January 16, 2015 Reference No. 1314470516-022-L-Rev0

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

COLLIERY DAMS, NANAIMO BC
AUXILLIARY SPILLWAY – CONCEPTUAL DESIGN

Dear Mr. Seward,

1.0 INTRODUCTION

As requested Golder Associates Ltd. (Golder) has undertaken additional studies for the City of Nanaimo (CON) in relation to the ongoing dam safety assessment for the Colliery Dams in Nanaimo, BC. In particular, as directed by the CON, the studies presented in this letter comprise the following;

- Review water distribution in overtopping situation and how it impacts overtopping flow rate;
- Review capacity of existing spillway; and,
- Review concept of alternate swale/drainage course to Harewood Creek.

This letter provides a summary level discussion of the above items, and, if necessary, will be followed with a more detailed technical report describing the analyses and design development.

2.0 WATER DISTRIBUTION

In order to evaluate the pattern of water release from the reservoir in the design storm event, a more detailed evaluation of flood routing was undertaken. The HEC-HMS model was modified to account for water release over both the dam and the right abutment, in order to facilitate separating the dam and right abutment overtopping flows. Additionally, additional point survey information was used to refine the model geometry and the level of detail of the analysis was increased to match the available point data. The hydrology, reservoir storage, and existing spillway parameters remain unchanged.

The model was run for the design flows (1000 year event plus 2/3 of the difference between the 1000 year flood and the PMF); key findings from this revised analysis are as follows:

- The flow over the right abutment is a small proportion of the total flow of 143 m3/sec - about 4 m3/sec; and,

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- The peak overtopping dam flow increased slightly (by about 4 m3/sec, which is less than 10% of the total overtopping flow), due primarily to the revised geometry and model refinements.

3.0 SPILLWAY CAPACITY

As requested, a review of the Lower Dam spillway capacity has been carried out. The key inputs to the hydraulic model (in particular, the spillway geometry) have been checked. The hydraulic review has confirmed the previously reported spillway capacity results (Golder 2014). Key findings related to this assessment are as follows;

- The spillway capacity is approximately 55 m^3/sec;
- Due to the spillway geometry and the formation of hydraulic jumps, flows begin to overtop the spillway walls at lower flow rates (beginning at 35 m^3/sec); and,
- The above calculated spillway capacity is greater than capacities previously reported (eg WMC 2002). Since the previous reports do not provide a complete summary of model inputs and assumptions, it is not possible to definitively determine the reason for the differing calculated capacities. However, it is considered likely that the previous capacities may have been based on a different definition of spillway capacity, for example the previous spillway capacity may have been based on the onset of a hydraulic jump that exceeded the spillway wall height.

4.0 AUXILLIARY SPILLWAY TO HAREWOOD CREEK

4.1 Description

As a means to provide additional flood routing capacity for the Lower Dam, the incorporation of a second spillway has been considered. With this approach, the existing spillway would remain in place and serve as the primary spillway, while a second spillway (an 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. This section of the letter outlines findings related to the conceptual design development for this option. It is noted that this evaluation addresses only engineering the engineering aspects of the project and does not address the environmental, aesthetics, or permitting aspects of the work.

The key factors considered in developing this concept are as follows:

- Spillway Capacity. The required capacity of the auxiliary spillway is 88 m3/sec, based on the design requirement of 143 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 aligned to provide the minimum length of spillway channel. The alignment selection has been based primarily on topographic considerations as a means to minimize the spillway length and depth of excavation;

- Spillway conceptual design.
  - Spillway Channel. As shown on Figures 1 and 2, an open channel spillway has been selected for the spillway. This is expected to represent the lowest cost option for the spillway, but will result in a larger footprint than other options which would require steeper side slopes. As here is no information on ground conditions, side slopes for this option have been conservatively set at 2H:1V.
  - 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, a labyrinth weir has been selected as the recommended type based on the above considerations. Preliminary analyses indicate a weir of 13 m (l) x 13 m (w) and 3 m in height would be sufficient to pass the design flow. Other weir types considered include,
      - Concrete ogee weir. This options was discounted due to its large size and large footprint (it would need to be in excess of 35 m long, based on a crest elevation of 72.1 m).
      - Mechanical systems. Various options are available which could provide a smaller footprint such as the Obermeyer weir, gated systems and fuse gate spillways. However, such systems would require ongoing maintenance, may require operational control in order to be activated in a storm and would result in larger surge flows when activated. Such surge flows could result in greater impacts to downstream water courses (such as Harewood Creek), with attendant erosion and environmental impacts, and would also present a public safety hazard due to the rapid changes in flows which could be experienced in these release events.
  - Geometry and hydraulics.
    - Weir location. The location of the labyrinth structure is flexible, and requires consideration of aesthetics, hydraulics, constructability (in particular, cofferdam construction) and cut and fills volumes. As shown on Figure 1 the labyrinth has been located well into the abutment (into the slope) in order to make it less visible and to facilitate cofferdam construction.
    - A spillway channel of a minimum of 10 metres width is required for this option. The channel is sloped at about 2%.
- Channel armouring.
  - The upstream approach channel is envisioned to not require armoring due to the low-velocity, sub-critical flows approaching the labyrinth weir.
  - The downstream outlet channel experiences flow velocities of approximately 5.5 m/sec and 1.5m depth. Therefore the lower 2m (vertical) of the channel will need to be armored. A number of armouring solutions are considered to be feasible, including rip rap, tied concrete blocks (eg Armorflex), gabions and reinforced vegetative covers.

- Harewood Creek. As shown on Figure 1, the downstream portion of Harewood Creek will form part of the spillway system. It is anticipated that some stream improvements may be required in order to be able to accommodate the increased flows the channel will experience. In particular armouring is likely to be required at the confluence of the new spillway and Harewood Creek.

4.2 Construction Considerations

A detailed constructability assessment has not been undertaken for this project; however, the following factors have been identified and will require further consideration if this option is to be further developed.

- **Construction access.** The site is assumed to be accessed from the south using the existing paved trail off of Harewood Mines Road. This option assumes that suitable laydown is available at or near the Harewood Mines Road junction to facilitate construction traffic and enable offloading of equipment and materials. Traffic management and control (vehicles and pedestrians) may need to be considered in the event that suitable off-road space is not available. In addition, the presence of overhead utility lines at the access point may present a constraint to the construction approach, with the resultant impact to project cost and schedule if equipment needs to be sized to manage the height restrictions, or if utilities need to be relocated.

- **Site clearing requirements.** Site clearing will be required over the footprint of the spillway structure, as well as additional requirements in order to facilitate construction (i.e., for laydown, equipment movements, access, etc.). The site clearing requirements have not been evaluated in detail at this stage; however, it is anticipated that the construction staging and methodology will aim to reduce site clearing and stripping needs.

- **Cofferdam construction.** There are many options available for construction of a cofferdam to maintain a safe and dry working area. At this conceptual design stage, there is little information available to confirm with certainty the approach that offers the best solution to maintain safety of the work area. Options include using earthen berms, sheet piles, inflatable systems, and portable dam systems. Lowering the water level to facilitate the works is also a potentially viable option. However, each option has its benefits and constraints, including health and safety, environmental, community / stakeholder, schedule and financial implications. The success of any approach requires availability of further detailed information including, but not limited to, site investigation data including confirmation of base contours, design of all the stages of the construction, analysis of loading conditions (during installation and operation), etc. All of which should be discussed within the regulatory framework for in-water works.

- **Excavation.** At present it is assumed that the material to be excavated to facilitate construction of the auxiliary spillway comprises a combination of overburden soils and weak bedrock. The presence of competent bedrock, potentially requiring blasting, will have a significant bearing on the cost of construction. As such, further intrusive investigation is required to inform this aspect of the design concept.

- **Other construction impacts.** A detailed assessment of potential risks and constraints from construction, including health and safety, environmental, cultural, financial, constructability, etc. should be assessed during design development. Requirements for environmental control including sediment and erosion measures, dewatering management, and water treatment have not been assessed in detail. However, an allowance has been included in the cost estimate for each item.

An environmental and cultural resources assessment has not been undertaken as part of this work.

4.3 Estimated Cost

4.3.1 Estimate Classification

Based on the current level of study and available information (in particular the lack of geotechnical information), a conceptual-level cost estimate for the proposed spillway concept construction has been developed as a Public Works Government Services Canada (PWGSC) Class C estimate, or Class 2 estimate according to the Association for the Advancement of Cost Engineering International (AACEI). A Class C estimate is based on a typical design development of 2% to 15% and has an expected accuracy in the order of -20% to +50%. A Class C estimate is considered to be sufficient for informing investment decisions and obtaining preliminary project approvals.

The costs have been based primarily on unit rates developed when preparing the cost estimate for the previous labyrinth weir design. The estimated cost for this option is **$3.4M (range $2.7M to $5.1M)**, which excludes,

- Owners costs (investigations, design, construction management, permitting, etc.); and,
- Upgrades to Harewood Creek.

4.4 Further Work

In the event that this option is selected for further development, the following additional items of work are suggested in order to advance the design, assess construction and environmental impacts and refine the cost estimate;

- Assess geotechnical conditions as a basis for design development and construction cost estimating;
- Design development, including;
  - Alignment and design optimization;
  - Hydraulic, structural and geotechnical design, including further assessment of weir options and weir dimensioning;
  - Temporary works optimization, including cofferdam design;
- Constructability assessment and cost estimating, including construction staging and site area requirements;
- Assess potential need for hydraulic improvements to Harewood Creek;
- Assess environmental and cultural impacts; and,
- Aesthetics and landscape architecture evaluation as a means to minimize the intrusion of the structure.

5.0 CLOSURE

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

Yours very truly,

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Bruce R. Downing, P.Eng.
Principal

ORIGINAL SIGNED

Josh Myers, P.E.
Water Resources Engineer

ORIGINAL SIGNED

Katherine McCann
Construction Cost Estimator

BRD/kn

Attachments: Figure 1: Auxiliary Spillway To Harewood Creek Conceptual Plan
Figure 2: Auxiliary Spillway To Harewood Creek Conceptual Sections

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6.0 REFERENCES

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

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.

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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.

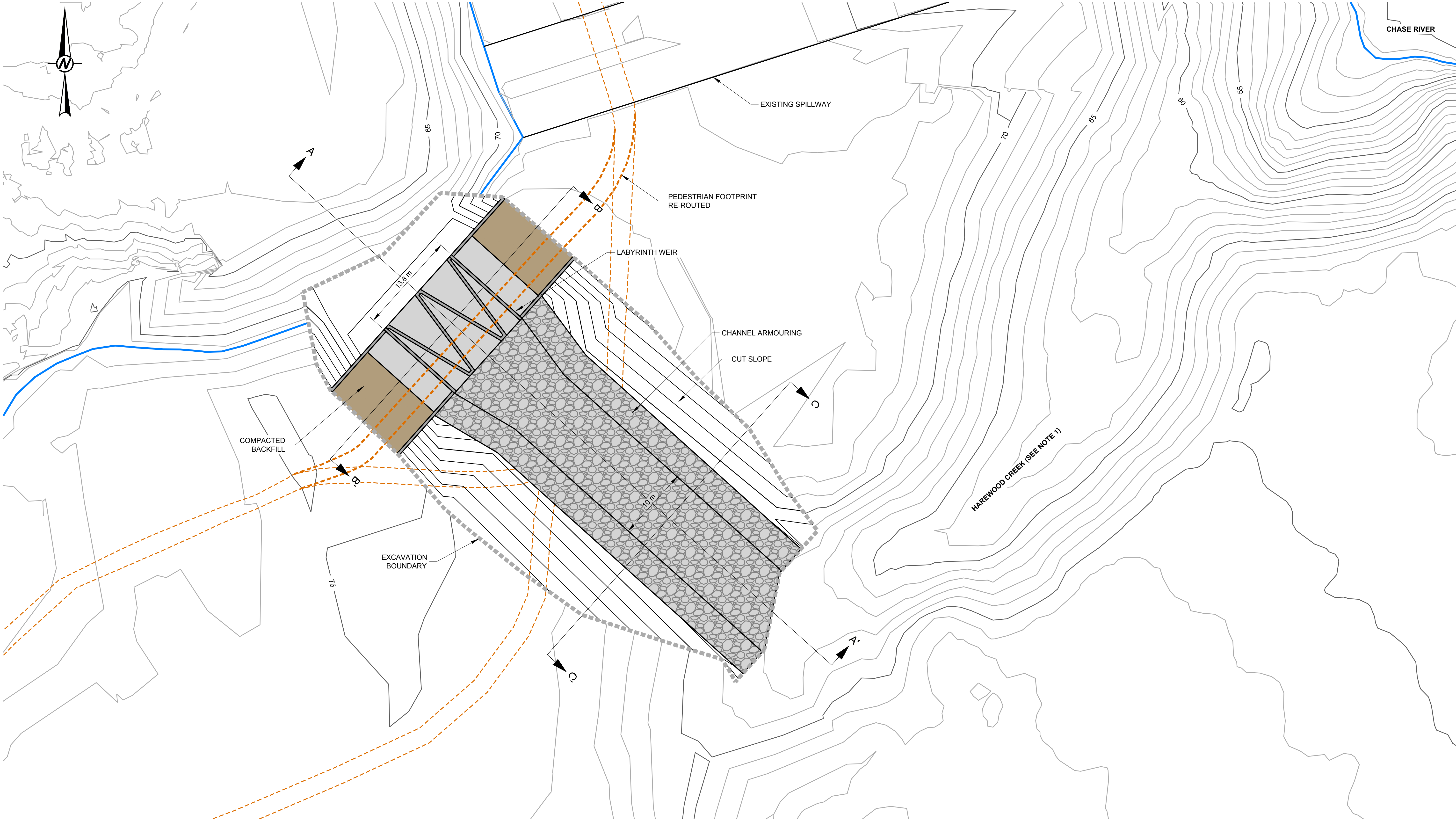
Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater 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.



NOTE

1. IMPROVEMENTS TO EXISTING HAREWOOD CREEK CHANNEL MAY BE REQUIRED, BUT ARE NOT YET DEFINED.

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).

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CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-01-15
PREPARED	RP
DESIGN	RP
REVIEW	JG
APPROVED	BD

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK CONCEPTUAL PLAN

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	0	1

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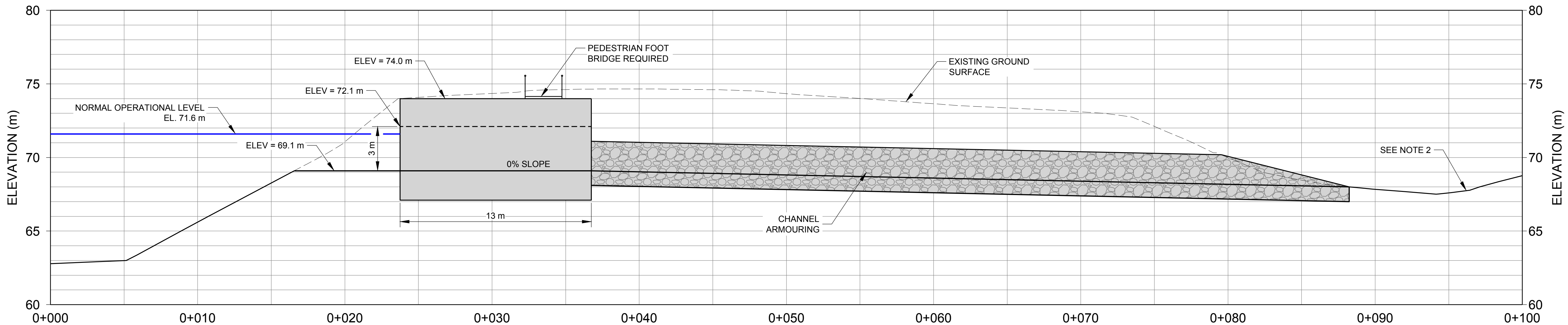

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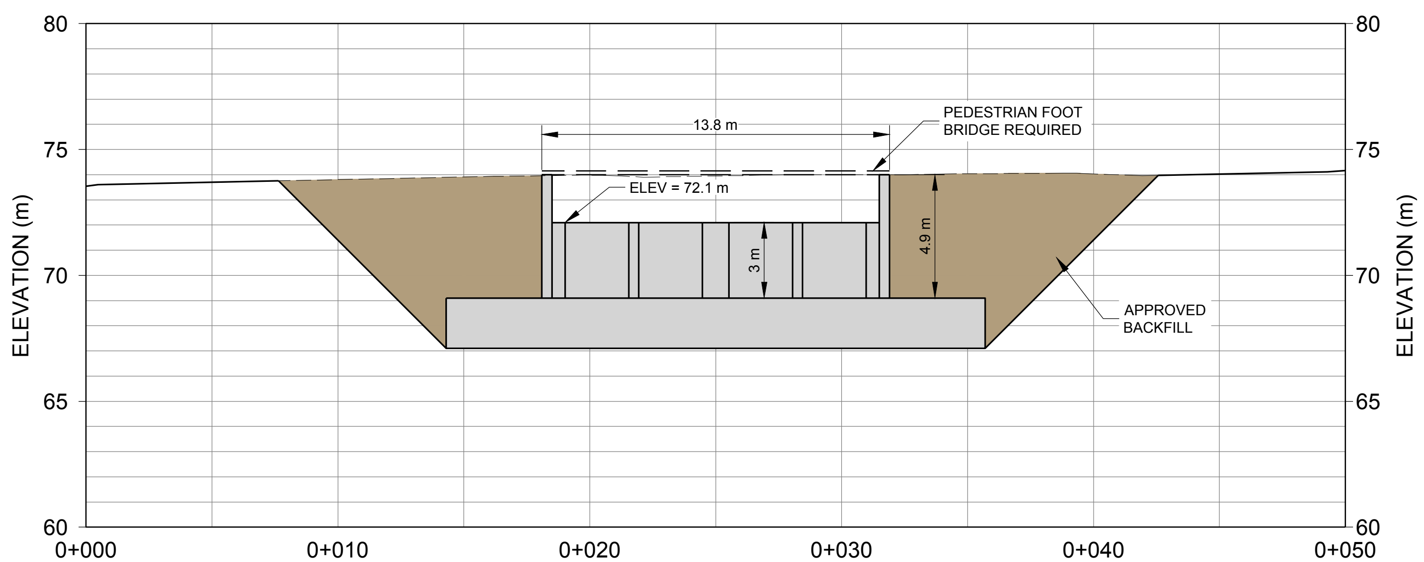

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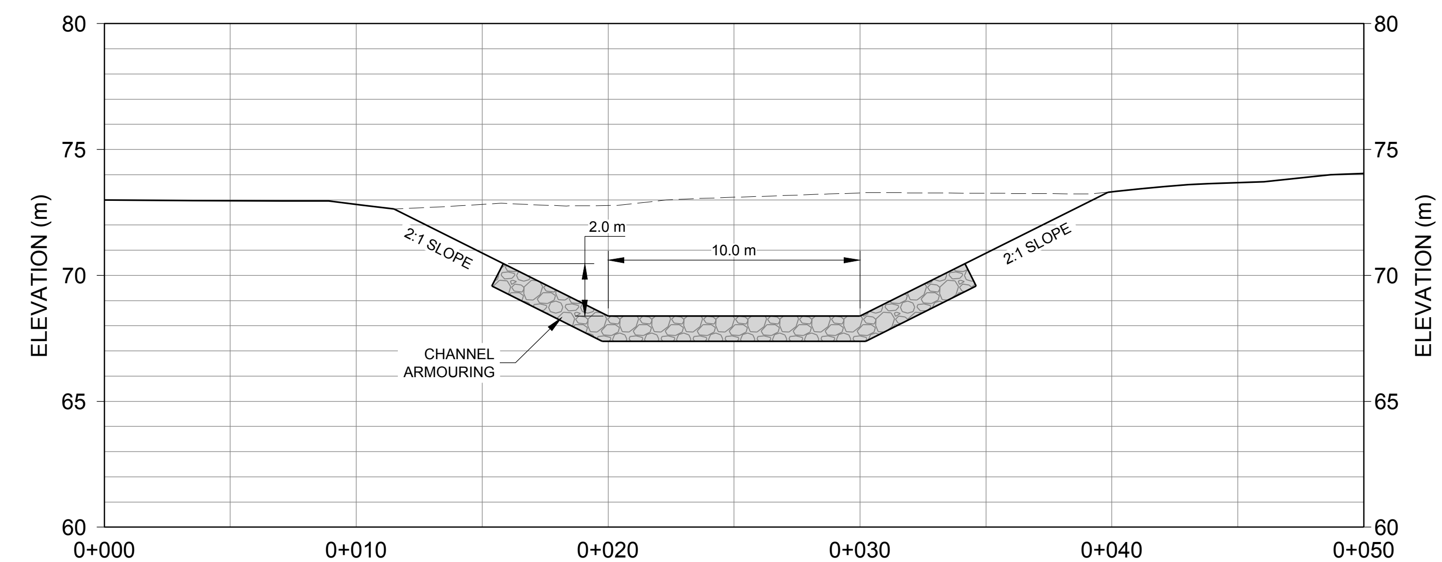

SECTION C-C'
SCALE 1:300

NOTE

1. STRUCTURE DIMENSIONS ARE CONCEPTUAL AND NOT YET DEFINED.
2. IMPROVEMENTS TO EXISTING HAREWOOD CREEK CHANNEL MAY BE REQUIRED, BUT ARE NOT YET DEFINED.

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CLIENT
CITY OF NANAIMO

PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-01-15
PREPARED	RP
DESIGN	RP
REVIEW	JG
APPROVED	BD

TITLE
AUXILIARY SPILLWAY TO HAREWOOD CREEK
CONCEPTUAL SECTIONS

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	2500	0	2