam Overtopping Protection facility, which includes the following components;

1. Overtopping protection of the dam crest;
2. Overtopping protection for the downstream face of the dam, and abutment contacts (if necessary);
3. Erosion protection in the vicinity of the downstream toe of the dam;
4. Re-grading of the dam and dam crest in order to meet the hydraulic requirements of the facility;
5. Temporary works (roads, work areas, and clearing requirements, etc) as required in order to construct the facility.
6. Maintenance or replacement of park features, aesthetics and landscape, trails.

The facility does not include a new bridge over the existing spillway and improvements to the existing spillway, which will be carried out by Others.

B. **Intent**

This document provides the design and construction requirements for the Dam Overtopping structure including:

1. the technical and performance requirements for the facility;
2. the environmental requirements to be observed during the construction of the facility;
3. recreation and aesthetic requirements for the completed facility.

C. **Reference Documents**

All design shall be carried out to internationally recognized standards, including the latest version or edition of the following references:

1. Canadian Dam Association, Dam Safety Guidelines (2013);
2. FEMA Technical Manual – Overtopping Protection for Dams, May 2014;
3. Relevant ASTM Specifications, in particular ASTM D7276-08 (Standard Guide for Analysis and Interpretation of Test Data for Articulating Concrete Block (ACB) Revetment Systems in Open Channel Flow); and D7277 -08 (Standard Test Method for Performance Testing of Articulating Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow).

D. **Project Data**

The following reports provide background information relevant to the design and construction of the Dam Overtopping protection facility.

1. Golder Associates Ltd. 2014a. "Factual Geotechnical Report on Colliery Dams Remediation Project", April, 2014.
2. Golder Associates Ltd. 2014b. Report on "Colliery Dams– Dam Stability", July 2014.

3. Golder Associates Ltd. 2014c. Report on "Colliery Dams – Hydraulics, Hydrology and Dam Breach Analysis", July 2014.

4. Golder Associates Ltd. 2014d. Report on "Colliery Dams – Remediation Options", August 2014.

2. DESIGN PRINCIPLES

A. The purpose of the Dam Overtopping protection facility is to increase the flood routing capacity of the Lower Colliery Dam. The total required flood routing capacity (inflow design flood, IDF) of the Lower Dam is 144 m3/sec, part of which will be contained within the spillway and part of which will be routed over the dam. Based on analyses carried out for a re-shaped downstream dam surface (Golder 2014d), the flow over the dam in the IDF for that design is approximately 45.4 m3/sec. This value may differ depending on the final contouring of the dam crest.

The purpose of this Specification is to address the requirements for the Dam Overtopping Protection in order to provide protection to the dam to resist erosion caused by that portion of the flow which passes over the dam.

B. The design-build contractor shall demonstrate, through comprehensive geotechnical and hydraulic analyses, that the performance requirements and tolerances for the facility will be met over the Design Service Life of all components of the facility.

C. The design-build contractor shall demonstrate, through examples of previous successfully completed dam projects (which have characteristics similar to the Lower Colliery Dam) to suitability of the proposed Dam Overtopping protection design for the Lower Dam.

D. The design-build contractor shall carry out analyses and model testing to verify the suitability of the proposed design. The design shall be demonstrated to provide sufficient hydraulic capacity to route the design storm per the requirements stated herein. For storm events up to the design storm, the overtopping protection design shall be demonstrated to adequately resist failure which could involve, but is not limited to the following mechanisms:

1. Sliding of the overtopping protection down the embankment slope;

2. Scour of the overtopping protection approach and exit channels.

3. Scour of the overtopping protection throughout the entire area of protection, including the embankment crest, slope, and toe.

4. Undermining of the overtopping protection at the perimeter of the armoring on the embankment crest, abutments, and toe.

5. Uplift of the overtopping protection due to hydrostatic and hydrodynamic forces.

6. Piping of embankment materials below the overtopping protection.

7. Damage to the overtopping protection due to debris impact.

8. Loss of components of the overtopping protection (anchors or cables) which provide resistance to movement and uplift.

Engineering analyses shall be completed that demonstrates resistance to these failure mechanisms in both present and future conditions. Therefore the potential for settlement and movement of the embankment should be determined. Critical values for embankment movement which will make the overtopping protection unsuitable shall be provided. Critical values for the resisting components which will make the overtopping protection unsuitable shall also be provided.

E. The Design Service Life of the facility shall be a minimum of 75 years.

F. Overtopping Protection should be installed on a dam surface that has been re-graded to produce smooth and uniform flow across the overtopping protection and to minimize hydraulic turbulence.

1. It is anticipated that the dam crest and downstream face of the dam will be contoured to concentrate flow in the central part of the dam and direct the flow away from the dam abutments.

2. Where modifications are made to the dam crest, the crest elevation shall not be lowered below the current minimum crest elevation (El 73.4 m).

G. Design of the Overtopping Protection should be carried out to meet the stability requirements of the Lower Dam, including;

1. The addition of Overtopping Protection for the dam shall not adversely affect the seismic performance of the dam;

2. The installation of Overtopping Protection for the dam (re-grading and installation of erosion protection elements) shall not adversely affect the dam stability (shallow and deep slope stability), and shall not cause dam settlement, displacement or damage to the dam and concrete core.

3. The addition of Overtopping Protection for the dam shall not adversely affect the groundwater conditions (phreatic surface, seepage flows, etc) within the dam, or the downstream drainage collection and monitoring system within the dam.

4. The design of Overtopping Protection shall consider the stability of the dam during a dam overtopping event.

H. An energy dissipation structure or an extension of the armoring at the downstream toe is needed to minimize scour from the hydraulic jump which is expected to form at the downstream toe of the dam.

I. Where articulated concrete blocks are to be used for Overtopping Protection,

1. Block stability during the design storm in to be in accordance with manufacturer's design criteria.

2. Manufacturer's design criteria shall be developed in accordance with ASTM D7276 and D7277.

3. Requirements for an underdrain system, filtration, separation and subgrade preparation shall be addressed.

4. Articulated concrete block material and manufacturing processes shall meet ASTM D6684.

5. Articulated concrete block, cables, and anchors shall have a minimum design life of 75 years. Materials shall be compatible with the site conditions and the existing dam embankment materials.

6. Articulated concrete blocks should be placed on the smooth, re-graded dam surface in a way such as to minimize block protrusions.

7. Articulated concrete blocks shall be keyed into the subsurface at the upstream and downstream ends. The depth of embedment should be greater than the scour depths expected at the upstream and downstream ends of the overtopping protection during the design storm.

J. Where soil anchors are to be used with articulated concrete blocks as part of the Overtopping Protection, the following shall apply;

1. Articulated concrete block anchors extending into the embankment shall be designed using soil parameters anticipated during overtopping performance of the structure for the materials in the embankment. Anchor capacity should be reduced due to pore pressure development occurring

during saturated embankment conditions. Anchor performance shall be evaluated during positive and negative pressure fluctuations which will occur at the toe of the dam during a hydraulic jump.

2. Articulated concrete block anchors shall not impact the performance of the existing dam under normal or seismic conditions.

3. ENVIRONMENTAL REQUIREMENTS

A. The design-build contractor shall be responsible for environmental protection during all construction activities at all locations it performs work. Work locations may include, but are not limited to, the Work Site, contractor laydown areas and site access routes.

B. If in-stream works are contemplated, the design-build contractor will apply additional environmental controls as required. An on-site Environmental Monitor will be provided during all in-stream works.

C. No deleterious materials may enter any watercourse at any time.

D. All machinery working on the project is to be inspected and confirmed to be free of contaminants and in good working order prior to commencement of work.

E. All machinery working on or adjacent to water will be required to use non-petroleum vegetable oil based hydraulic fluids.

F. Imported construction materials must be confirmed to be clean and free from contamination prior to use.

4. CONSTRUCTION REQUIREMENTS

A. The design-build contractor shall design the works and develop construction means and methods to prevent damage to existing structures.

B. The design-build contractor is responsible for selecting the appropriate machinery and equipment that considers the site conditions, character of materials, facility usage and existing structures that may be encountered during construction activities.

5. RECREATION AND AESTHETIC REQUIREMENTS

A. Maintenance or replacement of park features, aesthetics and landscape, trails, public access including access for disabled persons on trails and to swimming, and service vehicle functions to the dam crest and any other existing park areas disturbed by construction.

B. Protection of existing trees, woods and vegetation outside of the core construction disturbance area, and re-vegetation of all non-paved or non-manicured disturbed areas to provide erosion control, habitat and park setting.

6. SUBMITTALS

A. The following submittals shall be provided with the preliminary design submission:

1. Preliminary geotechnical and hydraulic analyses to demonstrate the conformance of the design to these Design Requirements.

2. Prior to mobilisation to site, the design-build contractor will be required to develop an Environmental Protection Plan (EPP) for review and acceptance. The EPP shall present the procedures by which the design-build contractor shall establish and maintain quality control for environmental protection of all items of the work, and the means and methods that will be used to

comply with the project Environmental Management Plan (EMP) and all required permit conditions. The EPP shall address all construction activities.

3. Prior to mobilisation to site, the design-build contractor will provide a comprehensive Construction Work Plan that details the means and methods for completion of the construction work.

4. Provide a park, trail, re-vegetation and recreation restoration site plan, grading plan and sections/profiles, planting concept plan, vegetation retention plan, and related written design rationale. Include related estimates for capital cost and for one year maintenance of all installed works and one year warranty in the overall project budget, and provide separate cost breakdowns for information. Both maintenance and warranty period shall be one year from the date of Substantial Completion. Costs included will be for all park, trail restoration and revegetation works by the design/build contractor including full supply of all hard and soft landscape, installation, and establishment watering and landscape maintenance to BC Landscape Standard levels (medium for park areas and background for slope areas).Documents describing the construction methodology, sequencing, equipment, materials and construction schedule shall be submitted to demonstrate conformance to these Requirements.

END OF SECTION

APPENDIX D
Visualizations of Auxiliary Spillway Design Concepts

DRAFT
28 MAY 2015

PROJECT	Colliery Dams Nanaimo, BC			
TITLE	Auxiliary Spillway to Harewood Creek Context Plan			
Golder Associates	PROJECT No. 1314470516		PHASE No. 2500	
	DESIGN	DC	24 June 15	SCALE: NTS	REV.
	CADD	----		Figure D-1
	CHECK	JG	25 June 15	
	REVIEW			

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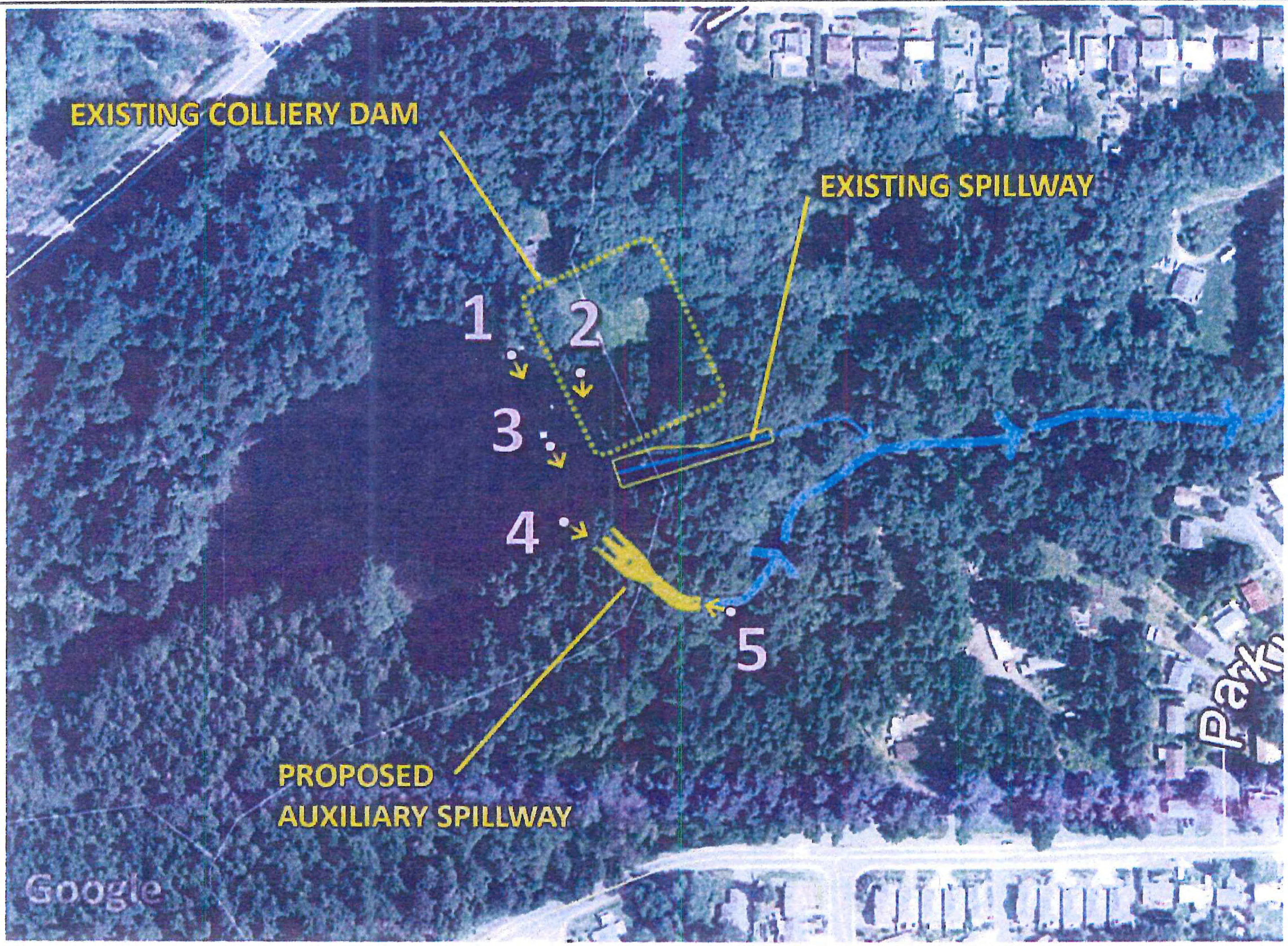

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TITLE	Auxiliary Spillway to Harewood Creek Illustration Key			
Golder Associates	PROJECT No. 1314470516			PHASE No. 2500
	DESIGN	DC	24 June 15	SCALE: NTS / REV.
	CADD	----		Figure D-2
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	REVIEW			

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28 MAY 2015

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View from across the lake

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PROJECT	Colliery Dams Nanaimo, BC			
TITLE	Auxiliary Spillway to Harewood Creek Anchored Channel Option 1			
Golder Associates	PROJECT No. 1314470516		PHASE No. 2500	
	DESIGN	DC	24 June 15	SCALE: NTS	REV.
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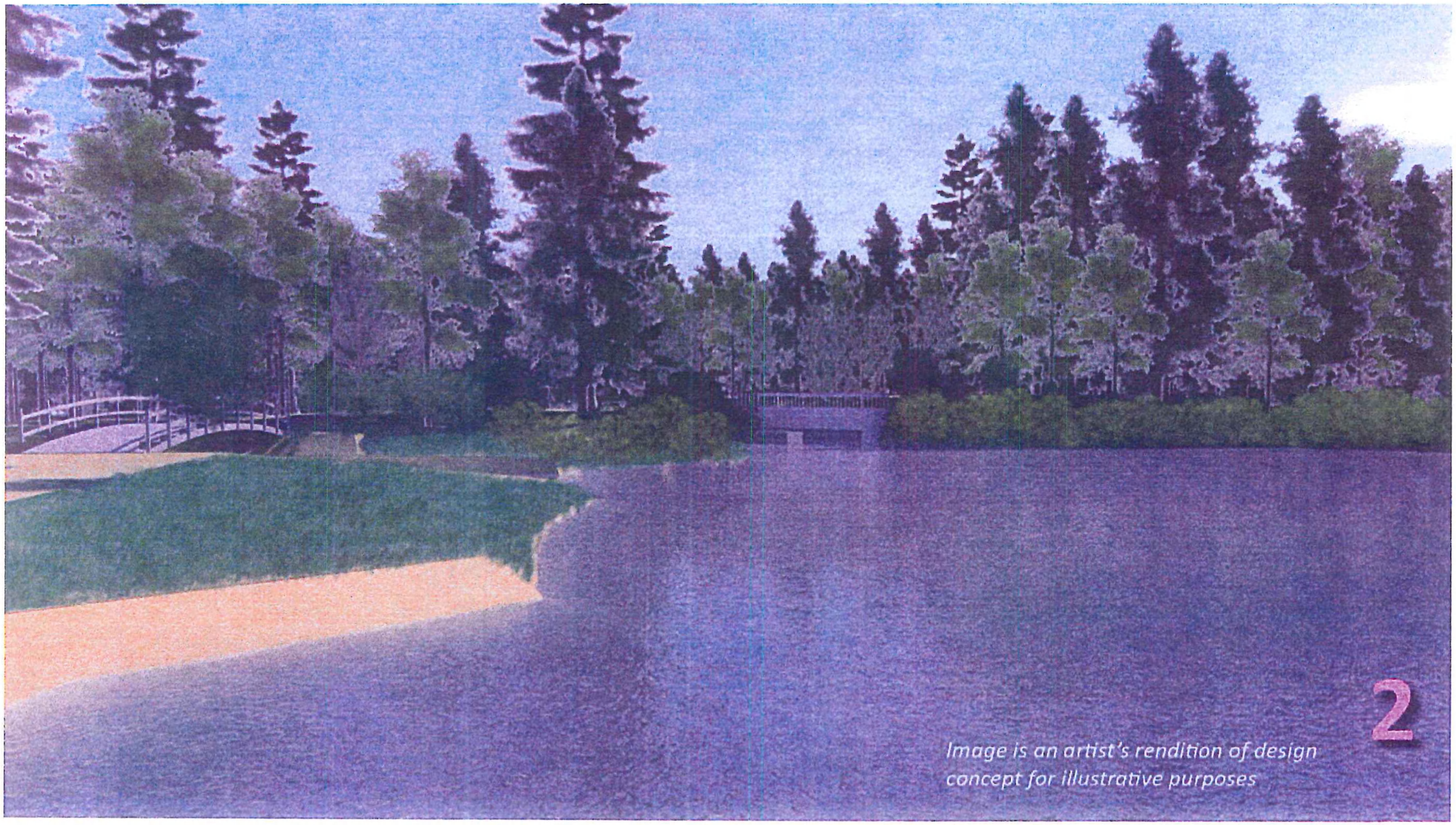

View from the lake

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28 MAY 2015

PROJECT	Colliery Dams Nanaimo, BC
TITLE	Auxiliary Spillway to Harewood Creek Anchored Channel Option 1

Golder Associates

PROJECT No. 1314470516			PHASE No. 2500	
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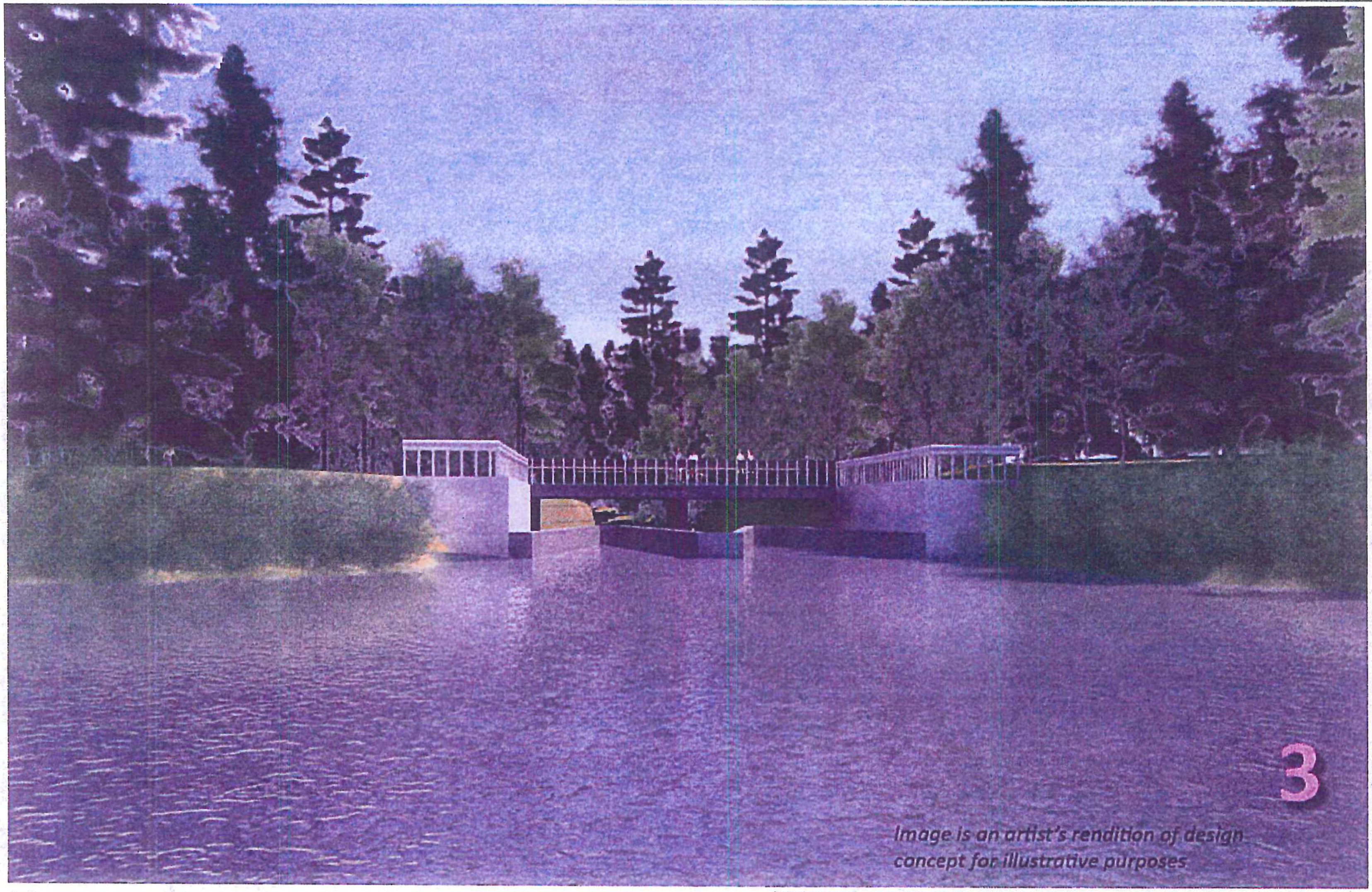

View approximately from the floating dock

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28 MAY 2015

PROJECT	Colliery Dams Nanaimo, BC				
TITLE	Auxiliary Spillway to Harewood Creek Anchored Channel Option 1				
Golder Associates	PROJECT No.	1314470516		PHASE No. 2500	
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	REVIEW				

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Areal view from the north

PROJECT	Colliery Dams Nanaimo, BC				
TITLE	Auxiliary Spillway to Harewood Creek Anchored Channel Option 1				
Golder Associates	PROJECT No.	1314470516		PHASE No. 2500	
	DESIGN	DC	24 June 15	SCALE: NTS	REV.
	CADD	----		Figure D-6	
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28 MAY 2015

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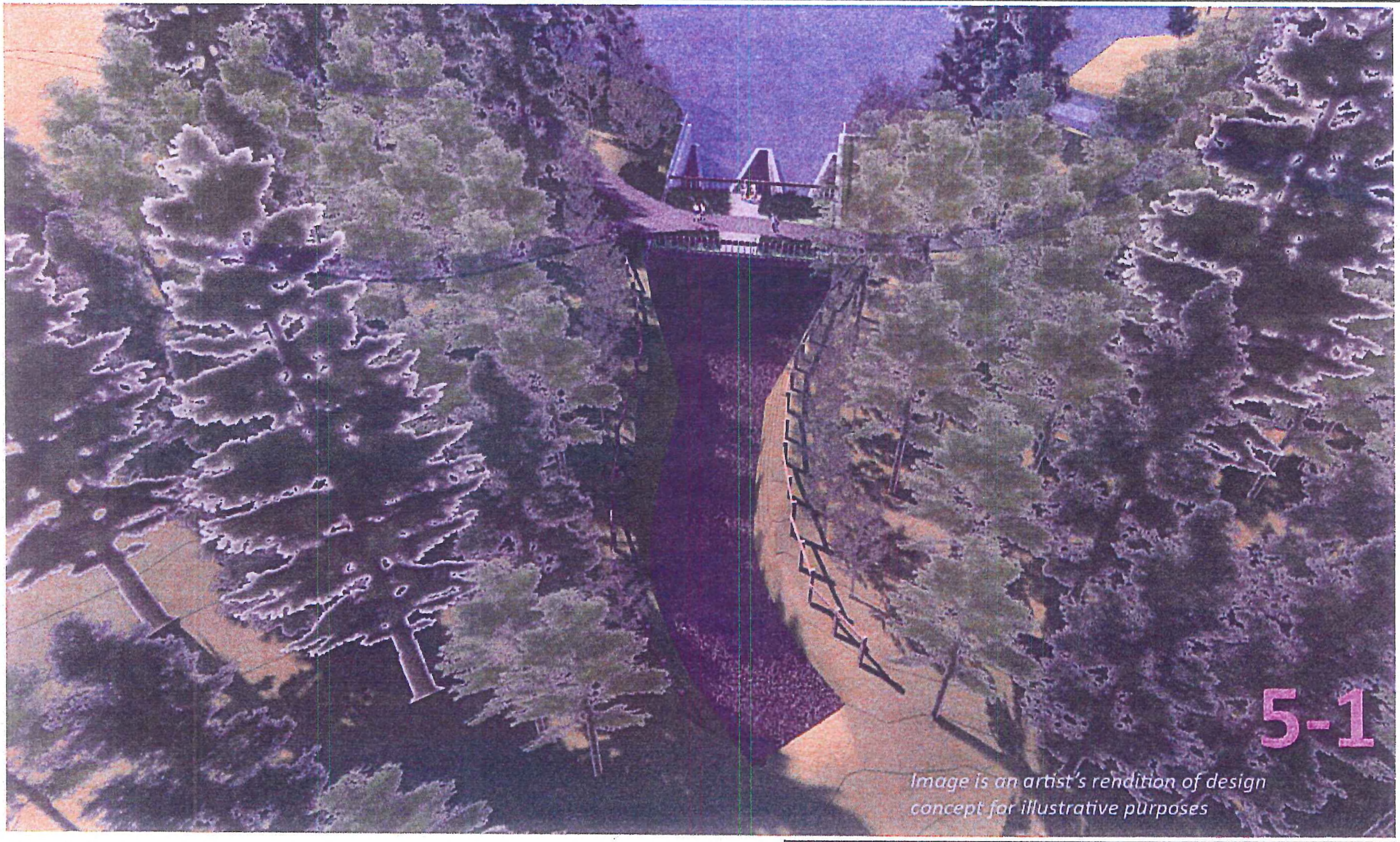

Areal view from the south

DRAFT
28 MAY 2015

PROJECT
Colliery Dams
Nanaimo, BC

TITLE
Auxiliary Spillway to Harewood Creek
Anchored Channel Option 1

Golder Associates

PROJECT No.	1314470516		PHASE No. 2500	
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Areal view from the north

PROJECT	Colliery Dams Nanaimo, BC
TITLE	Auxiliary Spillway to Harewood Creek Labyrinth / Box Culvert Open Channel Option 2

PROJECT No.	1314470516		PHASE No. 2500	
DESIGN	DC	24 June 15	SCALE: NTS	REV.
CADD	----		Figure D-8	
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Golder Associates

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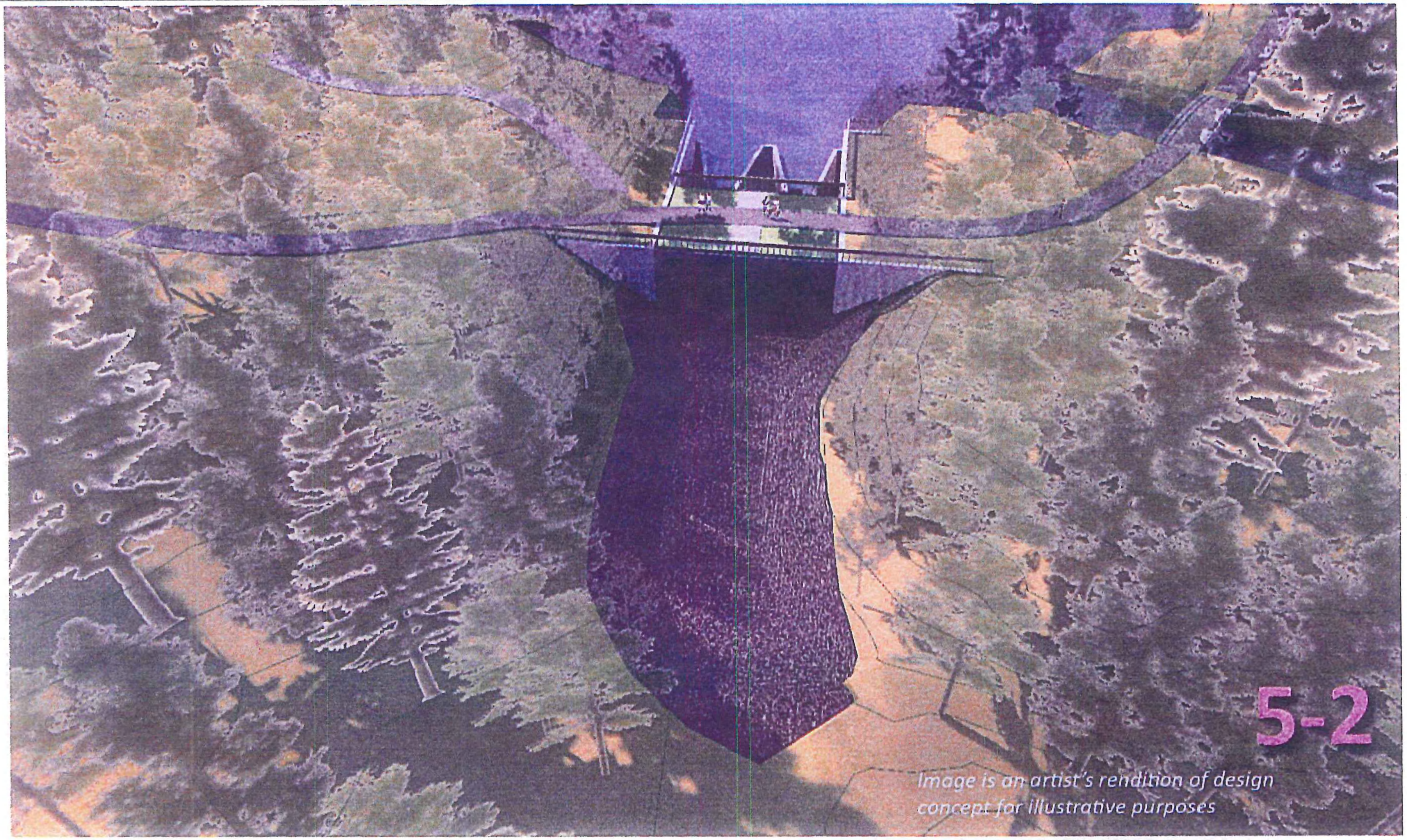
28 MAY 2015



Areal view from the south

PROJECT	Colliery Dams Nanaimo, BC
TITLE	Auxiliary Spillway to Harewood Creek Labyrinth / Box Culvert Open Channel Option 2

Golder Associates					
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DESIGN	DC	24 June 15	SCALE:	NTS	REV.
CADD	----		Figure D-9		
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28 MAY 2015

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Areal view from the north

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28 MAY 2015

PROJECT	Colliery Dams Nanaimo, BC				
TITLE	Auxiliary Spillway to Harewood Creek Labyrinth / Box Culvert and Cover Option 3				
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	REVIEW				

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Areal view from the south

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28 MAY 2015

PROJECT	Colliery Dams Nanaimo, BC				
TITLE	Auxiliary Spillway to Harewood Creek Labyrinth / Box Culvert and Cover Option 3				
Golder Associates	PROJECT No.	1314470516		PHASE No. 2500	
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APPENDIX E
Auxiliary Spillway – Basis (Exclusions and Limitations)

1.1.1 Auxiliary Spillway - Basis (Exclusions and Limitations)

1.1.1.1 Basis of Estimate

The cost estimate has been prepared based on the design concept outlined in the report, but it must be noted that subsurface site conditions remain to be determined and design development is ongoing. The current concepts have been analyzed as if the designs were frozen and details have been inferred from those concepts. Assuming that the designs do not change in scope, but are merely developed into further detail, we can expect accuracy on the order of -20 / + 50%.

Given the current uncertainties, this estimate may be used for initial comparison of options but should not be used for final budgeting purposes.

The following paragraphs describe the assumptions, limitations, inclusions and exclusions of the estimate.

1.1.1.2 Available Site Information

There is no borehole or geotechnical subsurface exploration results available along the proposed auxiliary spillway alignment. Conditions have been extrapolated from site visits and information available from past studies and investigations, as discussed in Section 3.2.1 and 3.2.2. Completion of a geotechnical investigation program would be essential if the City desires to reduce the uncertainties associated with the cost of the project.

It has been assumed that a layer of organic material overlays glacial till, which are in turn underlain by bedrock, varying between one and five metres below the surface. The rock is assumed to be competent and require no temporary support if exposed in the walls of the excavation and no major treatment to cracks in the invert if exposed.

It is anticipated that the existing ground and bedrock can serve as a plug, or "natural cofferdam" while work downstream in the new channel occurs. The plug would be excavated and removed during the final stage of construction.

1.1.1.3 Groundwater during Construction

Some seepage from the lake near the inlet is anticipated, but it is expected this can be managed and removed from the foundation and trench with small pumps. Groundwater and surface water at the spillway outlet will be filtered with a series of drain rock and filter fabric decanting berms, prior to draining into Harewood Creek. No allowance has been included for cut offs or similar measures to control seepage.

1.1.1.4 Alignment and Cross Sections

The horizontal and vertical alignments are shown on Figures 6a through 11b and on drawing C-S201 of Appendix A. These can generally be subdivided into five cross-sections:

- Labyrinth Weir (intended to control flows and dissipate energy in the peak event);
- Box Culverts (intended to provide a pathway and natural look over the channel);

- Soil-anchored channel (intended to convey peak flows in a narrow channel, thus minimizing footprint and visual impact near the lake);
- Rip-rap channel (intended to convey peak flows at minimal cost); and
- Rip-rap swale (intended to limit erosion during occasional non-peak flows).

The alignment daylights into Harewood Creek, at which point no slope treatment or energy dissipation measures are anticipated due to the curved alignment of the downstream channel and flow velocities.

1.1.1.5 Vegetation

It is estimated that 25-40 trees will need to be removed to make way for both the spillway alignment and construction machinery access. These trees are anticipated to be left onsite to decompose naturally, and no sale value has been assigned. It should be noted that the actual number of trees removed will be a function of the solution selected. For example, the use of box culverts necessitates the use of larger heavy equipment with larger clearance requirements.

1.1.1.6 Access

It is anticipated that the site will be accessed from Harewood Mines Road, via a narrow gravel and paved path system. Providing construction equipment access will require:

- Removing some trees along the perimeter of the path;
- Removing and reinstating an existing wooded pedestrian bridge across a tributary to Harewood Creek;
- Bridging the creek with a combination of a CSP culvert, drain rock, filter fabric and temporary structural fill. This will prevent excavation in the creek bottom, and all but eliminate sediment deposition. It will ensure that flow remains unrestricted. However, in the event that DFO requires the crossing span the wetted perimeter of the creek, a temporary bridge may be required complete with additional foundation work and tree-cutting along the access path;
- Closing the south side of the existing spillway and the path to Harewood Mines Road to the public for the duration of construction; and
- The use of the gravel parking area on Harewood Mines Road as a laydown area for parts and some equipment, complete with a site trailer. This parking area will also likely be used for staging dump trucks entering and leaving the work site.

1.1.1.7 Disruptions

No allowances have been made to account for issues such as work stoppages and other restrictions beyond a contractor's control. The estimate contemplates unrestricted access to the site during normal working hours.

1.1.1.8 Labour Agreements

The estimate contemplates an "open site" with no restrictions on union or non-union labour.

1.1.1.9 Project Management, Construction Management and Quality Control

The estimate is provided from the perspective of a contractor bidding on the project, who will provide Site and Construction Management for the benefit of the contractor. Project Management, for the benefit of the owner, will be provided by the City and is not included in the estimate.

Standard MMCD quality control is included in the estimate. Owner-side quality assurance is not.

1.1.1.10 Environmental Protection during Construction and Permitting

Sediment fencing is included to control surface runoff only. A floating filter dam and/or bubble curtain is included to limit the impact on fish in the lake during removal of the upstream plug upon the completion of the project.

Compliance with environmental regulations and best practices is included to the extent known. Pursuit of and adherence to project-specific fisheries or other environmental permits are not included but are expected to be required. If authorization were required to remove the upstream plug or install fish curtains to facilitate blasting, this could engender further costs and risks to the schedule.

1.1.1.11 Overhead and Profit

The estimate assumes a competitive tendering process in the Nanaimo marketplace. It includes a 15% allowance for overhead and profit, in addition to the bare direct and indirect costs for equipment, labour and materials.

1.1.1.12 Disposal

It is expected that any surplus material generated from excavating (i.e., the bulk of the excavation) will be hauled offsite and disposed in the Nanaimo area.

1.1.1.13 Slope Treatments and Visual Enhancements

No allowance has been made for vegetated covering of the rip rap or shotcrete walls. Numerous options can be explored at later stages, such as spraying growing medium from Denbow, Hilfiker or other specialty suppliers. Natural wood debris can be placed in or around the shotcrete flume.

1.1.1.14 Asphalt

The existing asphalt pathway crossing the proposed spillway alignment will be removed and reinstated over the new box-culvert crossing. Asphalt damaged during trucking and equipment access operations will be removed and reinstated (likely extending from the existing bridge over the existing spillway, to the junction southwest of the new spillway). This will result in little if any net gain or loss in the length of asphalt path system.

1.1.1.15 Schedule

A preliminary construction schedule was contemplated at the time the cost estimate was developed. The ideal construction window is during the drier season from July to October. The work is anticipated to take approximately 3 months to complete (if constructed during the summer/ early fall months) plus an additional 1 month for mobilization and demobilization (2 weeks at the start and 2 weeks at the completion of construction). If constructed during the winter months, the project would likely take 6 months to complete. Delaying the work until 2016 would probably incur additional costs.

Work would normally occur Monday to Friday from 7 am to 5:30 pm, with occasional night or weekend work to accommodate discrete events or conditions.

Forest fire season presents a risk to the schedule, since work will occur in the forest and thus subject to any bans issued by the Ministry of Forests or local Fire Department.

1.1.1.16 Rebar

As the detailed design is not yet complete, the estimate contemplates a rebar density of 75 kg/m3 in the weir.

1.1.1.17 Channel Bottom

The estimate does not contemplate the need for a uniform channel bottom, and some variations are anticipated owing to the minimum depth required for drilling and blasting.

1.1.1.18 Shotcrete Walls

For the Anchored Channel Option, the estimate contemplates conventional shotcrete and soil nail shoring over the full depth of the excavation.

1.1.1.19 Permanent Fencing

Budget pricing has been included for wood post fencing over the box culverts (parallel to the pathway) and along the sides of the new shotcrete channel (for applicable options).

1.1.1.20 Value engineering and other options not contemplated in the current estimate

- Vegetative slope treatments for aesthetics;
- Possible options to replace rip-rap with other slope treatments; and
- Using the timber generated onsite to generate visually pleasing features.

1.1.1.21 Contingency and Risk

A suggested contingency of 20% has been added to allow for items, conditions or events for which the state, occurrence or effect is uncertain, and which are expected to result in additional costs. These include but are not limited to planning and estimating errors, minor price fluctuations, and minor design developments. The contingency is part of the estimate, and is expected to be expended.

The contingency does not include major scope changes such as end product specifications, capacities, sizes, or locations; extraordinary events such as strikes and civil disturbances; management reserves; or escalation and currency effects.

1.1.1.22 Notes

Items which should be considered while evaluating the options include:

- Little or no information exists about the subsurface conditions or location of the bedrock horizon. Potential impacts of ground conditions that differ from what was assumed include but are not limited to:
- A higher bedrock horizon could require additional blasting;
- A lower bedrock horizon could reduce the stability of the slopes during construction and thus increase the amount of material to be excavated;
- The balance of topsoil, overburden and bedrock, combined with landscaping and aesthetic requirements, may alter the amount of material that must be disposed of or imported from offsite;
- Given the desire for a natural appearance and lack of flows outside of the PMF, no rip-rap has been imported at present and armouring is limited to the rock that has been generated onsite (with surplus rock disposed of offsite);
- Discovery of coal slag beyond could increase disposal costs;
- Groundwater inflows, if greater than expected, could significantly increase the amount of dewatering required and thus the construction cost;
- A longer construction schedule could push overheads up, and a late start pushing construction into the winter months could significantly increase costs;
- Longer, higher, deeper or more visually appealing weirs, tunnels or surface treatments would have increased costs;

- If tree cutting is further restricted, reduced working room and access road width could result in lower productivities and increased costs;
- Site security (beyond what is required to protect equipment and seacans from everyday thieves, or prevent the general public from getting hit by trucks) is not included;
- We have assumed that Harewood Creek, south of the lake, can be bridged with a combination of a CSP culvert, drain rock, filter fabric and temporary structural fill. This will prevent excavation in the creek bottom, and all but eliminate sediment deposition. It will ensure that flow remains unrestricted. However, in the event DFO requires the crossing span the wetted perimeter of the creek, a temporary bridge may be required complete with additional foundation work and tree-cutting along the access path;
- We have assumed that a plug can remain upstream of the labyrinth weir, to be removed only upon commissioning of the channel. We have allowed for bubble curtains to protect aquatic life while blasting, and expect the plug removal can be conducted with a minimum of sediment deposition in the lake. However, if DFO requires a Fisheries Authorization and additional mitigation measures, cost increases and schedule delays could result;
- Geotechnical investigation program and detailed design have not been included; and,
- Public safety measures have not been addressed in detail at this stage.

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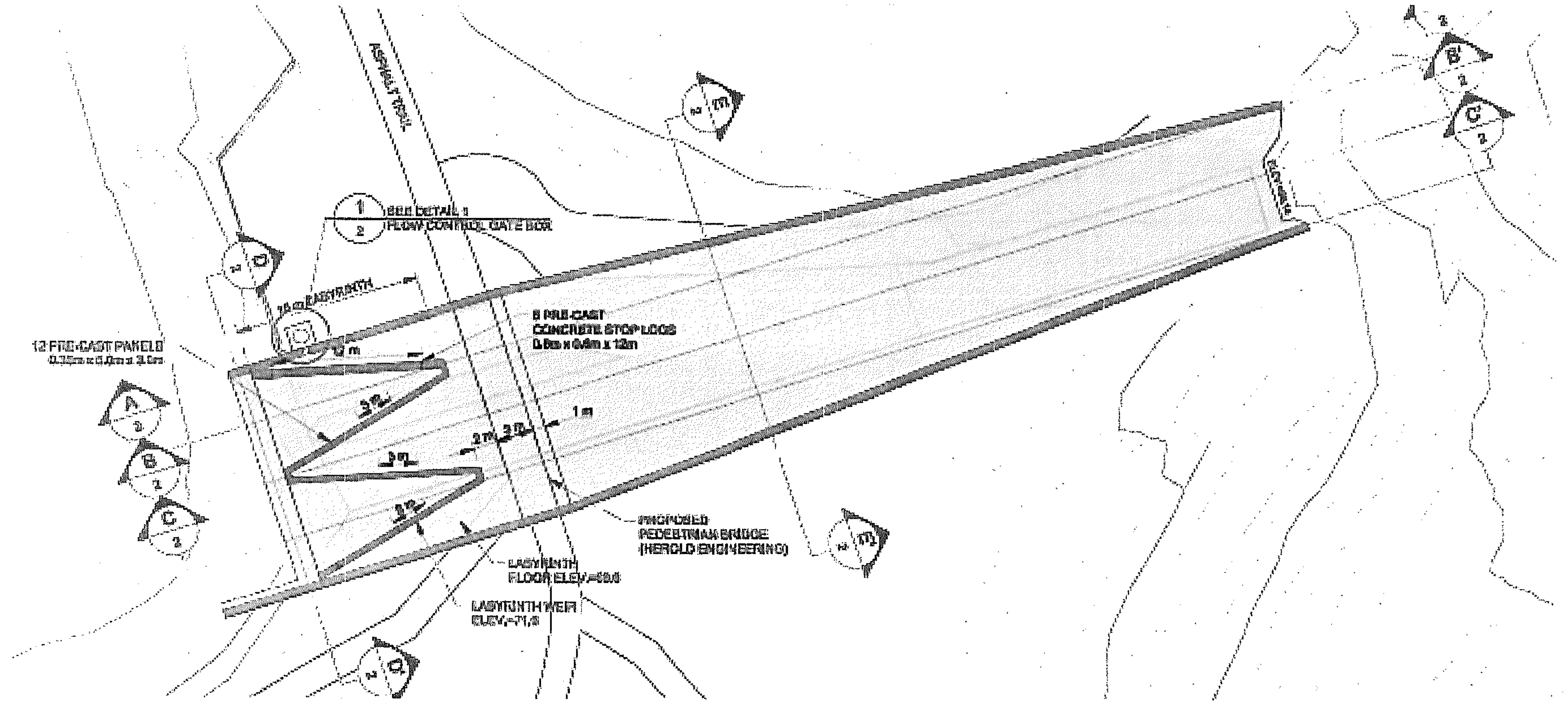
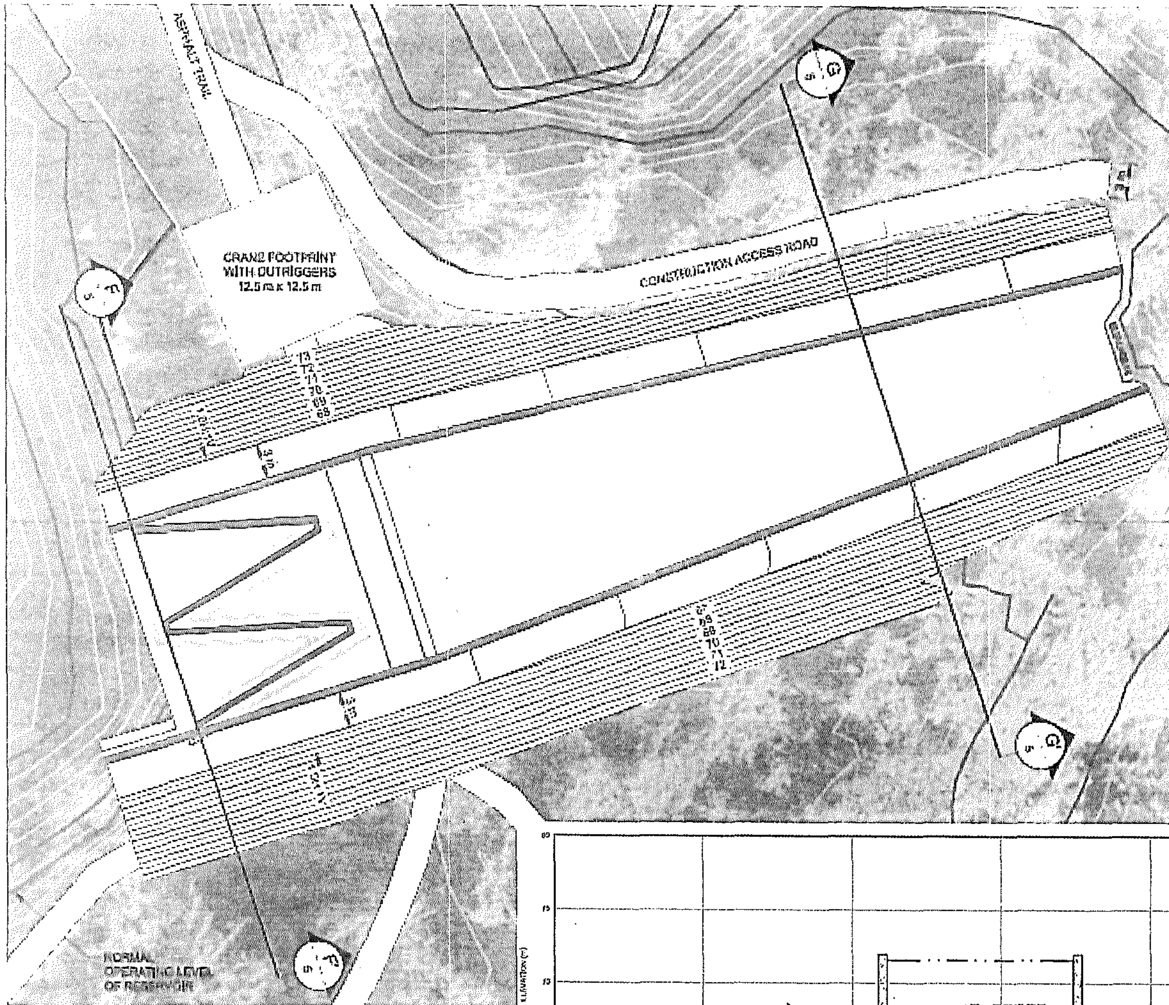
Lower Dam: Labyrinth Spillway Plan



- 18 m wide at spillway entrance tapering to ~10 m wide.
- Total labyrinth height 3 m – 3 of the walls comprised of 12 pre-cast concrete panels and 1 wall comprised of 5 pre-cast concrete stop logs.
- Stop logs enable controlled draw down of reservoir following seismic event. (or for repairs, etc)
- Low level outlet for dry season releases

ATTACHMENT C

Lower Dam: Labyrinth Spillway Excavation Plan and Section (18 m)

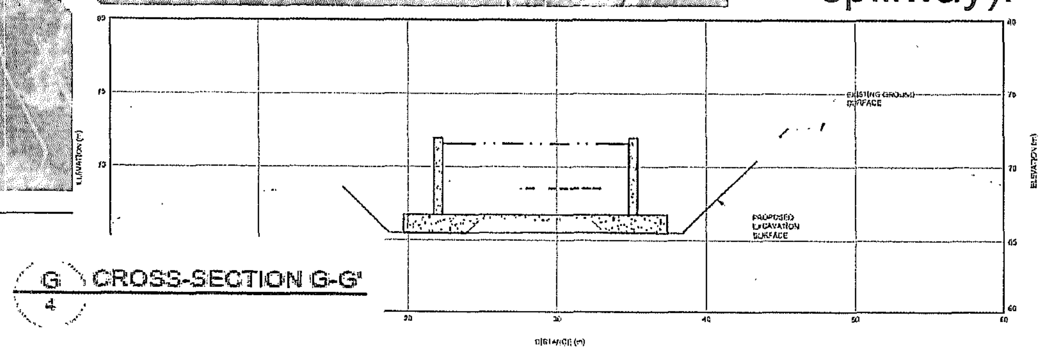


Construction Sequence

- Construct lab first
- Sectional removal and construction of spillway – starting from downstream

Footprint

- Loss of ~2050m^2 of habitat permanently (includes existing spillway footprint)
- Disturbing of habitat during construction – footprint ~2850m^2 (including existing spillway).

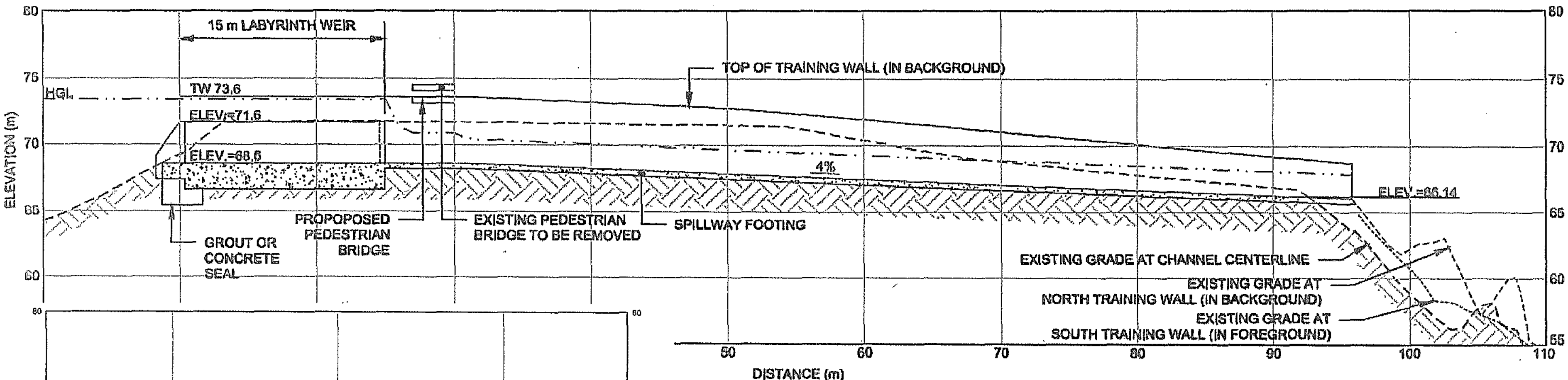


CROSS-SECTION G-G'

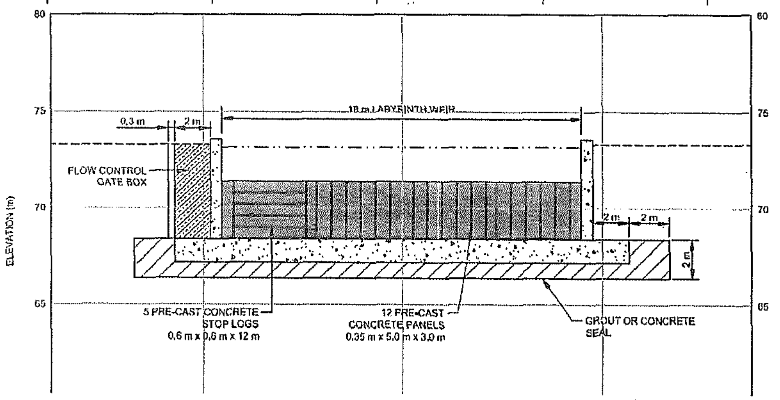
May 20, 2014

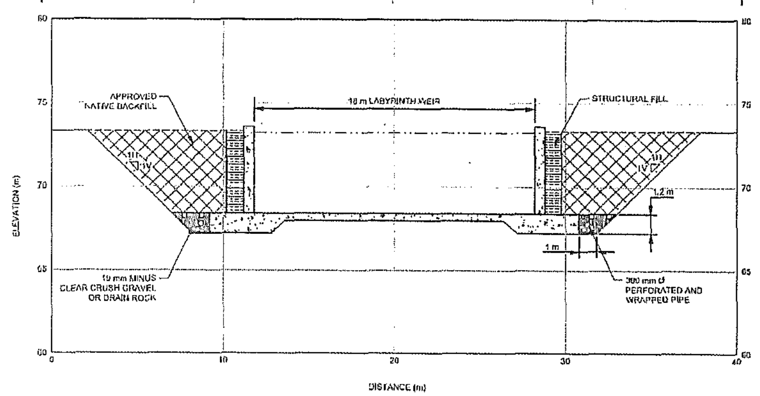
Golder Associates

Lower Dam: Labyrinth Spillway - Sections



CROSS-SECTION B-B'
SEE SCALE A

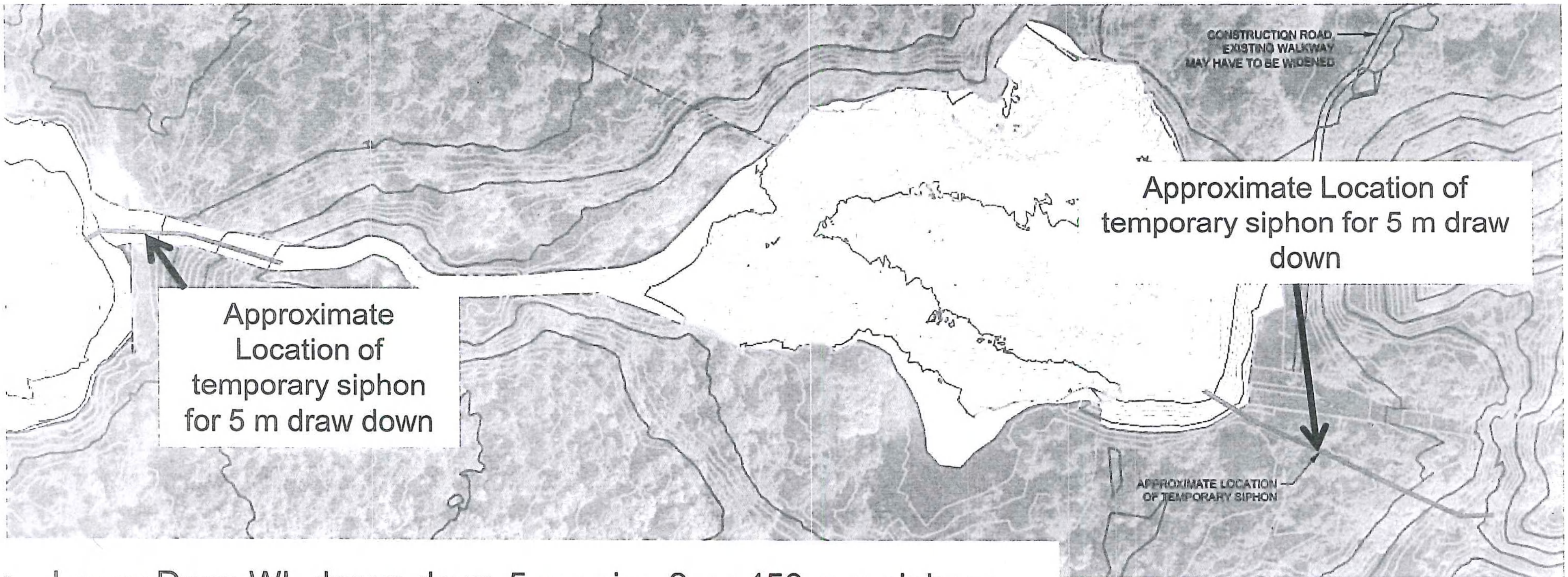




CROSS-SECTION E-E'

- Total Wall height 5 m at spillway entrance tapering to ~3 m high.
- Uncertainty of foundation materials – particularly beneath the weir
  - Excavation assumed to be half in rock and half in soil
- Grout or concrete seal required at spillway entrance and drainage along channel base.
- Heavy reinforced concrete walls and foundation

Lower Dam: Labyrinth Spillway Diversion and Draw Down of Reservoirs



- Lower Dam: WL drawn down 5 m using 2 ea 450 mm siphons.
- Middle Dam: WL drawn down 5 m using 2 ea 450 mm siphons
- Cofferdam required at the Lower Dam only.
- The ideal construction period is Jul-Aug-Sept and 2 siphons supply capacity that's more than 600% of anticipated base flow.
- Flood in excess of diversion capacity to be routed through construction works
  - Cannot pass water over concrete less than 72 hrs - to be addressed in EMP.