Water AECOM

Capital Regional District Regional Parks

Gardom Pond Dam Evaluation North Pender Island

Prepared by:

AECOM
200 – 415 Gorge Road East 250 475 6355 tel
Victoria, BC, Canada V8T 2W1 250 475 6388 fax
www.aecom.com

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200 – 415 Gorge Road East
Victoria, BC, Canada V8T 2W1
www.aecom.com

250 475 6355 tel
250 475 6388 fax

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Sigi Gudavicius, P. Eng.
Senior Engineer, Hydrology
Capital Regional District
Integrated Water Services
479 Island Highway
Victoria BC V9B 1H7

Dear Sigi:

Re: Gardom Pond Dam Evaluation
North Pender Island

We are pleased to submit the enclosed Gardom Pond Dam Evaluation Report. This report compares the impacts and costs of upgrading Gardom Pond Dam to current Provincial Dam Safety Standards with the impacts of decommissioning the dam, based on conceptual designs.

This report illustrates our minimum recommended improvements to Gardom Pond Dam in order to meet the Provincial Dam Safety Standards for both scenarios noted above. We trust the report is sufficient detailed and satisfactory. Please do not hesitate to contact me if you have any questions

Sincerely,
AECOM Canada Ltd.

Daryl Henry, P.Eng.
Senior Project Manager
DH

Encl.

Distribution List

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description

AECOM Signatures

Report Prepared By:

Norman Guild, P.Eng.
Senior Consulting Engineer

Report Reviewed By:

Daryl Henry, P.Eng.
Senior Engineer

Executive Summary

Gardom Pond Dam is located on North Pender Island and impounds water in a small (0.76 ha) reservoir known as Gardom Pond. The dam is of earthfill construction, is approximately 40 m long and 4 m in height, and was built between 1977 and 1979. In 1997, the dam was given a High Classification with respect to Downstream Failure Consequences by the BC Dam Safety Branch.

A Dam Safety Review completed in 2011 by Ryzuk Geotechnical identified several significant deficiencies including slope stability of the embankment during a large earthquake, inadequate spillway capacity, suspect integrity of the low-level outlet, and the potentially disastrous effect in terms of dam erosion of the bursting of either of the 50 mm dia. water supply pipelines that are owned by the Razor Point Improvement District (RPID) and which run through the crest of the dam.

The principal stakeholders in Gardom Pond Dam and its related facilities include the six water licence holders and the Razor Point Improvement District. One of the licence holders is the Capital Regional District; on behalf of the Pender Island Park Commission, Regional Parks is representing the Parks Commission in this study..

In early January 2013, CRD Regional Parks requested AECOM to prepare a report which would compare the impacts and costs of upgrading Gardom Pond Dam to current Provincial Dam Safety Standards with the impacts and costs of decommissioning the dam. AECOM retained Thurber Engineering Ltd. to provide geotechnical expertise for the review of the stability of the earthfill dam. Subsequently their scope of work was extended to include a risk assessment with respect to the potential impact that decommissioning of the dam, and hence lowering of the reservoir, might have on the yields of nearby water wells.

AECOM's study has included the following:

- A review of existing data including the Ryzuk Geotechnical 2011 Dam Safety Review
- Two site visits to view existing facilities, talk to residents and evaluate dam upgrading and decommissioning options
- An assessment of the non-compliance issues identified in the 2011 Dam Safety Review
- Development of improvements to the dam and related facilities to make them compliant with current Dam Safety requirements; also costing of the improvements
- Development of an alternative decommissioning (breaching) scenario for the dam with estimated costs
- Preparation, in tabular form, of a list of pros and cons of rehabilitation versus breaching
- A desk top study by Thurber Engineering Ltd. to evaluate the potential risk to the yields of nearby water supply wells should the dam be decommissioned.

With respect to upgrading the existing facilities, the following has been proposed:

- A berm would be constructed along the downstream toe of the present dam embankment to stabilize the dam during the design earthquake. It would incorporate suitably graded materials to allow it to function also as a drain.

- Upstream slope protection would be provided.

- An adequately sized spillway would be constructed near the left (facing downstream or east) abutment of the dam but **not** on or through the dam. A precast concrete bridge would span the spillway to maintain road access for residents to the east of the dam. The relocation would provide improved access for maintenance/observation and would significantly reduce the length, and hence the cost, of the new spillway channel. The existing spillway outlet would be plugged with a small berm.

- The existing low-level outlet would be plugged with grout and all pipework/valving removed.

- A siphon would be installed to permit reservoir drawdown in the absence of the low-level outlet.
- The RPID water pipes running through the dam, together with any pipe headers, valving, etc., would be removed.
- A new HDPE-lined spillway channel would be constructed downstream of the dam to convey spillway flows safely, and without erosion, to the ocean. A culvert would be provided under Razor Point Road.

The alternative decommissioning (breaching) scenario would involve:

- Cutting a vertical slot near the centre of the dam to lower the water level in the pond to preconstruction levels. Loc Bloc walls would be used to retain the earthfill, a riprapped channel would be created through the dam, and a precast concrete bridge would be used to span the breach to maintain road access for residents to the east of the dam.
- The existing spillway outlet would be plugged with a small berm.
- The existing low-level outlet would be removed entirely.
- A new HDPE-lined spillway channel would be constructed downstream of the dam to convey spillway flows safely, without erosion, to the ocean. A culvert would be provided under Razor Point Road.
- An environmental impact assessment of the lowering of the water level in Gardom Pond to identify any mitigative measures that might be required.

Costs for the two alternatives have been developed to an accuracy commensurate with the scope of the study. A contingency factor of 35% has been applied to reflect conceptual design and the need for further collection of field data, which address unknowns such as:

- **Field Investigations**: geotechnical drilling, surveys and pond bathymetry
- **Dam Improvements**: extent of upstream slope protection and condition of dam face, unknown concrete spillway and siphon lengths, presence of rock
- **Decommissioning Low-Level Outlet**: unknown pipe condition and required grout volume
- **Spillway Alignment to Ocean**: Sections of steep grades (>25%) and transitions, sourcing of riprap, adjustments to alignment to minimize impacts to trees, alterations to Razor Point Road crossing.

The estimated capital costs for upgrading and decommissioning the dam and related facilities are as follows:

Rehabilitation	$938,000
Decommissioning	$422,000

Additional costs, which are beyond development during this study, will include the costs associated with acquiring the necessary easements; ongoing operation, maintenance, surveillance and reporting costs to the BC Dam Safety Branch (Rehabilitation only); and the cost of removing the RPID water services from the dam.

The least expensive alternative is the decommissioning of the dam. However, additional factors such as the aesthetic beauty of the pond, the riparian and aquatic habitat created by the pond and its value as a resource for the adjacent Pender Island community park, need to be considered in the decision-making process. In addition, the pond is the only source of emergency fire storage in the area except for the ocean, which is not an easy alternative to develop. A properly rehabilitated dam and spillway should also reduce the risk of dam failure.

In the end, decision makers other than AECOM will need to make the final choice. The information presented in this report can be used to assist the decision makers in arriving at a consensus among stakeholders.

Finally, improvements to Gardom Pond Dam and spillway will have to be made if the pond is to be retained. It is expected that the BC Dam Safety Branch will no longer tolerate a wait and see approach.

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1. Introduction

In early January 2013, CRD Regional Parks requested AECOM to prepare a report which would compare the impacts and costs of upgrading Gardom Pond Dam to current Provincial Dam Safety Standards with the impacts and costs of decommissioning of the dam.

2. Gardom Pond Dam and Reservoir

2.1 Location

Gardom Pond Dam and Reservoir are located on North Pender Island to the north of Razor Point Road, some 6 km southeast of BC Ferries' Otter Bay ferry terminal. Ferry access to the Island is primarily from the Swartz Bay Terminal. Figure 1 presents a location plan for the site and Photos 1 through 8 in Appendix A depict the existing facilities.

The dam lies between 6604 and 6608 Harbour Hill Road and is accessed from Harbour Hill Road by way of Gardom Lane. Gardom Lane continues across the dam crest in an easterly direction to provide residential access for properties 6604 and 6602. The dam spillway (outlet channel) is located some 100 m northwest of the dam and appears to be located on Lot 12 owned by the Capital Regional District and designated as a CRD Regional Park. The spillway channel exits the reservoir in a westerly direction continuing across Lot 12 and a short section of property 6610 in a defined channel before turning 90° to the south to cross beneath Gardom Lane. It continues to flow south in a natural channel through property 6610 to the Harbour Hill Road drainage ditch, which conveys flow to the Razor Point Road drainage ditch. Flows are directed to a natural drainage course that runs to the ocean across properties 6618 and 6616 Razor Point Road.

The reservoir lies within properties 6602, 6604, 6606, 6608, CRD Lot 12 and 6600 Blk, Harbour Hill Road.

A site plan is presented in Figure 2.

2.2 History

Gardom Pond Dam was constructed between 1977 and 1979 of compacted brown silt with some clay, is approximately 40 m long and 4 m in height, and was originally built with a crest width of 2.4 m and upstream and downstream slopes graded to 2.6H:1V. A 6" diameter AC low-level outlet was provided beneath the dam, near centreline, and a spillway channel was excavated some 100 m to the northwest of the dam: the channel entrance is uncontrolled and the channel cross section varies from 0.4 m to 1.0 m wide with 1H:1V side slopes.

For approximately 10 years after 1979, the low-level outlet was used to provide water supply to local residents until a switch was made to groundwater supplied from a well located to the west of Gardom Pond owned by the Razor Point Improvement District. Well water is pumped to two nearby water storage tanks. Each tank supplies a 50 mm dia. PE pipe, which reportedly runs along the bottom of Gardom Pond, up the upstream face of the dam and through the crest of the dam at a depth of approximately 0.9 to1.0 below grade. The two pipes join in a common header pipe on the downstream face of the dam and thereafter follow a statutory right-of-way to Harbour Hill Road to supply water to the Razor Point Improvement District (RPID) water distribution system.

At some unknown date, the crest of the dam was widened in the downstream direction to approximately 5 m, resulting in a general downstream slope with a grade of 1H:1V and with a localized grade of 0.5H:1.0V above the low-level outlet chamber.

Effective 4th April, 1995, six water licences were issued for Gardom Pond for land improvement (aesthetic) purposes. Authorized works included dam and spillway structures.

In 1997, the dam was given a High Classification with respect to Downstream Failure Consequences by Mr. John Baldwin of the BC Dam Safety Branch.

Ryzuk Geotechnical completed a Dam Safety Review in 2011 for the Gardom Pond Dam and Works Stakeholders. The review noted several significant deficiencies including slope stability during a large earthquake, inadequate spillway capacity, suspect integrity of the low-level outlet and the potentially disastrous effect in terms of dam erosion if either of the 50 mm dia. water supply pipelines running through the crest of the dam should burst.

At some time in the past few years, Gardom Pond has been used as a source of emergency fire supply for RPID. This practice is not encouraged by the Dam Safety Branch. The low-level outlet has also been used for emergency fire supply in the recent past.

In November 2011, the RPID received a letter from the Capital Regional District's lawyer, Andrea Brace, stating that the RPID is the owner of the low-level outlet of Gardom Pond Dam. It also states that, as the owner of the low-level outlet and the upper water lines, RPID is required to properly inspect, maintain and repair these works. The CRD further advised as follows: "... the CRD will be looking to the Improvement District to bring its works, including the low-level outlet and upper water lines, into compliance with the Statutory Right-of-Way (conditions) and as well, to satisfy the issues raised by the (dam safety) engineer and the Dam Safety Officer regarding these works and their impacts on the dam."

Finally, an Environmental Covenant has been placed by the owners of property 6604 Harbour Hill Road on the entire lot area which includes a portion of Gardom Pond and possibly a small section of the eastern portion of the present dam.

2.3 Water Licences

As noted previously in Subsection 2.2, there are six water licences held on Gardom Pond. They are shown below in Table 2.1.

Table 2.1 – Gardom Pond Water Licences

Licence No.	Stream Name	Purpose	Quantity	Licensee	Priority Date
C109506	Gardom Pond	Land Improvement	1.25 ac.ft.	CRD Victoria	04/04/1995
C109507	Gardom Pond	Land Improvement	1.25 ac.ft.	[redacted] 6602 Harbour Hill Road	04/04/1995
C109510	Gardom Pond	Land Improvement	1.25 ac.ft.	[redacted] 6604 Harbour Hill Road	04/04/1995
C109511	Gardom Pond	Land Improvement	1.25 ac.ft.	[redacted] 2838 W.38th Ave., Vancouver	04/04/1995
C111318	Gardom Pond	Land Improvement	1.25 ac.ft.	[redacted] 103-533 Walter's Edge Cresc., West Vancouver	04/04/1995
C111639	Gardom Pond	Land Improvement	3.75 ac.ft.	TWAM Developments Ltd. 570 Blackburn Rd., Salt Spring Island	04/04/1995

2.4 Dam Safety – Non-Compliance Issues

Ryzuk Geotechnical (Ryzuk) identified several non-compliance issues in their 2011 Dam Safety Review. These issues are discussed in detail in the following sections.

2.4.1 Gardom Pond Dam

Ryzuk reported that "the global stability of the dam is not at risk considering the normal and extreme loading conditions. However, the deformation analysis of the dam indicated that under extreme loading conditions, such as a large earthquake, movement of the order of centimetres may be experienced in the embankment, which may be sufficient to create transversal and longitudinal fissures/cracks in the dam structure."

The aforementioned fissures are of concern as they are potential pathways for stored water to escape from the reservoir through the dam. As water flows through the fissure it has the potential to widen the fissure through erosion, leading to a partial or full breach of the dam. Water could be released almost instantaneously following a large earthquake.

Thurber Engineering Ltd. (Thurber), geotechnical subconsultants to AECOM for the evaluation of Gardom Pond Dam, have estimated that crest settlement under an earthquake with an annual exceedance probability of 1:2500, would be between 20 to 30 cm when there is a peak firm ground acceleration of 0.6 g. In addition, crest settlement of over 80 cm was predicted for the 1:10,000 event when there is a peak firm ground acceleration of 1.05 g.

Given the predicted crest movements, Thurber have concluded that ".. there is a reasonably good chance that cracking could be sufficient to induce considerable leakage that may result in an uncontrolled release of the reservoir shortly after the earthquake."

Thurber also noted that there was a lack of slope protection material on the upstream face of the dam.

Thurber Engineering Ltd.'s report is included as Appendix B of this report.

2.4.2 Spillway

Through visual inspection, historical data review, hydrological study and hydraulic assessment, Ryzuk noted the following:

- In 1979 the Inflow Design Flood for Gardom Pond was calculated to be 0.11 m^3/s and the spillway was designed to accommodate 0.4 m^3/s
- The spillway channel is currently overgrown and is in a general state of disrepair, thereby reducing its design capacity (Photos 5 through 7)
- Due to the reclassification in 1997 of the dam to a High Classification with respect to Downstream Failure Consequences, the spillway must be capable of accommodating an IDF of 0.87 m^3/s. Ryzuk calculated the capacity of the present spillway channel in its "vegetated" state to be only 80% of the required IDF.
- The current spillway capacity and associated freeboard (distance from the spillway invert to the dam crest) are incapable of preventing the IDF from overtopping the dam during a 24 hr. rainfall event. Overtopping could lead to a dam failure.

2.4.3 Low-Level Outlet

There is no accurate as-built information regarding the low-level outlet other than the knowledge that it is a 6" diameter pipe and that it has an unknown number of concrete collars at an unknown spacing along its length. The concrete inlet chamber has not been observed for several years.

There is a concrete chamber at the downstream end of the pipe, which houses two control valves (100 mm dia. and 50 mm dia.). Having control valves at the downstream end of the pipe instead of the upstream end of the pipe subjects the entire pipe to full reservoir water pressure at all times. This is not a recommended method of design and leakage from the pipe could travel along the pipe eroding material from the dam over time resulting in a potential breaching of the dam through piping.

The pipe is now almost 35 years old and nearing the end of its life expectancy.

2.4.4 Razor Point Improvement District Water Pipes

The presence of two pressurized pipes at a depth of 0.9 – 1.0 m below the crest of the dam is a major hazard to dam safety. A burst pipe through aging, damage from roadworks on the crest, or embankment fissuring/movement could cause a major dam failure.

2.4.5 OM&S Plan and Emergency Procedures Plan

Ryzuk noted in 2011, "...we understand that (formal) inspections have been completed annually since 1997 and almost daily site surveillance of the dam system has been carried out by one of the Gardom Pond Stakeholders" and "...it is evident that the owners have been very compliant with all regulations and guidelines related to properly managing the Gardom Dam."

2.5 Environmental Considerations

Gardom Pond creates riparian and aquatic habitat for aquatic species, waterfowl and local wildlife. It also has aesthetic value as a pleasant locale for local residents.

Gardom Pond also helps to some degree, in recharging groundwater that supplies local domestic wells.

It also acts "unofficially" as fire storage for the Razor Point Improvement District.

3. Required Improvements to Dam and Related Facilities

Based upon a review of existing information, two site visits, topography from the CRD Atlas (2 m contour interval), AECOM has developed conceptual designs for the improvements necessary to bring Gardom Pond Dam and related works into compliance with current Dam Safety Standards.

It must be noted that detailed topographic and bathymetric surveys have not been undertaken to date and that a geotechnical drilling program has not been conducted. Both surveys and drilling will be required prior to preliminary/final design.

A brief level survey was conducted by CRD/AECOM on 13th February, 2013, to obtain relative elevations along the dam crest and the spillway channel from the Pond to Gardom Lane, and to confirm the Pond freeboard. A nominal Elevation of 100.00 m was given to the top of the well owned by property 6606 Harbour Hill Road. It was determined that the existing spillway inlet was at El. 99.10 m and that the lowest elevation at the centre of the dam crest was El. 100.096 m (say El. 100.10). Therefore normal freeboard is 1.0 m. It was noted that crest elevations near both the left and right abutments were 100.71 m and 100.75 m, respectively.

3.1 Dam

3.1.1 Geotechnical

Given the predicted crest movements under seismic loadings briefly summarized in subsection 2.4.1 and discussed in detail in Thurber's report, a stabilization berm would need to be constructed along the downstream toe of the embankment. The berm would be constructed of suitably-graded materials so that it could perform the dual function of acting as a drain. The top of the berm would be approximately 1.2 m below the crest of the dam and would have a minimum width of 2.0 m. The berm would slope downwards with a gradient no steeper than 3H:1V, resulting in the toe of the existing dam being shifted approximately 6 m further downstream.

Thurber have provided further guidance on the gradation of the berm/toe drain in their report in Appendix B.

Thurber have also recommended that slope protection be provided for the upstream face of the dam, extending from the dam crest to at least 2 m below full pond elevation.

3.1.2 Civil

The RPID water pipes currently buried within the dam must be removed together with all valves, pipe manifolds and housings. They must be relocated from the dam embankment, including the abutments and the toe(s).

The practice of rapidly drawing down the reservoir for fire supply should be avoided as it could result in sloughing failures of the upstream slope of the dam.

3.2 Spillway

3.2.1 Width

BC Dam Safety Guidelines for the Rehabilitation of Dams state that "A spillway width of less than 4 metres wide is <u>not</u> recommended for high or very high consequence dams." As Gardom Pond Dam is classified as a **high-** consequence dam, a spillway width of 4 m has been selected for this report.

3.2.2 Inflow Design Flood (IDF)

A brief hydrological assessment, building upon work undertaken by Ryzuk in the Dam Safety Review, was undertaken to develop the IDF for Gardom Pond Dam. General hydrological parameters used are presented in Table 3.1 below.

Table 3.1 – IDF – General Hydrological Parameters	
Catchment Area	6.88 ha (including Pond)
Pond Surface Area	0.76 ha
Highest Elevation	108 m
Average slope	10%

For a high-consequence dam, the IDF should be 1/3rd between the Q_{1000} and the Probable Maximum Flood (PMF).

For Gardom Pond Dam, the Q_{1000} was determined by two methods; the Rational Formula Method and the National Resources Conservation Service (NRCS) Peak Flow Method, and an average value selected. A time of concentration of 30 minutes was used, averaged from the BCMoT – TAC Water Management Method and the Hathaway Formula. Rainfall intensities used for the calculations were derived by extrapolation of the Victoria International Airport IDF curves. Multiples for 200-yr. and 1000-yr. rainfall intensities were calculated from the 100-yr. intensity. Rainfall intensities were increased by 5% to account for the elevation of the site. The 100-yr., 30-minute intensity was then used in the Rational Formula with a flood runoff factor (C) of 0.56 to calculate Q_{100} peak flood flow. A multiplier was applied to this flow to derive the Q_{1000} peak flood flow. Similarly, the 100-yr., 24-hr. rainfall intensity was used in the NRCS Peak Flow Method to determine the Q_{100} peak flood flow.

The resulting two Q_{100} values were averaged and the multipliers applied to the average value to determine the Q_{200} and Q_{1000} peak flood flows. the results are shown in Table 3.2.

The Probable Maximum Flood Estimator for British Columbia was used to determine the PMF using the equation for Vancouver Island, allowing the final IDF, representing a value 1/3rd between the Q_{1000} and the PMF to be derived. All these values are presented in Table 3.2.

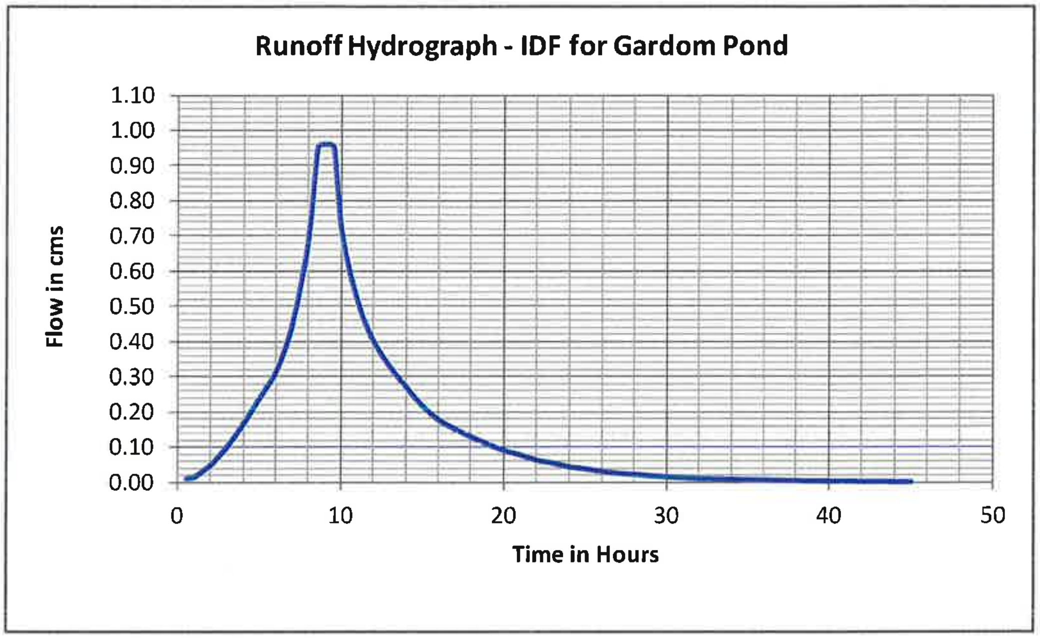
Table 3.2 – Calculated Peak Flows for Gardom Pond	
Q_{100}	0.33 m^3/s
Q_{200}	0.36 m^3/s
Q_{1000}	0.44 m^3/s
PMF	2.00 m^3/s
IDF	0.96 m^3/s

3.2.3 Reservoir Routing

Ryzuk noted in their Dam Safety Review that an IDF of a magnitude similar to the value defined in this report would result in overtopping of the dam crest during a 24-hr. rainfall event with the existing spillway in place.

To assess the ability of a new 4-m wide spillway (with its crest at the same elevation as the existing spillway) to prevent dam overtopping, a synthetic hydrograph was developed for a 24-hr., 100-yr. return period storm event.

Finally, a spike was applied to the hydrograph to reflect the peak value of the IDF (0.96 m^3/s) derived during this study. The spike was applied around the time to peak of the hydrograph, approximate ½ hr. on each side. Graphic capabilities of Excel were used to smooth the curve. The resulting hydrograph is shown below.



Routing of the hydrograph through Gardom Pond resulted in an insignificant (2%) reduction of the IDF but did clearly show that the water level would only rise to 0.29 m above the spillway crest, leaving 0.71 of freeboard to the dam crest. Therefore, a new 4 m wide spillway is recommended.

3.2.4 Spillway Location and Configuration

The new spillway would require a dedicated channel to convey peak flows to the ocean. The longer the channel, the greater the cost would be. Leaving the spillway at the present location would require a new channel (the existing channel is inadequate) that is approximately 60% longer than a new proposed channel alignment constructed adjacent to Gardom Dam's east abutment. In addition, two road crossings would be required instead of one, if the original alignment were to be upgraded.

Therefore it is proposed to relocate the Gardom Pond Dam spillway to a site immediately to the east of the left abutment of the dam as shown on Figures 2 and 3, and Photos 9 and 10. The spillway would be constructed on original ground, i.e., not on, or through, the dam and would lie on properties 6606 and 6604 Harbour Hill Road, crossing beneath Gardom Lane and through the BC Hydro Right-of-Way (EF41060) and Easement EF41632.

Details of the new spillway are shown on Figure 4. It would consist of a 4-m wide concrete channel with its entrance set at a nominal elevation of 99.10 m, and with sidewalls a minimum of 1.00 m in height. Where topography dictates the height of the channel could be increased by the addition of precast concrete Loc Blocks. The upstream approach channel to the spillway would be left in as natural a state as possible and would not, in this case, require installation of a debris log boom due to the limited amount of floating debris on the lake and the frequency of inspection of the dam and spillway by CRD inspectors and local residents under the existing Operation and Maintenance Plan. The downstream end of the concrete channel would extend to beyond the toe of the upgraded dam and would then enter a small riprap head pond to permit spillway flows to make the transition from the concrete channel to the HDPE-lined channel that would then convey flows to the ocean.

In order to maintain road access to properties 6604 and 6602 Harbour Hill Road, a simple bridge would be constructed across the top of the spillway. From the limited topographic information currently available, it is believed that the elevation of Gardom Lane at the centreline of the proposed spillway is approximately 1.0 m above the lowest elevation of the dam crest, i.e. nominal El. 101.1 m. The use of a precast/prestressed concrete bridge is one solution to allow quick installation and minimum access disturbance to the residents of properties 6604 and 6602. Temporary access, during construction of the concrete spillway channel could be provided daily by the contractor on an agreed schedule.

A staff gauge would be incorporated into the spillway structure.

3.2.5 Existing Spillway Plug

It will be necessary to prevent water from leaving Gardom Pond through the original spillway once all rehabilitation works have been completed. A low berm with an impermeable core will be required to plug the outlet. The exact length of the berm will have to be established by detailed survey at a later date. For now an allowance has been made for a 10-m long berm, 1 m high with 3H:1V upstream and downstream slopes.

3.3 Low-Level Outlet

3.3.1 Existing Outlet

As previously discussed, the low-level outlet is of poor hydraulic design with respect to being pressurized at all times beneath the dam and is nearing the end of its life expectancy.

As it is a threat to dam integrity, it is recommended that it be taken out of service by being carefully filled with grout. Pond drawdown under careful environmental monitoring would be the preferred scenario for implementing the grouting procedure since there is not an upstream valve/gate on the pipe.

3.3.2 Proposed Siphon

Dam Safety practice requires that a reservoir can be drawn down behind a dam for inspection purposes. Therefore it is wise to replace the grouted outlet pipe with a siphon pipe.

The proposed 300 mm dia. HDPE siphon would be incorporated into the spillway design with the control chamber located adjacent to outside of the channel wall on the north side of Gardom Lane. The siphon location is shown in plan view in Figure 3 and in section view on Figure 4.

Given the preliminary relative elevations of the dam crest, pond full storage level and the low-level outlet inlet level, it has been determined that a 300 mm dia. HDPE pipe approximately 50 m in length will suffice, allowing the pond to be drawn down in approximately 35 – 40 hrs.

The siphon works will include an inlet screen and check valve, concrete pipe anchors to keep the pipe on the reservoir bottom, priming chamber complete with air release valve and a connection for filling the pipe, and a gate valve with a "goose neck" air break at the downstream (discharge) end of the pipe. The pipe would discharge into a small rock pit, which in turn would discharge to the new spillway channel.

4. Required Improvements Downstream of Dam

4.1 Spillway Channel

4.1.1 Routing and Sizing

Spillway flows need to be conveyed in a dedicated channel from the end of the concrete spillway to the ocean. The proposed route and required right-of-way (ROW) for the aforementioned channel is shown on Figure 2 and a typical cross section of the spillway channel is shown on Figure 4.

The channel must be lined to accommodate the steepness of the terrain to be crossed (10% - 30% gradient). Riprap lining and use of an HDPE liner were investigated. The lack of suitable rock in required quantities on Pender Island precluded the use of a riprap lining as costs to import rock were prohibitive. An HDPE liner with a trapezoidal cross section, as shown on Figure 4, was selected to convey the design flow of 0.96 m^3/s.

With respect to conveying spillway flows beneath Razor Point Road, the spillway channel would discharge into a localized riprapped head pond which will feed a 1000 mm dia. CSP culvert running beneath Razor Point Road. At this stage of conceptual design, it is assumed that local road drainage would continue to be conveyed by the existing system on Razor Point Road: this might require diverting runoff, flowing from the east in the ditch on the northern edge of Razor Point Road, prior to its entry to the dedicated spillway channel head pond.

4.1.2 Rights-of-Way to be Obtained

For the purpose of this report a new right-of-way, 4 m in width, has been proposed and essentially runs parallel to the RPID ROW through 6606 and 6604 Harbour Hill Road; passes through 6602 Harbour Hill Road and 6621 Razor Point Road to Razor Point Road ROW; crosses beneath Razor Point Road in a culvert; and follows the property of 6618 Razor Point Road to the ocean, a total distance of approximately 400 m.

It should be noted that when detailed legal and topographic survey data is further clarified, the route of the channel can be refined within the ROW and the ROW itself can be locally adjusted to minimize disturbance to trees and existing facilities. For example, the location of the water pipes in the RPID 4-m wide ROW is currently unknown. It might be possible to overlap the proposed 4 m spillway channel ROW with the RPID 4-m ROW to reduce disturbance. In addition, the new ROW location along the east side of Harbour Hill Road may require further adjusting to the east to preserve a stand of trees and/or to avoid conflict with the RPID water supply system. Similarly, there are opportunities to locally adjust the ROW along the property line of 6618 Razor Point Road to deviate around trees and water system facilities near Razor Point Road.

5. Capital Cost of Rehabilitation Improvements

Costs have been developed to an accuracy commensurate with the scope of the study. Unit prices from previous contracts within the AECOM database have been used together with some discussion with a local contractor.

Quantities have been derived from the conceptual sketches of the location and size of the upgraded facilities presented in Figures 2 through 4.

At this stage of conceptual design, a contingency factor of 35% has been applied.

Allowances have been made for Care of Water and for Environmental Monitoring Services during construction. Care of Water includes protection of Gardom Pond and its riparian habitat during excavation for the new spillway, construction of the plug berm across the existing spillway and the grouting of the existing low-level outlet. It also includes protection of any watercourses paralleled or crossed by the new spillway channel. With respect to Environmental Monitoring, the services of an Environmental Monitor are recommended to ensure the contractor follows their "Care of Water" Plan and to provide advice on any lowering of Gardom Pond during outlet pipe grouting and siphon installation.

An allowance has also been made for a simple Environmental Assessment Report that would provide guidance during engineering design.

Table 5.1 summarizes the rehabilitation improvements required and their attendant costs.

Table 5.1 – Capital Cost of Rehabilitating Gardom Pond Dam and Related Facilities

Item	Quantity	Unit	Unit Cost	Amount
Mobilization and Demobilization	1	LS	$ 60,000	$ 60,000
Environmental Monitoring				
Initial Environmental Assessment	1	LS	$ 10,000	$ 10,000
Construction Monitoring	1	LS	$ 5,000	$ 5,000
Demolition				
Decommission Existing Spillway - Berm Plug	1	LS	$ 4,500	$ 4,500
Dam Construction Upgrades				
Grout Low Level Outlet	1	LS	$ 12,000	$ 12,000
Downstream stabilizing - Toe berm	1	L.S.	$ 130,000	$ 130,000
Upstream stabilization - Riprap	1	L.S.	$ 85,000	$ 85,000
Channel Spillway Excavation	350	m^3	$ 18	$ 6,300
Concrete Spillway	85	m^3	$ 1,200	$ 102,000
Precast concrete bridge slab w/ guardrails	1	LS	$ 25,000	$ 25,000
Rip Rap Energy dissipater pond at spillway exit	20	m^3	$ 300	$ 6,000
Contractor's care of water management	1	LS	$ 10,000	$ 10,000
Rock Blasting	50	m^3	$ 200	$ 10,000
Siphon				
300 mm HDPE Siphon Pipe w/anchors	70	m	$ 250	$ 17,500
Siphon Inlet Cage and check valve	1	ea.	$ 5,000	$ 5,000
Control chambers and valving; control valves	1	LS	$ 13,000	$ 13,000
Fill Siphon and Test System	1	LS	$ 1,500	$ 1,500
Spillway Channel to Ocean				
Tree clearing - Spillway construction	20	ea	$ 200	$ 4,000
Brush removal - Spillway construction	2000	m^2	$ 2	$ 4,000
Channel Excavation	475	m^3	$ 18	$ 8,550
Spillway erosion liner - w/ "SmartDitch Trapezoid"	400	m	$ 180	$ 72,000
Culvert Construction - Razor Point Road				
Supply & Install 1.0 m dia. CSP	20	m	$ 300	$ 6,000
Supply & Install precast headwall.	1	LS	$ 5,000	$ 5,000
Excavation (bury pipe & regrade road)	600	m^3	$ 10	$ 6,000
Gravel Base (depth to be specified)	200	m^2	$ 25	$ 5,000
Asphalt (depth to be specified)	200	m^2	$ 60	$ 12,000
			Subtotal	$ 625,350
			35% Contingency*	$ 218,873
			15% for Engineering	$ 93,803
			Construction Total	$ 938,025

Additional Costs:

A. Costs associated with acquiring the necessary easements, which will have to be added to the above total. These costs will include legal surveys, negotiating costs, acquiring and registering costs and final staking costs.
B. Costs associated with the removal of RPID water serrvices from the dam.
C. There will be ongoing operation, maintenance, surveillance and reporting costs to the BC Dam Safety Branch.

* ***Contingency Factor Allowances:***

1. Field investigations: geotechnical drilling, topographical survey and pond bathymetry
2. Dam improvements: extent of upstream slope protection, conditon of upstream face, unknown seepage issues during toe berm construction, unknown syphon and concrete spillway lengths, presence of rock
3. Low-level Outlet: unknown pipe condition and grout volume anticipated to fill unforeseen voids
4. Spillway Alignment to Ocean: adjustments to minimize impacts to trees, sections of steep grades (>25%), gradient transitions, sourcing of any riprap, required alterations to Razor Point Rd. crossing

6. Alternative Dam Breaching Scenario

6.1 Environmental Considerations

If the dam were breached and Gardom Pond lowered to its original water level, some 3 to 4 m lower than present day, there would be a loss of riparian and aquatic habitat of up to 4,000 m^2. Local aquatic species and waterfowl would be impacted, although there would still be pond and marsh area remaining. At present it is understood that the pond is not stocked with fish.

It had been suggested by local residents that lowering of the pond could have subsequent impacts on the yields of neighbouring domestic water yields. However, a reduced pond size would also decrease the aesthetic value of Gardom Pond for local residents and visitors to CRD's Regional Park that borders the water body. Thurber Engineering have conducted a desktop study which suggests that lowering of the water level would have limited impact on the pond's ability to recharge local aquifers. Their study forms part of their overall report, which is included in Appendix B.

6.2 Dam Breaching Requirements

6.2.1 Logistics

The dam's crest is also the access road to properties 6604 and 6602 Harbour Hill Road. Cutting a trapezoidal slot (breach) in the dam with a base elevation at the original creek bed and with a top elevation equal to the top of the dam, is not considered an ideal breaching method as the access road would be entirely removed from service. This would require a new road to be built either upstream of the dam along the old bottom of Gardom Pond or on the downstream side of the dam where the existence of residential structures and poor topography will impede construction. Regardless of the new access route selection, either upstream or downstream of the dam, a precast road bridge over the breach outlet would still be required.

Therefore a breach cross section other than trapezoidal was investigated.

6.2.2 Breach Design

It is proposed to cut a breach with vertical side walls through the centre of the dam and to grade the existing dam crest and driveway access modestly (8% maximum) on either side of the breach toward a new precast/prestressed concrete bridge to maintain access across the new outlet channel to residents of 6602 and 6604 Harbour Hill Road. The location is shown on Figure 3 and in Photo 11.

To minimize blockage and obviate need for debris booms, the base width of the breach has been selected as 4 m. This width would adequately convey the 200-yr. period design flow of 0.36 m^3/s. It is proposed to use Loc Blocks for the vertical walls for this breach; these walls will act as the abutments for the aforementioned bridge. The channel through the breach will be riprapped with a 900 mm thick layer of 600 mm nominal riprap over a geotextile filter cloth. A cross section and longitudinal section of the breached dam is presented in Figure 4.

During construction of the breach it is recommended that the existing low-level outlet be removed in its entirety to avoid future collapse and possibly future remedial works for the breach channel.

Relocation of RPID water pipes on the dam may also be required.

6.3 Reservoir Outlet Channel

6.3.1 Routing and Sizing

After passing through the existing dam, the breach channel would be tapered gradually to a cross section capable of conveying the 200-yr. return period design flow of 0.36 m^3/s to the ocean. The aforementioned cross section would be trapezoidal and would be protected against erosion by an HDPE liner. The proposed channel route (ROW) is shown on Figure 2 and the channel cross section is shown on Figure 4.

6.3.2 Rights-of-Way to be Obtained

The breach channel would follow the same route from the toe of dam to the ocean as the proposed new spillway channel discussed in detail in Section 4.1.2 of this report. It would require the same 4 m ROW, be approximately 400 m long and be amenable to the same local adjustments within its ROW. The ROW would also be amenable to local adjustments.

As for the spillway channel, the breach would be culverted beneath Razor Point Road, however only a 900 mm dia. CSP culvert would be required as compared to a 1000 mm dia. CSP culvert for the spillway channel. It is also considered that local road drainage would be conveyed separately by the existing drainage system.

6.4 Cost of Breaching

Costs have been developed to an accuracy commensurate with the scope of the study. Unit prices from previous contracts within the AECOM database have been used together with some discussions with a local contractor.

Quantities have been derived from the conceptual sketches of the location and size of the upgraded facilities presented in Figures 2 through 4.

At this stage of conceptual design, a contingency factor of 35% has been applied.

Table 6.1 summarizes the cost of breaching the dam.

The allowances for Care of Water, an Environmental Assessment Report and for Environmental Monitoring services were discussed in Section 5 of this report. The principles apply equally to the breaching scenario.

Table 6.1 – Cost of Breaching Gardom Pond Dam

Item	Quantity	Unit	Unit Cost	Amount
Mobilization and Demobilization	1	LS	$ 40,000	$ 40,000
Environmental				
Initial Environmental Assessment	1	LS	$ 10,000	$ 10,000
Construction Monitoring	1	LS	$ 10,000	$ 10,000
Demolition				
Decommission Existing Spillway - Berm Plug	1	LS	$ 4,500	$ 4,500
Removal of RPID existing Water Service	N/A			
Dam Decommissioning				
Dam Breach Excavation and grade surplus material	475	m^3	$ 15	$ 7,125
Remove Low Level Outlet	1	LS	$ 4,500	$ 4,500
Construct Rip Rap Channel and Energy Dissipater	125	m^3	$ 300	$ 37,500
Precast concrete bridge slab w/ guardrails	1	LS	$ 25,000	$ 25,000
Concrete Lock Blocks	1	LS	$ 10,000	$ 10,000
Contractor's care of water management	1	LS	$ 10,000	$ 10,000
Spillway Channel to Ocean				
Tree clearing - Spillway construction	20	ea	$ 200	$ 4,000
Brush removal - Spillway construction	2000	m^2	$ 2	$ 4,000
Channel Excavation	475	m^3	$ 18	$ 8,550
Spillway erosion liner - w/ "SmartDitch Trapezoid"	400	m	$ 180	$ 72,000
Culvert Construction - Razor Point Road				
Supply & Install 900 mm dia. CSP	20	m	$ 300	$ 6,000
Supply & Install precast headwall.	1	LS	$ 5,000	$ 5,000
Excavation (bury pipe & regrade road)	600	m^3	$ 10	$ 6,000
Gravel Base (depth to be specified)	200	m^2	$ 25	$ 5,000
Asphalt (depth to be specified)	200	m^2	$ 60	$ 12,000
			Subtotal	$ 281,175
			35% Contingency*	$ 98,411
			15% for Engineering	$ 42,176
			Construction Total	$ 421,763

Additional Costs:

A. Costs associated with acquiring the necessary easements, which will have to be added to the above total. These costs will include legal surveys, negotiating costs, acquiring and registering costs and final staking costs.

B. Costs associated with the removal of RPID water services from the dam.

C. After the dam has been breached it is no longer considered a dam by the BC Dam Safety Branch, thereby avoiding the need for annual reporting on its condition. However, normal maintenance of the bridge over the breach, the breach opening and channel, including the culvert beneath Razor Point Road, would still be required.

* ***Contingency Factor Allowances:***

1. Field investigations: geotechnical drilling, topographical survey and pond bathymetry
2. Dam improvements: extent of upstream slope protection, conditon of upstream face, unknown seepage issues during toe berm construction, unknown syphon and concrete spillway lengths, presence of rock
3. Low-level Outlet: unknown pipe condition and grout volume anticipated to fill unforeseen voids
4. Spillway Alignment to Ocean: adjustments to minimize impacts to trees, sections of steep grades (>25%), gradient transitions, sourcing of any riprap, required alterations to Razor Point Rd. crossing

7. Pros and Cons of Rehabilitation versus Breaching

To assist decision-makers, a list of the positives and negatives has been prepared for both the rehabilitation and breaching options being proposed for Gardom Pond Dam and its related facilities. Quantitative and qualitative values have been considered. The comparison has been presented in tabular form (Table 7.1) for ease of reference.

Table 7.1 - Pros and Cons of Rehabilitation versus Breaching of Gardom Pond Dam

		Quantitative		Qualitative	
Parameter		Positive	Negative	Positive	Negative
1.	Capital Cost				
	Rehab		$0.938 million		
	Breach	$0.423 million			
2.	Annual Operation/Maintenance Cost				
	Rehab (dam, spillway, siphon, spillway channel, culvert)		$7,500		
	Breach (bridge, breach opening, breach channel, culvert)	$1,800			
3.	a) Annual Dam Safety Reporting and Inspection Cost				
	Rehab		$2,000		
	Breach	$0			
	b) 10-Year Inspections				
	Rehab		$35,000		
	Breach	$0			
4.	Ongoing Liability for Dam Failure				
	Rehab				✓
	Breach			✓	
5.	Minimal Loss of Riparian and Aquatic Habitat				
	Rehab	Insignificant			
	Breach		4,000 m^2		
6.	Aesthetic Value maintained				
	Rehab			✓	
	Breach				✓
7.	Impact on Local Wells				
	Rehab			No Impact	
	Breach				Minimal impact
8.	Dam to Ocean Channels Right-of-Way Width				
	Rehab		4.0 m		
	Breach		4.0 m		
9.	Cost of Maintaining Water Licences and Associated Liabilities				
	Rehab				No change
	Breach			Cancelled	
10.	Loss of Potential Fire Storage for RPID				
	Rehab			No loss	
	Breach				Major loss

8. Summary

Engineering, environmental and cost analyses have been performed to identify the quantitative and qualitative advantages and disadvantages of rehabilitating Gardom Pond Dam and its related facilities to meet current Dam Safety Branch standards for a dam with a High Consequence of Failure rating. Similar analyses were conducted for the breaching of the dam to reduce the water level in Gardom Pond to historic levels.

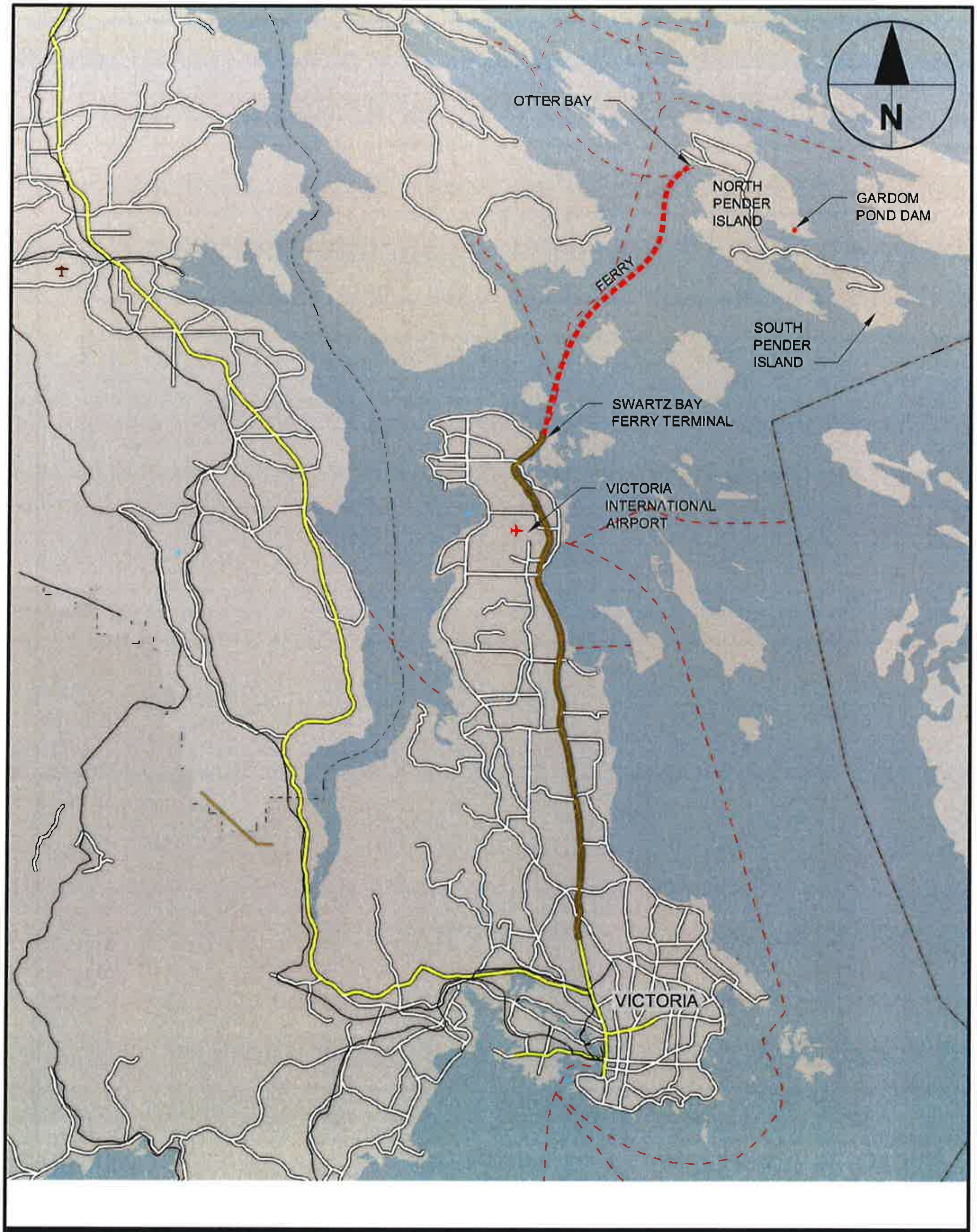
With respect to cost, both capital and operating, breaching the dam would be the least expensive option with capital savings of around $516,000 and greatly reduced annual operation, maintenance and Dam Safety reporting costs. Liability for dam failure would also cease to exist.

However, additional factors such as the aesthetic beauty of the pond, the riparian and aquatic habitat created by the pond and its value as a resource for the adjacent Pender Island community park, need to be considered in the decision-making process. In addition, the pond is the only source of emergency fire storage in the area except for the ocean, which is not an easy alternative to develop. A properly rehabilitated dam and spillway should also reduce the risk of dam failure.

In the end, decision makers other than AECOM will need to make the final choice. The information presented in this report can be used to assist the decision makers in arriving at a consensus among stakeholders.

Finally, improvements to Gardom Pond dam and spillway will have to be made if the pond is to be retained. It is expected that the BC Dam Safety Branch will no longer tolerate a wait and see approach.

Figures

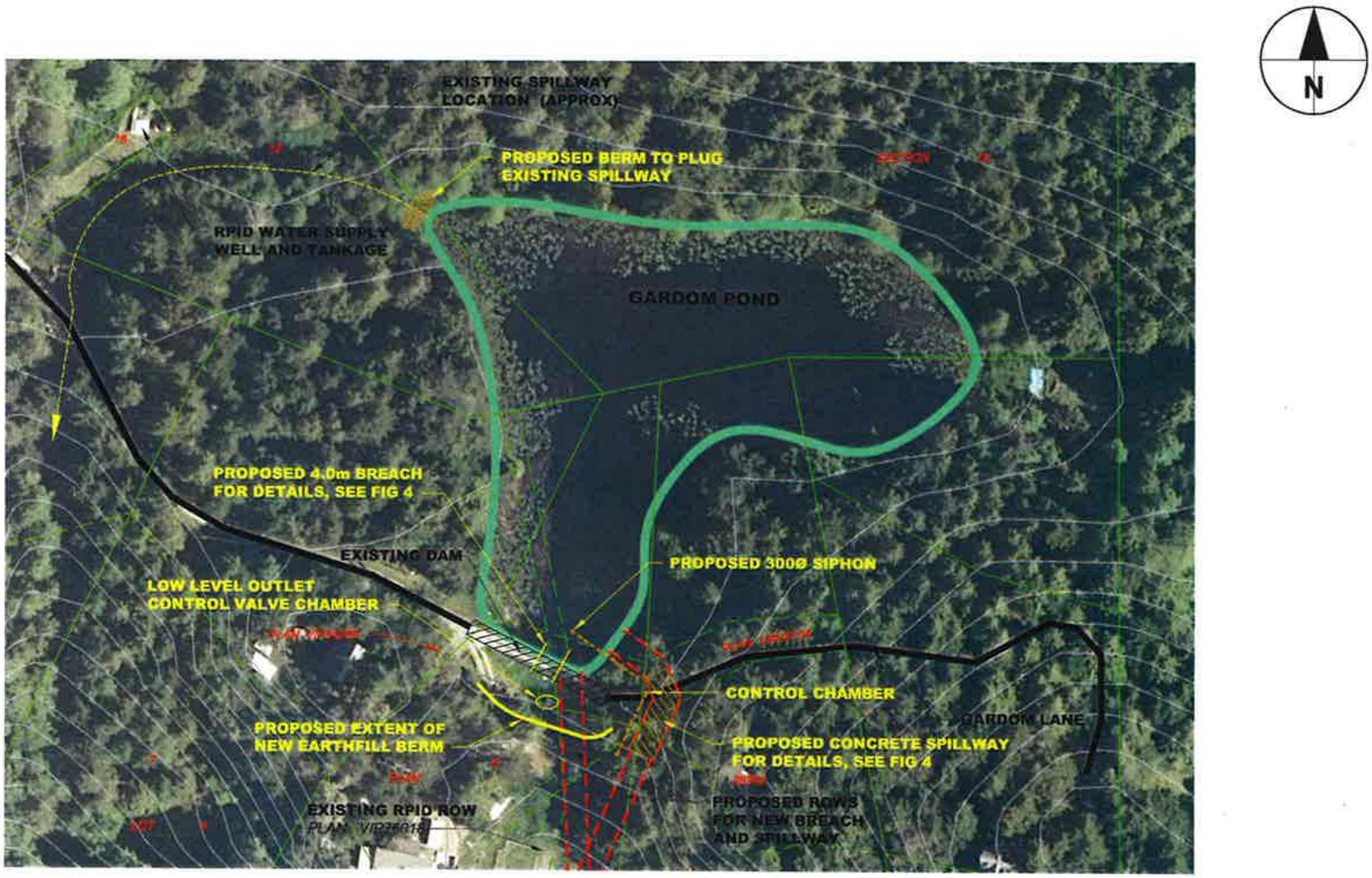


CRD REGIONAL PARKS
GARDOM POND DAM EVALUATION
NORTH PENDER ISLAND
Project No.: 60285876

LOCATION PLAN
NOT TO SCALE

AECOM
FIGURE 1

SITE PLAN
1:3000



PLAN
1:1000

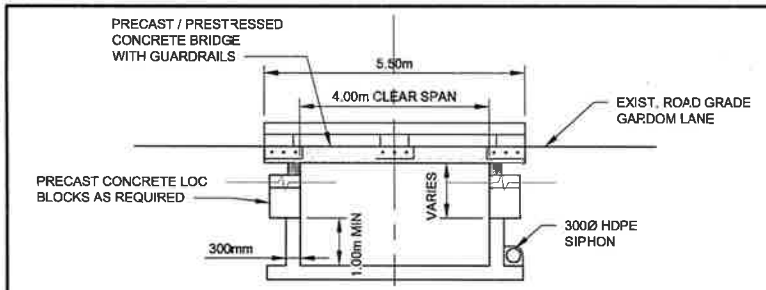
PLAN FOR RECOMMENDED DAM UPGRADE WORKS

CRD REGIONAL PARKS
GARDOM POND DAM EVALUATION
NORTH PENDER ISLAND
Project No.: 60285876 Date: 2013-06-14

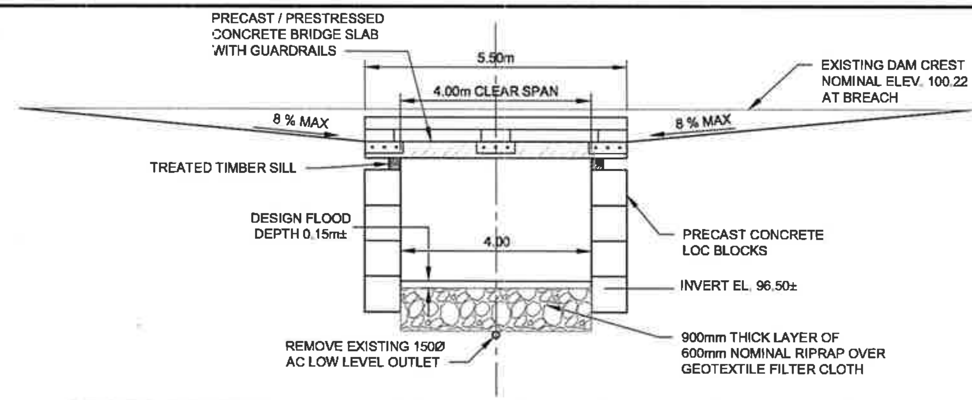
AECOM

Figure: 3

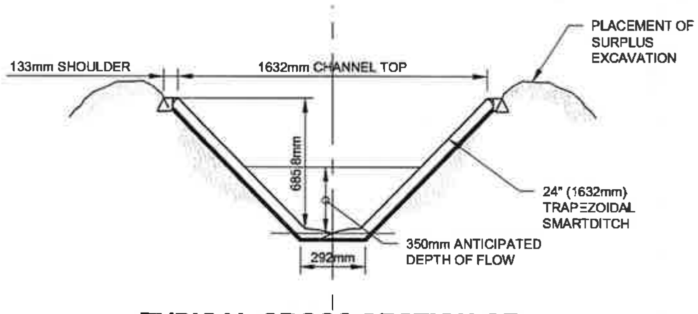
Project Management Initials: Designer: Checked: Approved: ANSI B 279.4mm x 431.8mm



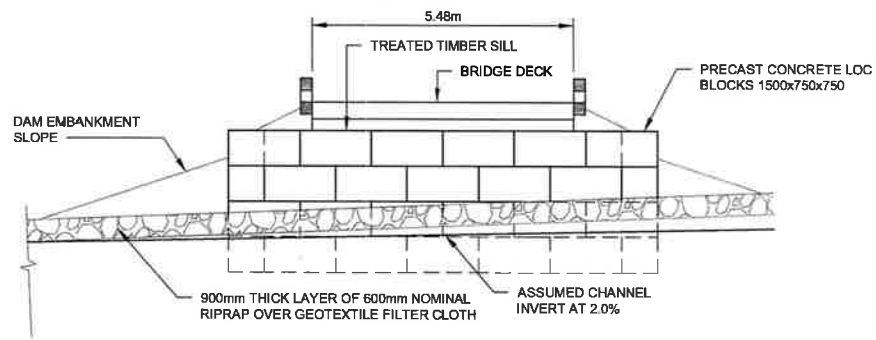
CROSS SECTION OF UPGRADED SPILLWAY LOOKING DOWNSTREAM
SCALE: 1:100



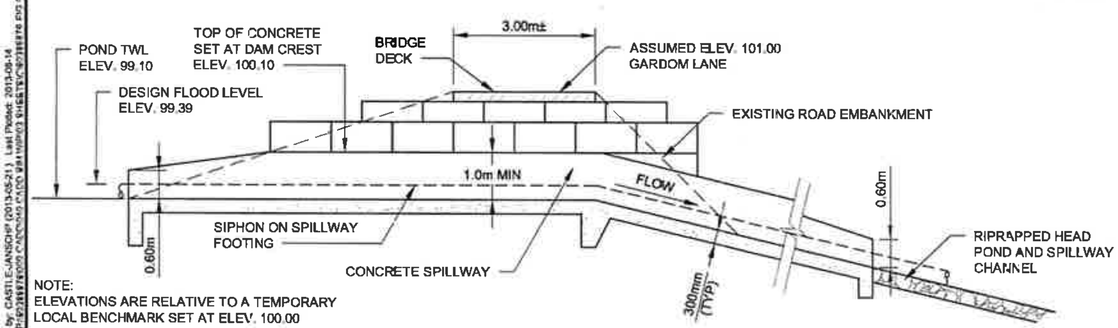
CROSS SECTION OF BREACHED DAM LOOKING DOWNSTREAM
SCALE: 1:100



TYPICAL CROSS SECTION OF SPILLWAY CHANNEL - DAM TO OCEAN
SCALE: 1:25

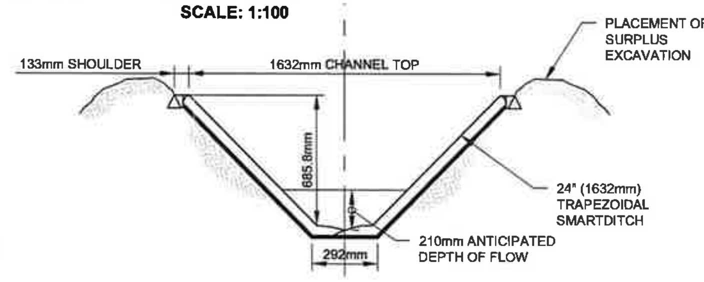


LONGITUDINAL SECTION OF BREACHED DAM
SCALE: 1:100



NOTE:
ELEVATIONS ARE RELATIVE TO A TEMPORARY LOCAL BENCHMARK SET AT ELEV. 100.00

LONGITUDINAL SECTION OF UPGRADED SPILLWAY
SCALE: 1:100



TYPICAL CROSS SECTION OF BREACH CHANNEL - DAM TO OCEAN
SCALE: 1:25

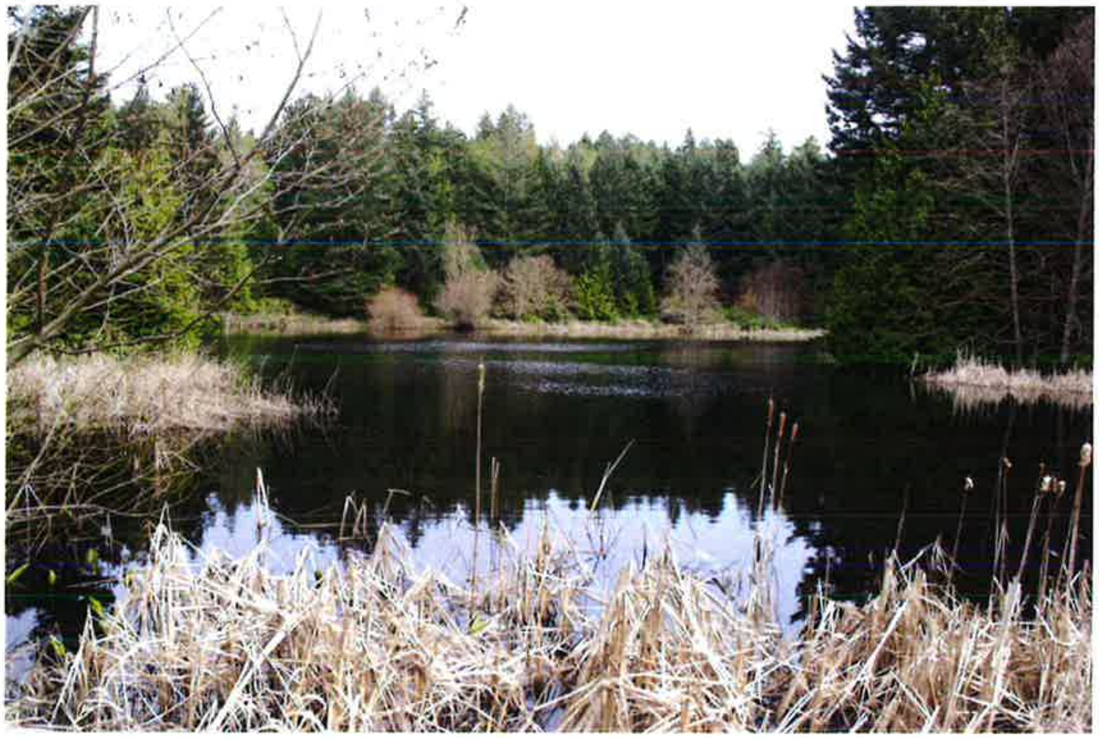
AECOM

Figure: 4

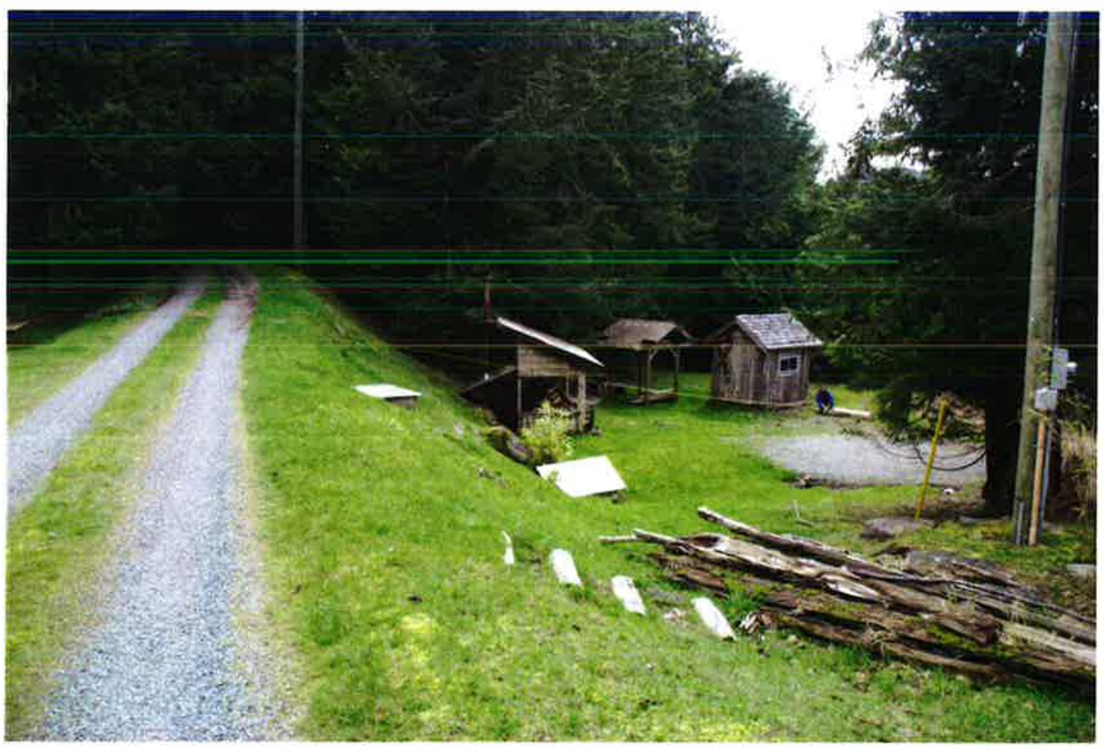
DETAILS OF DAM UPGRADE WORKS
AND ALTERNATIVE BREACH FACILITIES

CRD REGIONAL PARKS
GARDOM POND DAM EVALUATION
NORTH PENDER ISLAND
Project No.: 60285876 Date: 2013-06-14

Appendix A: Site Photos



Photograph #1 – Gardom Pond



Photograph #2 – Gardom Pond Dam

Photograph #3 – Looking Downstream from Dam at Centreline of Crest

Photograph #4 – Downstream Face of Dam

Photograph #5 – Existing Spillway Channel approximately 70 m Downstream of Pond (looking Upstream)

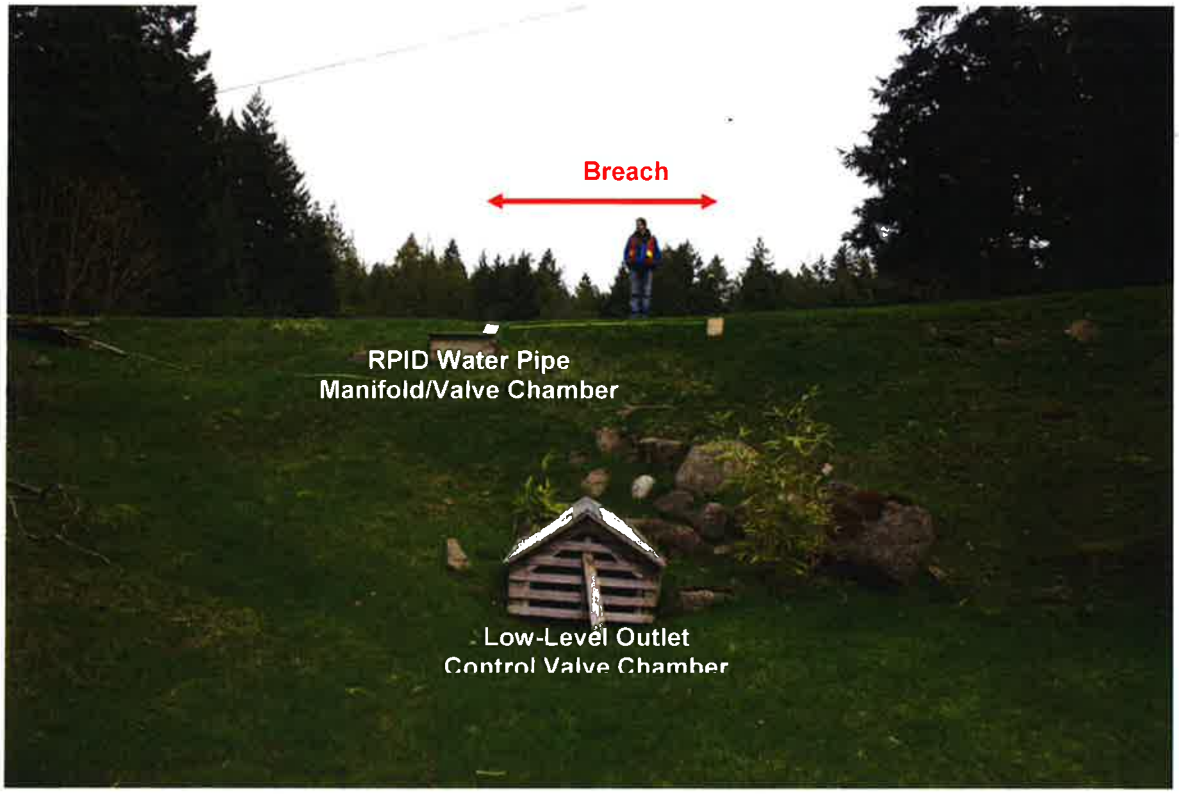
Photograph #6 – Existing Spillway Channel looking Downstream towards Gardom Lane (from Photo #5 location)

Photograph #7 – Existing Spillway Cross Section from Pond to Approx. Location of Photo #5

Photograph #8 – Location of RPID Emergency Fire Supply Standpipe

Photograph #9 – Proposed Site of New Spillway (engineer standing at location)

Photograph #10 – Possible Location of New Spillway beneath Gardom Lane (from left to right)



Photograph #11 – Proposed Location of Dam Breach

Appendix B:
Thurber Engineering Ltd. Report

THURBER ENGINEERING LTD.

May 17, 2013 File: 19-5438-94

AECOM
200 – 415 Gorge Road East
Victoria, B.C.
V8T 2W1

Attention: Mike Brady, P.Eng.

GARDOM POND DAM
GEOTECHNICAL ASSESSMENT

Dear Mike:

1. INTRODUCTION

This letter provides preliminary findings related to the geotechnical assessment carried out for Gardom Pond Dam on North Pender Island, BC. This assessment is being carried out in support of a larger AECOM study to evaluate the current condition of the Gardom Pond Dam with the objective of comparing the measures and costs required to upgrade the dam to current standards with the costs associated with decommissioning the dam.

The use of this letter is subject to the attached Statement of Limitations and Conditions.

2. SCOPE OF WORK

2.1 Geotechnical Component

The following scope of work was proposed for the geotechnical component of the Gardom Pond Dam study:

- Review supplied historical data and reports;
- Conduct a site visit to observe overall site features and conditions;
- Conduct a preliminary stability analysis using available data for a range of loading conditions;
- Estimate earthquake-induced dam deformations using a simplified statistical approach;
- Develop remediation alternatives, such as toe berms or flattening downstream slopes, and provide preliminary cost estimates;
- Comment on appropriate cut slope angles for decommissioning option;
- Prepare a summary report and attend one project meeting in Victoria.

This study is not intended to address the outstanding issues regarding the low-level outlet condition. No additional sub-surface investigations were carried out as part of this study. The parameters and geometry used for the slope stability analyses were based on observations and measurements from the site reconnaissance visit combined with information presented in the Dam Safety Review (DSR) report prepared by Ryzuk Geotechnical in 2011.

Please note that the scope of work identified above does not include a definitive assessment of the potential for internal erosion/piping of the dam. Such a study would require detailed construction records and/or the collection of specific in-situ testing data. The 2011 DSR report provides some discussion concerning the potential for internal erosion at this facility.

2.2 Assessment of Potential Water Supply Impacts

Thurber's work scope was increased to include an assessment of existing nearby groundwater drinking wells and to evaluate the potential impacts that dam decommissioning could have on existing groundwater supplies. This work scope included the following:

- Review of available well drilling logs;
- Review pertinent surficial geology mapping;
- Request selected property owners to fill out a "water supply survey questionnaire";

The assessment was to be qualitative in nature, and was only to provide comments on the relative risk (e.g., low, medium, high) of there being a potentially negative impact to the wells. A more detailed assessment of potential impacts of dam decommissioning would require an extended monitoring period and the installation of monitoring wells, and would not be carried out as part of this study.

3. SITE INSPECTION OBSERVATIONS

An inspection of Gardom Pond Dam was carried out on February 13, 2013 with representatives of AECOM and CRD Integrated Water Services present. The following is a summary of observations made during the inspection, with an emphasis on those items pertaining to the geotechnical and hydrogeological aspects of the structure.

- The dam can be accessed by a private road named Gardom Lane that crosses over the dam to provide access to two additional properties. The dam's right abutment starts near the property line of 6608 and 6606 Harbour Hill Drive and the dam's left abutment is near the boundary between 6606 and 6604 Harbour Hill Drive.
- The dam is approximately 40 to 45 m long and has a crest width typically ranging between 4.0 and 4.6 m, except for a locally widened area where the driveways accessing the properties at 6606 and 6608 Harbour Hill Drive are located. These driveways are actually located on Gardom Lane.

- The upstream face of the dam is obscured by vegetation (predominantly sedge grasses and reeds) near the waterline, although several small deciduous trees are located near the right abutment on the upstream side.
- It appears there has been some minor re-grading of the upstream slope, and a picnic table has been placed on a flat spot near the left abutment. The overall slope above the waterline was estimated as being graded between 15 to 18°, but this was difficult to measure given the above noted vegetation and overall variable slope conditions.
- The downstream slope is better defined and was measured using a hand inclinometer as having an average inclination of 35° with locally steeper zones approaching 40°. A poorly interlocked boulder stack is present on the central downstream slope in the vicinity of the outlet valve chamber, and supports a steeper section of the embankment. The stack is sloped at approximately 0.5H to 1V and extends midway up the slope.
- The downstream slope has been maintained such that no vegetation apart from grass is present. A small wooden shelter with a wood burning stove and stored firewood is located along the toe of the dam near the left abutment.
- At the time of the inspection, the reservoir was essentially at the full supply level, and the water level was measured (by survey) to be 0.84 m below the lowest point on the crest. The lowest point on the crest is at the right abutment, approximately where the driveway for the residence at 6606 Harbour Hill Drive is located.
- The maximum height of the dam measured to the east of the valve chamber is approximately 4.0 m.
- An access valve box is located approximately 1 m below the crest of the downstream slope near the middle of the dam. We understand this box was installed by the Razor Point Improvement District and provides access to the two shallow plastic water supply pipes that cross the dam at this location.
- The area downstream of the dam is characterized by a series of relatively flat, stepped benches or terraces, with a central drainage gully. Immediately below the dam, a relatively flat grassy area extends approximately 5 to 6 m beyond the downstream toe. Beyond this area is a flat gravel-surfaced parking area. Below the central section of the dam, the ground slopes down into a gully where a small seepage zone was observed on the slope. The seepage is exiting the ground closer to the right abutment.
- No cracks, scarps or other signs of significant deformation were noted on the dam. There is no evidence of erosion on either the downstream or upstream slopes. Some minor rutting was observed on the gravel road (Gardom Lane) that passes over the dam resulting in the edges of the crest having a slightly higher elevation than the centre.
- A bedrock outcrop was observed in the woods to the west of the pond/dam. This surface feature is not captured on the CRD Natural Areas map. No bedrock was observed in the left abutment area.
- There are a number of drinking water wells located around the south perimeter of Gardom Pond, with the closest two being at 6606 and 6608 Harbour Hill Drive. These two wells are approximately 15 m apart and were installed on the south side of the Gardom Lane. The well servicing 6606 Harbour Hill Drive is actually located on the

dam, whereas the one servicing 6608 Harbour Hill Drive is located beyond the right (west) abutment.

- The spillway for Gardom Pond is located on the northwest end of the reservoir. The spillway is a narrow, steeply sided channel excavated into overburden (clay) and flows in a westerly direction before entering an existing drainage that flows towards the south.

Selected photographs taken during the February 13, 2013 site inspection are provided in the Appendix of this report.

4. GEOTECHNICAL FINDINGS FROM 2011 DSR REPORT

The DSR report prepared by Ryzuk Geotechnical (Ryzuk) in 2011 provides a summary of the existing dam condition, including the results of a limited subsurface investigation carried out as part of the review. The following is a summary of pertinent information provided in the DSR report as it pertains to the geotechnical aspects of the dam.

- The upstream and downstream slopes were originally graded at 3H to 1V (18.4°)
- Following construction, the dam crest was widened to approximately 9 m from the original as-built width of 2.4 m, resulting in steeper downstream slopes. The report states the existing downstream slopes are generally graded at 1H to 1V, except for a localized steeper section above the outlet chamber (graded at approximately 0.5H to 1V).
- Based on the test holes completed along the dam alignment, the subsurface stratigraphy consists of a thin surficial layer of crushed gravel overtop of a 0.6 m to 1.2 m thick layer of silty gravelly sand underlain by approximately 3 m of silty clay fill. This clay fill is underlain either by stiffer natural clay, till and/or bedrock. Sampling was carried out to a depth of approximately 1.5 m, so below this depth the stratigraphy is inferred by DCPT blowcount data. Refusal on inferred bedrock occurred at depths ranging from 1.8 m to 4.8 m below the crest elevation.
- Ryzuk identified slope instability as one of the potential modes of dam failure, with the primary concern being stability during earthquake loading. Their assessment considered the performance of Gardom Pond dam for an earthquake having a 2% probability of exceedance in 50 years, which is also known as the 1 / 2,475 event. Their analysis applied a seismic coefficient equivalent to two-thirds of the Peak Ground Acceleration (PGA) from the 1 / 2,475 earthquake which equates to 0.40g for this site.
- Section 7.1 of the DSR report states that although the factor of safety is adequate under normal loading conditions that "when seismic loading is added to the analysis the model fails." This is interpreted as meaning the factor of safety drops temporarily below 1.0, indicating that permanent deformations are occurring but that an overall slope instability does not occur.
- The DSR report states that a finite element analysis was completed and predicted that under a large earthquake the dam would sustain permanent deformation "in the order of centimeters".

- Section 10.1 of the DSR report provides further clarification by stating that global stability of the dam is not an issue during extreme loading conditions, but that earthquake induced movements could be sufficient to trigger a subsequent seepage-related failure.

5. GEOTECHNICAL ASSESSMENT

One of the objectives of this study is to evaluate the measures that would be required to upgrade the Gardom Pond Dam to current dam safety standards. One of the conclusions of the Ryzuk DSR report is that upgrades required to improve the seismic performance of the dam would be cost prohibitive, and no preliminary recommendations for such improvements were provided. Instead, Ryzuk suggested the risk of post-earthquake dam failure could be mitigated by implementing an emergency evacuation plan for downstream residents within the likely inundation zone. However, given the proximity of downstream houses to the dam, this approach is likely not practical from a public safety perspective.

5.1 Seismic Hazard and Earthquake Design Ground Motions (EDGM)

The damage potential of an earthquake is determined by how the ground moves at a specific site and on how the structure located on that site have been constructed. In the case of an earth dam, it depends in part on the properties of the embankment fill as well as the properties of the foundation materials.

Seismic hazard can be evaluated using a probabilistic approach, whereby the ground motions at a site are estimated for a certain probability level. This approach includes the contributions to seismic hazard of all earthquake magnitudes at a variety of distances. In Canada, seismic hazard maps are prepared by the Geological Survey of Canada (GSC) and are derived from statistical analysis of past earthquakes and from advancing knowledge of Canada's tectonic and geological structure. On the maps, seismic hazard is expressed as the most powerful ground motion that is expected to occur in an area for a given probability level.

Alternatively, a deterministic approach can be employed to evaluate the seismic hazard from specific sources, such as a known active (or possibly active) fault. The deterministic approach assigns a maximum earthquake magnitude to the source, and then applies attenuation models to simulate the changes in the ground motions as the earthquake energy travels from the source to the site in question.

When a probabilistic assessment is conducted, ground motion values are given in terms of probable exceedance (i.e., the likelihood of a given ground motion value being exceeded during a particular period). The typical probabilities of exceedance provided by the GSC in the seismic hazard maps are the 2%, 5% and 10% probability of exceedance in a 50 year period, which corresponds to an annual exceedance probability of 1/2,475, 1/1,000 and 1/475, respectively. However, it is possible to extrapolate the ground motions for longer return period events.

Table 5.1 presents the annual exceedance probabilities for design earthquakes, as recommended in the 2007 Canadian Dam Association (CDA) Dam Safety Guidelines, for various dam classification levels. For the case of High and Very High dam classification levels, the EDGM value noted in the table must be justified to demonstrate conformance to societal norms of acceptable risk. As noted in the CDA Guidelines: "this justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by a seismic event." If such a justification cannot be provided, the EDGM from a 1/10,000 annual exceedance probability should be used.

TABLE 5.1
SUMMARY OF STABILITY ANALYSES

Dam Classification	Annual Exceedance Probability for EDGM
Low	1/500
Significant	1/1,000
High	1/2,500
Very High	1/5,000
Extreme	1/10,000

We understand that Gardom Pond Dam has a "High" dam classification, and thus the minimum recommended EDGM would correspond to an earthquake having and annual exceedance probability of 1 in 2,500. This is approximately equivalent to having a 2% probability of exceedance during any given 50-year period. Using the seismic hazard mapping prepared by the Geological Survey, the anticipated firm ground PGA value at the site corresponding to this annual exceedance probability would be approximately 0.60g. A copy of the seismic hazard calculation sheet, presenting the predicted ground motions for this site is attached in the Appendix. It is noted that Ryzuk reduced this ground motion by a factor of one third (i.e., to 0.4g). Justification for this reduction was not provided in the text of the report, but it is assumed that this reduction is in recognition that earth dams historically have a good track record in terms of seismic performance, particularly when the embankment and foundation soils have not liquefied. In some jurisdictions (such as highway design), it is common practice to reduce the predicted ground motions by as much as one half, and this may be in part recognition that road embankments can generally accommodate considerable deformation and still remain functional. It is noted, however, that the CDA Dam Safety Guidelines are silent on this issue and there is no indication that a reduction of predicted ground motions is acceptable in the context of dam safety.

Thus, for the purposes of our assessment, no reduction in the 0.60 PGA value was made. Furthermore, using the extrapolation method described on the Natural Resources Council website, the ground motions for the 1/10,000 event were also considered. This method resulted in an estimate PGA value of 1.05g. It is noted that extrapolation this far beyond the current database of earthquakes, involves a considerable amount of uncertainty.

5.2 Stability Analysis

As part of this study, Thurber completed a preliminary stability analysis of Gardom Pond Dam using the limit equilibrium software program Slope/W. Simplified embankment geometry and assumed soil layering and strength properties were used. The goals of the analysis were to confirm the conclusions stated in the Ryzuk DSR report and to provide preliminary guidance on the size and configuration of a toe berm. The first step was to model the dam under normal (static) operating conditions to confirm that reasonable factor of safety exists. For the geometry and soil conditions assumed in the analysis, a factor of safety of 1.5 to 1.7 was obtained under static full-supply conditions, and is considered acceptable. A pseudo-static analysis was then completed to model the impacts of seismic loading on dam stability. This method involves applying an increasingly larger seismic coefficient such that the factor of safety drops to 1.0. This value is known as the "yield coefficient". The estimated yield coefficient for the downstream slope of the dam is 0.18g.

If an earthquake induces ground accelerations less than the yield acceleration, permanent deformations would be expected to be very small. If, however, over the duration of an earthquake the ground motions exceed the yield coefficient value, significant permanent deformations may occur. Given that the earthquake design ground motions (EDGM) for this structure exceeds 0.18g, an estimation of earthquake deformations was carried out using a simplified statistical approach.

5.3 Estimation of Earthquake-Induced Displacements

An estimate of earthquake-induced crest displacements was made for the Gardom Pond Dam using the simplified analysis procedure developed by Bray and Travasarou (2007). Their method is an extension of the approach first developed by Newmark (1965). Newmark pointed out that when the factor of safety (FS) during earthquake shaking falls below 1.0 this did not necessarily indicate slope failure. He proposed that the total slope displacement along a slip surface, which accumulated during the times when FS < 1.0, should be used as the index of slope performance during an earthquake. Based on this premise, Newmark developed simple procedures for estimating slope displacements along a slip surface.

To advance this work, Bray and Travasarou conducted approximately 55,000 Newmark-type slope displacement analyses involving eight different soil slope configurations, ten different yield accelerations for each slope configuration, and 688 different recorded ground motions from a database compiled by the Pacific Earthquake Engineering Research Center (PEER 2005). From a regression analysis of the resulting slope displacements, they developed an equation to estimate the magnitude of slope displacement due to shearing of the soil along a slip surface.

Their method was validated using observations of 16 field case histories of earth and landfill fill performance during earthquakes. Like the Newmark method, the Bray and Travasarou procedure requires that a yield acceleration be determined. As noted above, the yield acceleration is the seismic coefficient required to reduce the factor of safety to 1.0.

The Bray and Travasarou method was used to estimate the potential dam slope displacements under an earthquake with a 1/2,475 annual exceedance probability. It was assumed that no amplification of the earthquake ground motions would occur, given the shallow bedrock conditions. We also considered ground motions from more extreme earthquakes, as described in Section 5.1. The estimated deformations based on this approach are presented in Table 5.2.

TABLE 5.2
SUMMARY OF EARTHQUAKE-INDUCED DEFORMATIONS

Analysis Case	Embankment Slope	Seismic Event	PGA	Estimated Movement (cm)
1	Downstream slope	1/2,475	0.60g	22
2	Upstream Slope (into reservoir)	1/2,475	0.60g	7
3	Downstream Slope	1/10,000	1.05g	80
4	Upstream Slope (into reservoir)	1/10,000	1.05g	30

Thus the estimated settlement of the crest under the 1/2,500 earthquake is estimated to be between 0.2 to 0.3 m, while over 0.8 m of settlement could occur for the 1/10,000 event. The above estimates are based on the assumption that neither the foundation or embankment fill materials would undergo liquefaction during the design earthquake. The reader is also reminded that the ground motions assumed for 1/10,000 earthquake are based on extrapolation and may be inaccurate.

The above ground motions listed in Table 5.2 are considerably greater than those identified in the Ryzuk report (i.e., their estimate for deformations was “in the centimeters”, suggesting a few centimeters). However, the Ryzuk assessment utilized the significantly lower input ground motion value of 0.4g. Using the approach described above and an input motion of 0.4g, the estimated crest movements were 10 cm and 3 cm for the downstream and upstream slopes, respectively, which would appear to be reasonably close to the deformation range predicted by Ryzuk. It is noted that there is no accepted standard for evaluating the performance of earth embankments during earthquakes. The approach used by Thurber in this evaluation is considered to be on the conservative side of the spectrum.

Given the predicted earthquake induced movements (shown in Table 5.2), there is a reasonably good chance that cracking could be sufficient to induce leakage in Gardom Pond Dam that may result in an uncontrolled release of the reservoir shortly after the earthquake. This failure mechanism is therefore considered plausible.

5.4 Recommended Stabilization Measure

5.4.1 Downstream Toe Berm

The recommended stabilization measure for Gardom Pond Dam is a berm constructed along the downstream toe of the embankment. Toe berms are commonly employed to stabilize slopes. The primary objective of the berm is to buttress the existing slope to increase its factor of safety and reduce the deformations that may occur during an earthquake.

In the case of Gardom Pond Dam, there is little information on the foundation conditions prior to construction, as well as the materials and methods employed during construction. For this reason, it is difficult to accurately predict the seismic performance of the existing structure, and it must be assumed that some cracking would still occur and this could lead to post-earthquake leakage. However, if the toe berm is constructed of suitably graded materials, it can also serve the dual function of a drain, allowing seepage to pass through the berm and minimizing the chance of an uncontrolled release of the reservoir. Therefore, even if the toe berm is unsuccessful in preventing significant cracking of the dam, leakage could still occur without inducing a seepage-related failure.

The general approach of a toe drain is to place progressively coarser materials in the downstream direction starting with a clean fine sand against the existing downstream slope and ending with a coarse rock fill on the exterior side of the berm. The gradation of the various materials, or zones, within the toe berm must be carefully selected by applying a number of filter design rules.

For the case of Gardom Pond Dam, it is anticipated that a 3-zone toe drain will be adequate. Specific gradation limits must be enforced for this work and it is possible that none of the granular materials would be available on Pender Island, although an effort to use local materials would obviously be made.

The recommended toe berm at Gardom Pond dam would have a height of at least two thirds of the existing dam, meaning the top of the berm would be approximately 1.2 m below the crest of the dam. The toe berm would have a minimum width of 2 m at the top, and slope downward with a gradient no steeper than 3H to 1V (18.4°). This would result in the toe of the dam being shifted approximately 6 m further downstream than the existing configuration. A sketch showing the proposed toe berm concept is attached as Figure 1.

We understand the existing low level outlet pipe and valve chamber would be decommissioned if the decision were made to upgrade the dam to current safety standards. Decommissioning of

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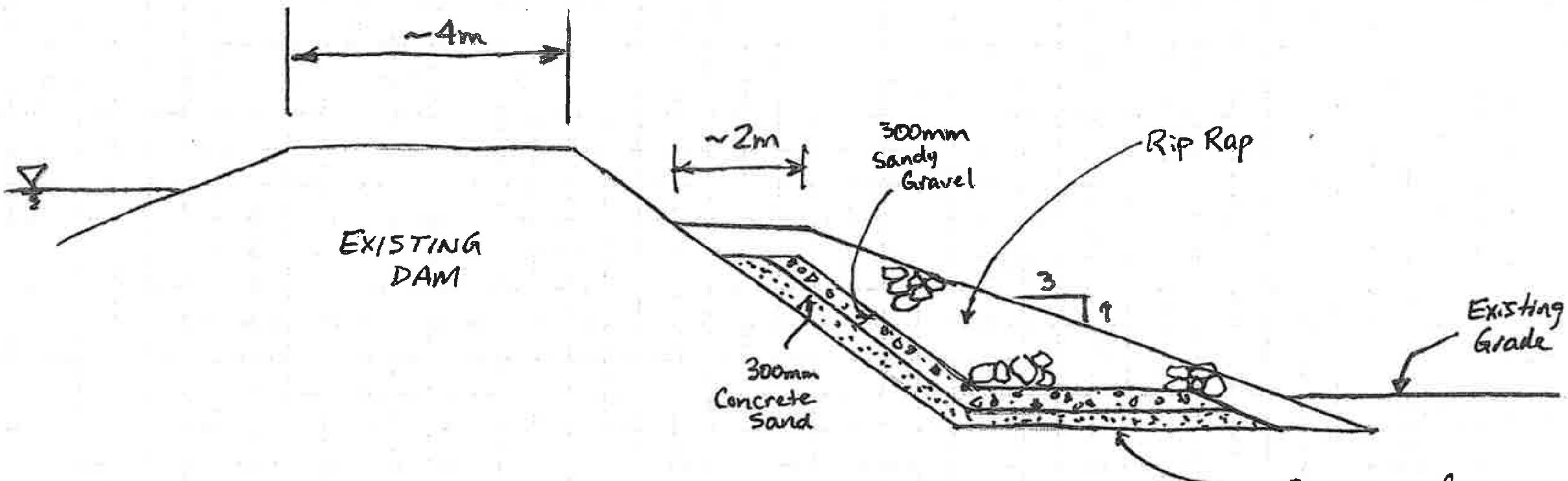

ILLUSTRATIVE CROSS-SECTION SHOWING PROPOSED TOE BERM

(NOT TO SCALE)

FIGURE 1

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS

Client AECOM

Project GARDOM POND DAM

Sheet 1 of 1 File No. 19-5438-94

Prepared by JBM Date

Checked by Date

the low level outlet pipe is recommended, as this pipe poses a significant risk to the dam in terms of a piping failure, as described in the DSR report. The proposed toe berm would extend over the current valve chamber location.

5.4.2 Upstream Slope Vegetation Removal & Erosion Protection

The upstream slope of the dam near the high water level is presently covered with vegetation, including sedge grass, reeds and several small trees near the right (west) abutment. Although the vegetation may be beneficial in terms of aquatic/riparian habitat, its presence makes it more difficult to adequately inspect the face of the dam for defects (such as cracks, depressions or animal burrows). The existing vegetation should be removed.

The CDA Guidelines state that the upstream slopes of embankment dams and their abutments should be provided with adequate against erosion. Rip rap is commonly used to provide this protection. If the decision is made to upgrade the dam it is recommended that rip rap be installed on the upstream face of the dam. The extent and gradation of the rip rap will need to be determined through an engineering assessment, but given the small reservoir size and limited fetch, it is anticipated that relatively small rock could be used for this purpose.

6. DECOMMISSIONING OF GARDOM POND DAM

If upgrading is not selected, we understand that Gardom Pond Dam will be decommissioned. Decommissioning would involve constructing a slot through the dam. The slot should be constructed with nominal 3H to 1V slopes. We understand a pre-cast concrete bridge would be installed to permit access over the decommissioned dam. This bridge would likely be supported on lock block abutment walls.

If decommissioning is carried out, a new channel would be required to convey run off through the slot and down to the ocean. The existing spillway channel would no longer be required.

7. RISK TO EXISTING DRINKING WATER WELLS

Upgrading the dam should not impact existing nearby drinking water wells as the normal operation level of the reservoir would remain unchanged. However, if the dam were decommissioned and the pond elevation returned to is original (lower) level, there was interest in evaluating the potential impacts to nearby well yields.

A preliminary, qualitative assessment was made of the potential impact of dam decommissioning on existing groundwater wells located adjacent to Gardom Pond. As part of this assessment, the following data sources were reviewed:

- Ministry of Environment (MoE) WELLS database information
- Water supply questionnaires received from property owners at 6604, 6606 and 6610 Harbour Hill Road and the Razor Point Improvement District
- Driller's logs for wells located at 6604, 6606, 6608 and 6610 Harbour Hill Road and the Razor Point Improvement District

The MoE WELLS information identified a total of 12 wells centred on the properties bordering Gardom Pond. Based on site visits and discussions with property owners, there well locations indicated on the data base are incorrect, although there are wells located elsewhere (typically alongside Gardom Lane).

There were four responses to a water supply questionnaire that was distributed by the CRD to nearby property owners. Driller's logs for the supply wells on 5 of the 6 subject properties were also provided to us. The results of the information collected are summarized in Table 7.1, attached.

Well log information indicated that all of the wells are completed in bedrock with a total depth that ranged from 38 to 94 m. The water-bearing fracture depths identified by the drillers ranged from 17 to 83 m and the well yields ranged from 19 to 227 L/min. A static groundwater level was only recorded by the driller on one well log where it was measured at a depth of 6 m.

Water quality information from the well surveys indicated occasional, seasonal issues with turbidity in two of the wells. These appear to be related to high precipitation events and may indicate that shallow surface water is entering the well, possibly as a result of inadequate flood protection around the well heads.

The Razor Point Improvement District provided an assessment of their well that was conducted by Brown, Erdman and Associates Ltd. (BEAL) in October 1981. BEAL estimated the long-term yield of the well to be 240 L/min based on 4 days of continuous pumping.

In our opinion, based on the well construction details and depths of bedrock fractures identified in the driller's reports, the presence of Gardom Pond is unlikely to have a significant effect on the nearby well yields and water quality. From the limited information reviewed here, the relative risk of significant impact to groundwater wells as a result of dam decommissioning is considered low. A more detailed assessment of the potential impacts would require the installation of monitoring wells and an extended period of groundwater monitoring which is outside the scope of this study.

8. COST ESTIMATE

The costs provided below exclude taxes and are considered preliminary and it is recommended that a generous contingency be applied for setting the project budget.

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TABLE 7.1

GARDOM POND DAM - GEOTECHNICAL ASSESSMENT
SUMMARY OF NEARBY WELL INFORMATION

PROPERTY	WELL TYPE	OVERBURDEN DEPTH		TOTAL DEPTH		ESTIMATED YIELD		STATIC WATER DEPTH		COMMENTS	WATER QUALITY REMARKS	DRILLER
		(feet)	(metres)	(feet)	(metres)	(USgpm)	(L/min)	(feet)	(metres)			
6604	Bedrock	9	3	275	84	5	19	~65	~20	Sandstone. Fractures at 27 and 81 m	Turbidity issues after rainfall	Tri K
6606	Bedrock	16	5	150	46	10	38	--	--	Sandstone. Fractures at ? and 37 m	none	Tri K
6608	Bedrock	7	2	125	38	8	30	--	--	Volcanic Rock (?). Fracture at 28 m	--	--
6610	Bedrock	5	2	150	46	30	114	--	--	Sandstone. Fracture at 42 m	Seasonal issues	Tri K
RPID	Bedrock	16	5	310	94	60	227	20	6	Sandstone. Fractures at 17, 24, 37, 52, 83 m	--	Drillwell

8.1 Toe Berm

Based on preliminary estimates, the approximate volume of materials required for construction of the toe berm are as follows:

Filter Sand:	150 m^3
Transition Material (sandy gravel)	150 m^3
Rip Rap	250 m^3

The estimated cost to supply and deliver these materials to the dam site, assuming they cannot be locally supplied, is estimated to be $90,000. The cost to construct the toe berm, including site preparation, placement and compaction is estimate to be approximately $40,000 plus tax. Thus the total construction cost is expected to be around $130,000. This assumes the materials are supplied by "truck and pup" deliveries via BC Ferries. This estimate does not include the costs for preparing a final design for the toe berm or the cost of conducting any engineering field reviews during construction. Construction of the toe berm would be expected to take approximately 10 days.

8.2 Upstream Slope Erosion Protection

To minimize the impacts on water quality, the level of Gardom Pond would need to be lowered prior to the removal of the vegetation on the upstream slope. Following removal of the vegetation, a non-woven geotextile would be installed on the slope and covered with a nominal 300 mm thick layer of sandy gravel bedding material.

For budgeting purposes, it is assumed rip rap layer would be 500 mm thick, extending downslope from the crest a distance of 10 m. The estimate volume of rip rap is 200 m^3 whereas the volume of the underlying granular bedding layer is estimate to be 120 m^3.

The estimated cost to install the upstream slope erosion protection is $85,000 plus tax, and this includes the supply of all materials. This cost does not include any fees associated with finalizing the revetment design or with conducting any engineering field reviews.

Environmental permits would be required to complete the upstream work, given that the planned work would impact riparian (and possibly fish) habitat. We have not included any costs associated with obtaining these environmental permits, although we have included a nominal cost of $5,000 for the contractor to supply and install sediment control measures.

9. CLOSING

We trust the information provided in this report meets your present requirements. If you have any questions, please contact our office.

Yours truly,
Thurber Engineering Ltd.
Kevin Sterne, P.Eng.
Review Principal

Jay McIntyre, P.Eng.
Project Engineer

Attachments

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STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering or environmental consulting practices in this area. No other warranty, expressed or implied, is made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed development, design objectives and purposes, and then only to the extent there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation or to consider such representations, information and instructions.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS WE MAY EXPRESSLY APPROVE. The contents of the Report remain our copyright property. The Client may not give, lend or, sell the Report, or otherwise make the Report, or any portion thereof, available to any person without our prior written permission. Any use which a third party makes of the Report, are the sole responsibility of such third parties. Unless expressly permitted by us, no person other than the Client is entitled to rely on this Report. We accept no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without our express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and this report is delivered on the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by us. We are entitled to rely on such representations, information and instructions and are not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

(see over ...)

c) Design Services: The Report may form part of the design and construction documents for information purposes even though it may have been issued prior to the final design being completed. We 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 the Report. Any differences that may exist between the report recommendations and the final design detailed in the contract documents should be reported to us immediately so that we can address potential conflicts.

d) Construction Services: During construction we must be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RISK LIMITATION

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause an accidental release of those substances. In consideration of the provision of the services by us, which are for the Client's benefit, the Client agrees to hold harmless and to indemnify and defend us and our directors, officers, servants, agents, employees, workmen and contractors (hereinafter referred to as the "Company") from and against any and all claims, losses, damages, demands, disputes, liability and legal investigative costs of defence, whether for personal injury including death, or any other loss whatsoever, regardless of any action or omission on the part of the Company, that result from an accidental release of pollutants or hazardous substances occurring as a result of carrying out this Project. This indemnification shall extend to all Claims brought or threatened against the Company under any federal or provincial statute as a result of conducting work on this Project. In addition to the above indemnification, the Client further agrees not to bring any claims against the Company in connection with any of the aforementioned causes.

7. SERVICES OF SUBCONSULTANTS AND CONTRACTORS

The conduct of engineering and environmental studies frequently requires hiring the services of individuals and companies with special expertise and/or services which we do not provide. We may arrange the hiring of these services as a convenience to our Clients. As these services are for the Client's benefit, the Client agrees to hold the Company harmless and to indemnify and defend us from and against all claims arising through such hirings to the extent that the Client would incur had he hired those services directly. This includes responsibility for payment for services rendered and pursuit of damages for errors, omissions or negligence by those parties in carrying out their work. In particular, these conditions apply to the use of drilling, excavation and laboratory testing services.

8. CONTROL OF WORK AND JOBSITE SAFETY

We are responsible only for the activities of our employees on the jobsite. The presence of our personnel on the site shall not be construed in any way to relieve the Client or any contractors on site from their responsibilities for site safety. The Client acknowledges that he, his representatives, contractors or others retain control of the site and that we never occupy a position of control of the site. The Client undertakes to inform us of all hazardous conditions, or other relevant conditions of which the Client is aware. The Client also recognizes that our activities may uncover previously unknown hazardous conditions or materials and that such a discovery may result in the necessity to undertake emergency procedures to protect our employees as well as the public at large and the environment in general. These procedures may well involve additional costs outside of any budgets previously agreed to. The Client agrees to pay us for any expenses incurred as the result of such discoveries and to compensate us through payment of additional fees and expenses for time spent by us to deal with the consequences of such discoveries. The Client also acknowledges that in some cases the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed and the Client agrees that notification to such bodies by us will not be a cause of action or dispute.

9. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on our interpretation of conditions revealed through limited investigation conducted within a defined scope of services. We cannot accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

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ATTACHEMENT

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Photo 1: Gardom Pond Dam from right abutment (Feb. 13, 2013)

Photo 2: Looking east along dam crest from right abutment (Feb. 13, 2013)


Photo 3: Area below downstream slope. Note outlet chamber and boulder stack.


Photo 4: Area below downstream slope (Feb. 13, 2013).

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Photo 5: Area downstream of dam – note terracing (Feb. 13, 2013).

Photo 6: Seepage area downstream of dam (Feb. 13, 2013).

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Photo 7: Gardom Pond from right abutment area (Feb. 13, 2013)

Photo 8: Upstream slope. Note vegetation along water line (Feb. 13, 2013).

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Photo 9: Valve cover for nearby well (Feb. 13, 2013).

Photo 10: Valve cover for nearby well (Feb. 13, 2013).

2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: , Thurber Engineering

April 24, 2013

Site Coordinates: 48.7747 North 123.2502 West

User File Reference: Gardom Pond Dam

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
1.202	0.803	0.372	0.185	0.601

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.*** Warning: You are in a region which considers the hazard from a deterministic Cascadia subduction event for the National Building Code. Values determined for high probabilities (0.01 per annum) in this region do not consider the hazard from this type of earthquake.

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.304	0.654	0.875
Sa(0.5)	0.195	0.430	0.580
Sa(1.0)	0.091	0.197	0.267
Sa(2.0)	0.043	0.094	0.129
PGA	0.157	0.329	0.440

References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français