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Village of Lions Bay

Water Storage Facilities Replacement

Contract Documents
Issued for Tender

Volume 3 of 3
Appendices

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Village of Lions Bay

Water Storage Replacement Project

AECOM Canada Ltd.
330 – 3292 Production Way
Burnaby, British Columbia
November 2017

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APPENDIX A
GEOTECHNICAL INVESTIGATION

November 15, 2017 Reference: VAN-00242641-A0

AECOM Canada Ltd.
4th Floor – 3292 Production Way
Burnaby, BC V5A 4R4 Email: Andreea.Irimia@aecom.com

Attention: Andreea Irimia, M.Eng., P.Eng., Civil Engineer

Re: Geotechnical Assessment Report
Municipality of the Village of Lions Bay, RFP.17.01
Water Storage Facilities Replacement

Dear Sir:

1.0 INTRODUCTION

As requested, EXP Services Inc. (EXP) has completed a geotechnical assessment for the proposed water storage facilities replacements for the Village of Lions Bay, BC. As part of the project two existing water storage tanks are considered for replacement, and two existing water storage tanks are being considered for removal. The main purpose of this geotechnical assessment is to identify any special geotechnical considerations, particularly with regards to the slope stability of the access roads, and to address foundation design requirements for replacement tanks and accessory structures.

Authorization to proceed with the work was provided by AECOM Canada, Inc. (AECOM), and services have been performed in general accordance with the Sub-Consultant Agreement between AECOM and EXP dated September 14, 2017 and Table 1 “Project Budget and Level of Effort” attached to EXP’s proposal dated April 19, 2017 (EXP File No. 999-00048059-PP).

2.0 SITE CONDITIONS AND PROJECT DESCRIPTION

It is understood that the project would entail the replacement of two existing water storage tanks identified as Harvey and Highway tanks, and the removal of two redundant tanks identified as Phase IV and Phase V tanks. The following provides a summary of proposed works at each of the four general work areas;

- Harvey Tank Site
  - Existing Harvey Tank is above ground. The tank is proposed to be demolished and replaced with an above ground concrete tank at the same location.
  - North of the Harvey Water Treatment Plant is a partially buried PRV chamber. The PRV chamber is proposed to be modified to have walk-in access.

- Phase IV and Phase V tanks
  - Both tanks are proposed to be demolished along with the structures around them. The tanks are not planned to be replaced.
  - There will be some changes in the water pipeline connections at each site.

  - There is an air valve proposed at Phase V tank site, located in a manhole.

- Bayview Proposed PRV
  - Located at the service road entrance to Phase IV and Phase V tanks, off Upper Bayview Road.
  - This PRV will be above ground, in a kiosk.

- Highway Tank
  - Currently there is an above ground storage tank. This will be demolished and replaced with a below ground tank, approximately 5.0m in height.
  - Currently there is also a large PRV chamber underground which is proposed to be modified to have walk in access.

3.0 KEY GEOTECHNICAL DESIGN ISSUES

Key geotechnical evaluation and design issues for the project are:

- Possible excavation, dewatering and stability considerations for any of the new tanks constructed on sloping ground that would require cutting into slopes to create a level foundation pad, including possible blasting;
- Tank foundation support and potential settlement considerations;
- Lateral pressures for portions of any of the new tank structures constructed below grade;
- Slope stability considerations for existing access roads and proposed tanks;

4.0 SUBSURFACE CONDITIONS

4.1 Surficial Geology

The Surficial Geology Open File 5322 published by the Geological Survey of Canada indicates several different surficial geology units among the locations of interest including the following:

Fraser Glaciation Deposits:

Glaciomarine ice-contact deposits:

The Highway tank site was the only location within this unit which is described to consist of deposits including; sand and gravel, stratified to massive and commonly faulted; generally > 3m thick; forming hummocky surfaces, may contain fossiliferous materials.

Ice-contact deposits:

The Bayview PRV location and the beginning of the access road from Bayview to Phase IV and V tanks were identified to be within this unit which is described to consist of; sand and gravel, stratified to massive and commonly faulted; generally > 3m thick; forming hummocky surfaces.

Post-Fraser Glaciation Deposits:

Slope Colluvium:

The Harvey, Phase IV, and Phase V tanks, the access road to Harvey tank, and the northern portion of the access road to Phase IV and V tanks were all located within this unit which is described as; rock fragments in a matrix of, boulders, gravel, sand, silt and minor clay; 1 to 10m thick; formed by bedrock weathering or reworking of unconsolidated deposits on steep (>30˚) slopes; commonly gullied.

4.2 Field Exploration Program

EXP's fieldwork was carried out on September 19 and 21, 2017 and included the following:

- A site reconnaissance was conducted to visually review the existing site conditions at each location, and along the access roads to the locations.
- As part of due diligence, a BC One Call was made, and prior to the commencement of the test pitting work, an electro-magnetic survey of the site was completed to locate buried utility lines. This survey was carried out by sub-contractor Quadra Utility Locating of Surrey, BC.
- A total of seven (7) machine dug test pits were excavated across the four general proposed work areas.
- A seismic refraction survey was conducted at the Harvey Tank site to better infer the bedrock profile and refine the foundation recommendations.

The following sections provide details on the field exploration program.

4.2.1 Site Reconnaissance

A site reconnaissance was conducted by a geotechnical engineer from EXP on September 19, 2017. The reconnaissance included visual review of geotechnical and topographical surface features for any evidence of potential geotechnical issues including; slope instabilities, rock fall hazards, and evidence of shallow bedrock outcrops.

4.2.2 Test Pit Exploration Program

A 50-series mini excavator supplied and operated by Atlas Leasing Ltd., was subcontracted by EXP to complete seven (7) test pits (designated as TP17-01 to TP17-07) and shown on the attached Figures 1 to 3 Test Pit Location Plan. The test pits were excavated to depths ranging from 1.5 to 3.7m.

All field work was carried out under the full-time supervision of a member of EXP geotechnical staff, who located the test pits in the field, examined and logged the subsurface condition encountered, and collected representative soil samples for visual examination and testing in our laboratory. Following completion of digging, the test pits were backfilled with excavation spoils and bucket tamped.

The locations of the test pits are shown on the attached Figures 1 to 3, Test Pit Location Plan, and logs of the test pits are presented in Appendix A.

4.2.3 Seismic Refraction Survey

As previously mentioned, a seismic refraction survey was conducted at the Harvey Tank site and consisted of laying out five seismic lines at the edges of the existing tank. The seismic line consists of a seismic cable with a series of geophones laid along the existing ground surface to measure compression waves induced from a seismic source. The geophone detectors measure the compressional velocity as it travels through the subsurface soils which can then be interpreted for different soil and bedrock layers.

4.3 Laboratory Testing

Laboratory tests were conducted on representative soil samples obtained from the test pits. The tests included natural moisture content determination and visual classification of soils. The moisture content tests were done in general accordance with the test procedures in ASTM D-2216. Results of the tests are shown on the test pit logs, provided in Appendix A.

4.4 Existing Site and Subsoil Conditions

The following sections provide site specific descriptions of the existing site conditions and subsoil conditions encountered at each of the proposed works locations.

4.4.1 Highway Tank Location

The Highway tank is located north of the intersection of the Oceanview Road and the off-ramp from northbound Highway 99 south of the Harvey Creek. The site is situated on a level bench that appears to be created by excavation of slope on the east and placement of fill to the west. Two test pits (TP17-01 and TP17-02) were excavated to the northwest of the existing tank and south of the existing tank. The following subsurface soil units were encountered.

UNIT A FILL - Sand, some gravel, trace silt, grading to sand and gravel, some silt to silty, compact, encountered in TP17-01 only, extending to 0.9m depth.

UNIT B Gravel and Cobbles, some boulders, some sand, some silt, compact, angular. Extending to full depth of excavation where refusal was met in both test pits at depths of between 2.0 and 2.3m.

4.4.2 Harvey Tank Location

The Harvey tank is located in between a switch-back turn on the existing gravel surfaced access road. The tank is situated on a level bench excavated into the eastern slope exposing bedrock below the uphill portion of access road, and a 1 to 2 block high retaining wall on the west of the site, retaining soil above the downhill portion of access road. Two test pits (TP17-03 and TP17-04) were dug in fill area to the west of the existing tank and south of the existing tank. To assist in determining depth to bedrock and to develop bedrock profiles, in addition to the test pit program, a subsequent seismic refraction survey was conducted by Frontier Geosciences Inc under subcontract to EXP. The results of the seismic refraction survey are included in Appendix B. The following subsurface soil units were inferred based on the results of the test pitting and subsequent seismic refraction survey results.

UNIT A FILL - Road base consisting of brownish grey sandy gravel with some silt, compact to dense 0.2m thick encountered in TP17-03 only.

UNIT B FILL - Sandy gravel to gravelly sand, with some cobbles and boulders, trace of silt, with boulders becoming more frequent with depth found in both test pits and becoming gravel and silt at 0.9m depth in TP17-04 only, layer extended to 1.5m depth.

UNIT C Sand, trace to some gravel, trace silt, occasional cobbles and boulders, compact, extending to full depth of excavation of 2.9m in TP17-03 and to 3.0m depth in TP17-04 where the pit was refused on an inferred large boulder.

UNIT D Bedrock - surface was inferred to be at depths of between 2.8m and 5.0m at the existing tank location, and was generally considered to be relatively flat to gently sloping down towards the west in the tank area.

4.4.3 Phase IV and V Tank Locations

As previously discussed it is understood that the Phase IV and V tanks will be removed. As requested, a test pit (TP17-05) was conducted at the Phase IV site only. Subsurface soils were in general agreement with the surficial geology mapping and generally consisted of one unit of soil as noted below:

UNIT A Cobbles and boulders with interstitial fine sand, some silt, compact to dense.

4.4.4 Proposed Bayview PRV Location

The Bayview PRV location is located at a bend in the road on Upper Bayview Road where the gravel access road to the Phase IV and V tanks meets Upper Bayview Road. The ground is generally flat, but slopes up towards the east and down towards the west a few metres from the proposed location. One test pit (TP17-05) was conducted at the proposed Bayview PRV location. Subsurface soils were in general agreement with the surficial geology mapping and generally consisted of one unit of soil as noted below:

UNIT A Gravelly cobbles and boulders with interstitial sand, some silt, compact to dense.

4.4.5 Access Roads

Oceanview Road (Harvey Tank Access Road)

The access road to the Harvey tank is paved for the first approximately 150m from the gate located on the cul-de-sac at the end of the public roadway. A rock stack wall with geogrid was noted on the downslope side for the first approximately 40 to 50m which ranged from about 1 to 4m high. Steep natural slopes are encountered below a small bend at the toe of the wall (approximately 1H:1V Horizontal: Vertical). Uphill of the rock stack wall, the downslope of the roadway embankment appears over-steepened and the fill appears to be partially held up by existing trees which show some signs of curvature or bulging from possible fill soil creep, and some longitudinal cracking was observed in the paved portions of the roadway. The upslope appears to have been excavated to provide the fill embankment soils on the down slope and is over-steepened for the first couple of metres, and then slopes up at what appears to be the natural slope of about 1H:1V.

At about 200m uphill (south) of the gate entrance, the road begins to widen and the road turns away from the steep natural slope as the natural slope also appears to become less steep on the upslope side of the road. As the road turns 180 degrees towards the north, the natural slopes moderate slightly before the road turns another switchback southwards approaching the Harvey tank site. As the road turns north again around the Harvey tank, the embankment steepens as bedrock is exposed east of the tank and becomes vertical. The cut slope on the east side of the road in this area becomes vertical into bedrock about 2 to 3m high with 1H:1V slopes above.

Access Road to Phase IV and V Tanks

The access road to the Phase IV and V tanks slopes up heading north from Upper Bayview Road and slope heights at the downslope on the west begin to rise from the intersection with Upper Bayview Road as the road climbs to the north. The fill and cut slopes are over-steepened, and it appeared the road was constructed with cut on the east deposited as fill on the west. The natural downslope and upslopes are steep, in the order of 1H:1V, until the road begins to turn towards the east where the road begins to travel directly up the slope which moderates to about 2.5H:1V. One test pit (TP17-06) was conducted at the fill edge on the west of the access road and subsurface soils generally agreed with those expected from the surficial geology mapping. A summary of the soils encountered is included below:

UNIT A FILL - Gravelly cobbles and boulders with interstitial sand, some silt, compact to dense, about 1.5m thick.

UNIT B Gravelly sand, some silt, occasional cobbles and boulders, compact to dense, extended to depth of exploration at 2.7m.

4.5 Groundwater Conditions

Groundwater was not encountered in any of the test pits at time of excavation and a static groundwater table is generally not expected be encountered within the depths of proposed construction. However, seepage associated with perched groundwater on top of dense soils or bedrock at depth may be encountered, particularly during winter periods and following extended precipitation.

5.0 SEISMIC CONSIDERATIONS

Based on published geological information of the region, EXP's experience nearby, site reconnaissance, and the test pit information obtained as part of the geotechnical exploration program described herein, the Site Classification for each of the subject locations can be taken as Site Class C. For firm ground at this site, for a 2% probability of exceedance in 50 years, the Peak Ground Acceleration can be taken as 0.40g. The spectral acceleration values may be taken as: SA(0.2) = 0.83, SA(0.5) = 0.59, SA(1.0) = 0.32, and SA(2.0) = 0.17.

Due to the relative density of the subgrade at this site, groundwater level not being encountered, and expected shallow bedrock, the proposed sites are not considered to be susceptible to liquefaction during a major seismic event.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Excavation and Dewatering

Temporary cut slopes less than 1.2m high could be cut to near vertical, and cut slopes in soil exceeding 1.2m should be cut no steeper than 1H:1V. The slope cuts should be protected with polyethylene sheeting to protect slopes against erosion during periods of "wet" weather. Excavations within looser/softer soils or in areas of groundwater seepage would need to be trimmed back to a flatter inclination, subject to review during construction.

Excavation depths that exceed Worksafe BC guidelines should be reviewed by a Geotechnical Engineer in accordance with WorkSafeBC.

It is estimated that groundwater, if encountered during the site stripping/excavation, could be controlled by pumping from sumps.

However, the design, operation, and maintenance of any required dewatering, and excavation slopes or shoring system should ultimately be the responsibility of the contractor. The contractor will need to determine the means and methods of dewatering and shoring necessary to meet the project requirements.

6.3 Foundation Design

6.3.1 Highway tank

6.3.1.1 Tank & Electrical Kiosk Foundations

The Highway tank and electrical kiosk should be founded on conventional shallow strip footings with slab-on-grade floor, raft slab, or a combination of both placed upon a bedding layer placed above Unit B soils or bedrock if encountered, as described below.

Due to the cobbley / boulder nature of Unit B, an uneven surface may result, with cobble and boulder intrusions encountered at the foundation level, it this condition is encountered it is recommended that the foundation be over-excavated 0.5m and reinstated with granular structural fill such as pit run gravel, granular base or clear crush rock compacted to at least 95% Modified Proctor Maximum Dry Density (MPMDD). The structural fill layer should extend at least 0.5m beyond the foundation footprint. The subgrade should be kept in an undisturbed condition prior to placing the structural fill. Foundations should be placed a minimum of 0.45m below grade for frost protection and confinement purposes.

Foundations supported on ground prepared as recommended above may be designed on the basis of a Serviceability Limit State (SLS) bearing pressures of 150 kPa for average contact area. A factored ultimate bearing resistance of 225 kPa (ULS) may be used when considering seismic loading. A Preliminary modulus of subgrade reaction of 48,000 kN/m^3 can be assumed for design.

Static settlement of the proposed new Highway Tank and electrical kiosk are estimated to be less than 25mm.

6.3.2 Harvey Tank

6.3.2.1 Tank Foundation and Existing Buried Chamber

The Harvey Tank could be founded on conventional shallow strip footings with slab-on-grade floor or raft slab, founded on a bedding layer placed above Unit C soils, as described below. It is also understood that the existing chamber will be upgraded to include a small addition, which could be founded on conventional shallow strip footings with slab-on-grade floor or raft slab, founded on a bedding layer placed above Unit B, C or bedrock as described below. Where placed on Unit B soils, the subgrade should be thoroughly compacted with a heavy ride-on type vibratory steel drum roller in order to achieve a minimum 95% MPMDD within at least the upper 300mm.

Due to the cobbley / bouldery nature of Unit B and C soils, an uneven surface may result, with cobble and boulder intrusions encountered at the foundation level, if this condition is encountered at design foundation subgrade level, it is recommended that the foundation be over-excavated 0.5m and reinstated with granular structural fill such as pit run gravel, granular base, shot rock or clear crush rock compacted to at least 95% Modified Proctor Maximum Dry Density (MPMDD). The structural fill layer should extend at least 0.5m beyond the foundation footprint. The subgrade should be kept in an undisturbed condition prior to placing the structural fill. Foundations should be placed a minimum of 0.45m below grade for frost protection and confinement purposes. As the foundation preparation for the existing tank could not be confirmed, upon removal of the existing tank foundation, EXP should be contacted to review the subgrade soils and test pits should be completed with the contractors on site equipment to confirm the previous subgrade preparation and to determine if any subgrade improvement such as excavation and replacement with compacted structural fill.

Foundations supported on ground prepared as recommended above may be designed on the basis of a Serviceability Limit State (SLS) bearing pressures of 150 kPa for average contact area. A factored ultimate bearing resistance of 225 kPa (ULS) may be used when considering seismic loading. A Preliminary modulus of subgrade reaction of 48,000 kN/m^3 can be assumed for design.

Static settlement of the proposed new Harvey Tank and buried chamber addition are estimated to be less than 25mm with differential settlement of about half the total over a span of 10m.

6.3.2 Bayview PRV

Bayview PRV should be founded on a bedding layer placed above Unit A gravelly cobbles and boulders as described below.

Due to the cobbley / boulder nature of Unit B, an uneven surface may result, with cobble and boulder intrusions encountered at the foundation level, it this condition is encountered it is recommended that the foundation be over-excavated 0.5m and reinstated with granular structural fill such as pit run gravel, granular base or clear crush rock compacted to at least 95% Modified Proctor Maximum Dry Density (MPMDD). The structural fill layer should extend at least 0.5m beyond the foundation footprint. The subgrade should be kept in an undisturbed condition prior to placing the structural fill. Foundations should be placed a minimum of 0.45m below grade for frost protection and confinement purposes.

Foundations supported on ground prepared as recommended above may be designed on the basis of a Serviceability Limit State (SLS) bearing pressures of 150 kPa for average contact area. A factored ultimate bearing resistance of 225 kPa (ULS) may be used when considering seismic loading. A Preliminary modulus of subgrade reaction of 48,000 kN/m^3 can be assumed for design.

Static settlement of the proposed PRV kiosk is estimated to be less than 25mm.

6.4 Slope Stability Assessment

6.4.1 Highway tank

As previously discussed, the Highway tank site slopes down towards the adjacent Harvey Creek to the north. No signs of slope instability were observed during the site reconnaissance.

To provide adequate stability for static and seismic conditions the new tank base and electrical kiosk foundations should be setback such that they are founded below a projection line of at least at a 2H:1V (Horizontal: Vertical) from the base of the creek.

6.4.2 Harvey Tank

As previously discussed in Section 6.3.1, for stability during seismic event, the proposed tank should be founded on bedrock if encountered or bedding layer and be structurally anchored into the Bedrock. No signs of slope instability were observed around the existing tank location. The Harvey tank location is generally flat and considered stable from a global stability point of view.

6.4.3 Bayview PRV

The immediate area surrounding the proposed Bayview PRV is generally gently sloping, and there are no site specific slope stability concerns.

6.4.4 Access Roads

As previously mentioned a reinforced rock stack wall was noted at the beginning of the access road to the Harvey tank which suggests that a previous washout or slope instability / sloughing may have and the reinforced rock stack was implemented as a solution to the works.

At both access road locations, the over steepened fill and cut slopes observed along the access roads are generally considered to be marginally stable and do not have static Factor of Safety (FOS) greater than 1.5, and based on soils encountered in test pits and observations during site reconnaissance, the estimated static FOS could be closer to 1.1.

The overall steep mountainous slopes above and below the road embankments / cuts are also considered to be marginally stable with an overall static FOS in the order of about 1.3 based on the assumed soil conditions.

During a period of extreme weather, (i.e. prolonged heavy rainfall, rapid snow melt, extended freeze thaw cycles, or seismic event) localized sloughing, or instability of slopes should be expected. As the road cuts/fills are considered to be less stable than the natural slopes, more frequent sloughing or localized instability should be expected along the steep road embankments and cuts, which would require maintenance and repair when such events occur.

Reinforced slopes or retaining structures could be considered to improve the stability and long-term performance of the road cut/fill prism in over-steepened areas generally noted in areas as shown on the attached Sketch 1 and Sketch 2. However, the stability of the natural slopes would generally still be marginal and localized instability during a seismic event or extreme weather event would still be likely.

6.5 Backfill

In general, backfill for excavations and trenches should consist of granular soil such as; reused excavated granular soils with less than 8% passing the 0.075mm sieve screened to remove oversize particles larger than 150mm, or 75mm minus pit run sand and gravel. The granular backfill should be placed in 300mm loose lifts and compacted to achieve at least 95% MPMDD. If work is to commence during the wet winter months, then it is recommended that fines content (% passing 0.075mm sieve) for granular soils be limited to a maximum of 5%.

Re-use of granular soils are subject to the review and approval of the Geotechnical Engineer at time of construction. Silty soils if encountered should not be re-used as backfill.

6.6 Lateral Earth Pressures for Below Grade Wall Design

Lateral earth pressures for design of below grade walls have been evaluated. Recommended design lateral earth pressures are presented in the attached Figure 4. In providing the pressure diagram it is assumed that the walls are "rigid" without freedom to rotate and that an at-rest pressure condition (non-yielding) would exist, where H is the height of the wall below grade. The seismic component was calculated based on the 2475-year return period earthquake according to BCBC 2012. It was assumed that level ground surface within the distance of H at the top of foundation walls could be accommodated, however, based on the sloping topography we understand this might not be achievable, and should be reassessed during final design once positioning of tanks and final grading details can be provided to EXP. A perforated drainage pipe should be considered as shown on Figure 4 to maintain a drained condition around underground facilities.

6.7 Pipe Bedding

Based on the interpreted subsoil conditions, the subgrade at pipe invert level could consist of variable conditions including; compact gravel, cobbles, boulders, sand, a mixture of those soils, or bedrock. Any existing loose sand encountered at the pipe subgrade should be re-compacted to at least 95% Modified Proctor maximum dry density (ASTM D-1557). The re-compacted fill and compact to dense granular soil or bedrock are considered suitable for the support of the utility pipe. A minimum bedding thickness equal to at least one quarter (¼) of the pipe diameter and not less than 150mm should be allowed for beneath the pipe. The bedding material should meet gradation specification for Type 1 "Granular Pipe Bedding and Surround Material" per MMCD Section 31 05 17 Item 2.7. Where bedrock or cobbley / bouldery soil is encountered the bedding layer should be at least 300mm thick with any pinnacle in bedrock and protracting cobbles / boulders removed prior to placing the bedding

Note that if any localized soft silt, organic silt or peat areas are encountered at the bottom of the trench excavation, they should be over-excavated a minimum of 450mm below pipe invert and replaced with the specified pipe bedding material along with a non-woven geotextile fabric (such as Nilex 4551 or approved equivalent) below the bedding directly on the soft subgrade. Further, the excavation should be fully dewatered prior to placing and compacting the bedding material. If significant water seepage is encountered and the water cannot be effectively drained, a 19mm minus clear crush gravel should be used as pipe bedding and compacted to achieve the equivalent of the specified compaction.

6.9 Subgrade Review and Testing

Engineering review of site foundation subgrade preparation, excavation stability and monitoring and testing of backfills should be carried out by EXP during the progress of the work. This will allow for geotechnical aspects of the project to be verified for compliance with the geotechnical recommendations and allow for design changes during construction, as appropriate.

7.0 CLOSURE

Please be advised that the contents of this report are based on preliminary information and drawings provided to us and our understanding of the project as described in this report.

This report was prepared for the exclusive use of AECOM, the Village of Lions Bay, and their designated consultants/agents and may not be used by other parties without written consent of EXP Services Inc. The attached "Interpretation & Use of Study and Report" forms an integral part of this report and must be included with any copies of this report.

We appreciate this opportunity to be of service to you. If you have any questions regarding the contents of this report, or if we can be of further assistance to you on this project, please call the undersigned.

Yours truly,

EXP Services Inc.

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, R. A. S. KORHONEN # 43423

2017-Nov-15

Renee Korhonen, P.Eng.
Geotechnical Engineer

Ben Weiss, P. Eng.
Senior Geotechnical Engineer

Enclosures:
- Interpretation & Use of Study and Report
- Figures 1 to 3 - Test Pit Location Plan
- Figure 4 - Lateral Earth Pressure on Non-Yielding Walls
- Sketches 1 & 2 - Over-Steepened Road Cut / Fill Slopes
- Appendix A - EXP Test Pit Logs (TP17-01 to TP17-07)
- Appendix B - Seismic Refraction Survey Results (Interpreted Bedrock Elevation, Site Plan & Interpreted Depth Sections SL-1 to SL-5)

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering consulting practices in this area. No other warranty, expressed or implied, is made. Engineering studies and reports do not include environmental consulting unless specifically stated in the engineering report.

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 THE REPORT

The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose 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 are only valid to the extent that 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.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming 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. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT

a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates 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 and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising 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 all persons making use of such documents or records should be aware of, and accept, this risk. 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 persons providing information.

c. To avoid misunderstandings, **exp** Services Inc. (**exp**) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by **exp**. Further, **exp** should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor's work is being carried out in general conformity with **exp**'s recommendations. Any reduction from the level of services normally recommended will result in **exp** providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

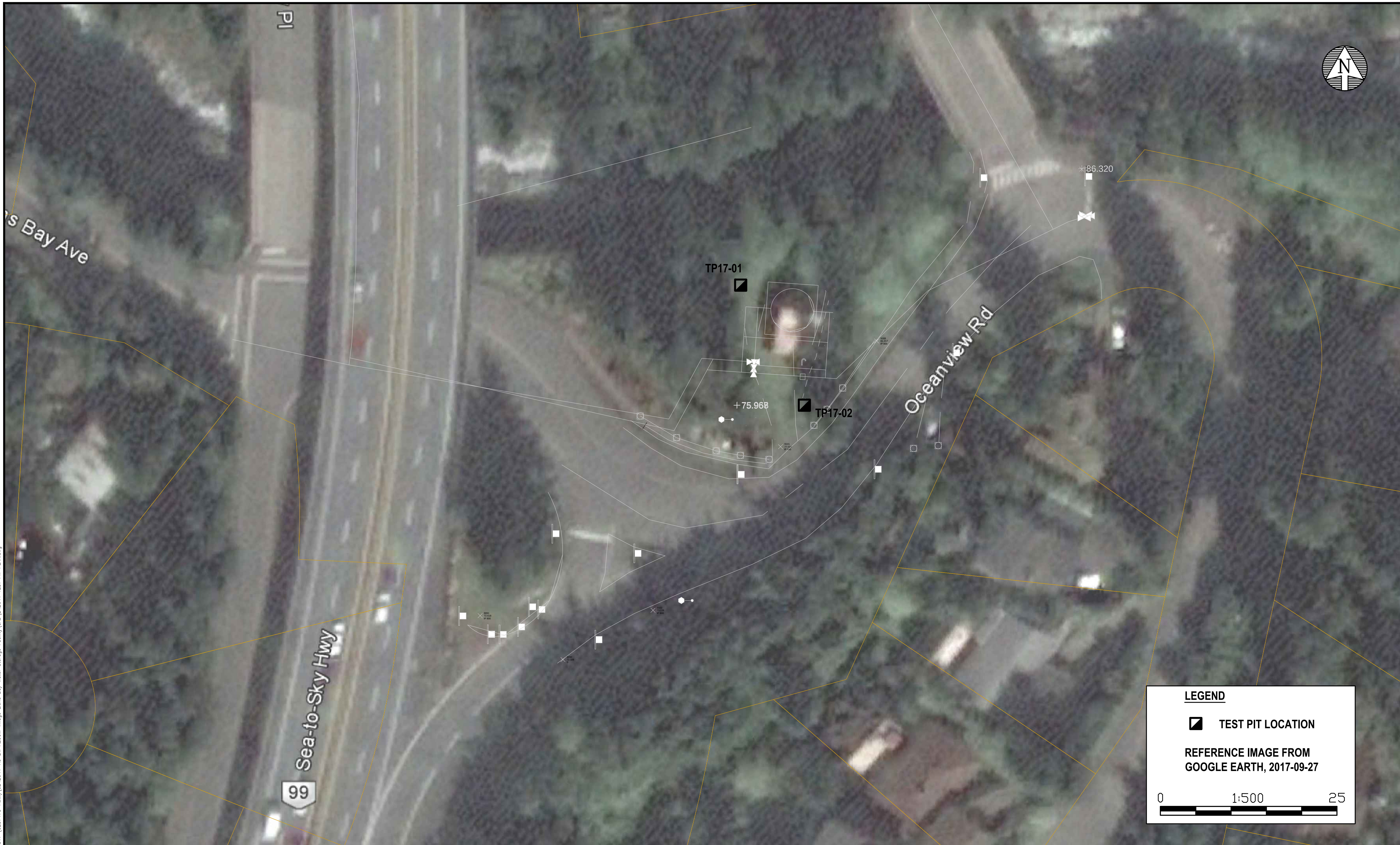
When **exp** submits both electronic file and hard copies of reports, drawings and other documents and deliverables (**exp**'s instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by **exp** shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by **exp** shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of **exp**'s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except **exp**. The Client warrants that **exp**'s instruments of professional service will be used only and exactly as submitted by **exp**.

The Client recognizes and agrees that electronic files submitted by **exp** have been prepared and submitted using specific software and hardware systems. **Exp** makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

Figures and Sketches

Figures 1 to 3 - Test Pit Location Plan
Figure 4 - Lateral Earth Pressure on Non-Yielding Walls
Sketches 1 to 2 - Over-steepened roadway cut / fill slopes



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DFTR.	
DSGN.	
CHK.	
REVISIONS	No. / DESCRIPTION / DATE
CLIENT	AECOM CANADA LTD.
PROJECT	VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT
PROJECT NO.	VAN-00242641-A0
TITLE:	TEST PIT LOCATION PLAN HIGHWAY TANK
DATE	2017-09-27
SCALE:	1:500
DWG NO.	FIGURE 1

L:\2017 (0237475-A0...)\0242641-A0 BW AECOM Village Lions Bay Water Storage Facility\CAD\242641 TEST PIT PLAN.dwg
Oct 25, 2017 – 2:49pm

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Burnaby, British Columbia V5G 4W3
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DFTR.	REVISIONS		
DSGN.	No.	DESCRIPTION	DATE
CHK.			

CLIENT: AECOM CANADA LTD.

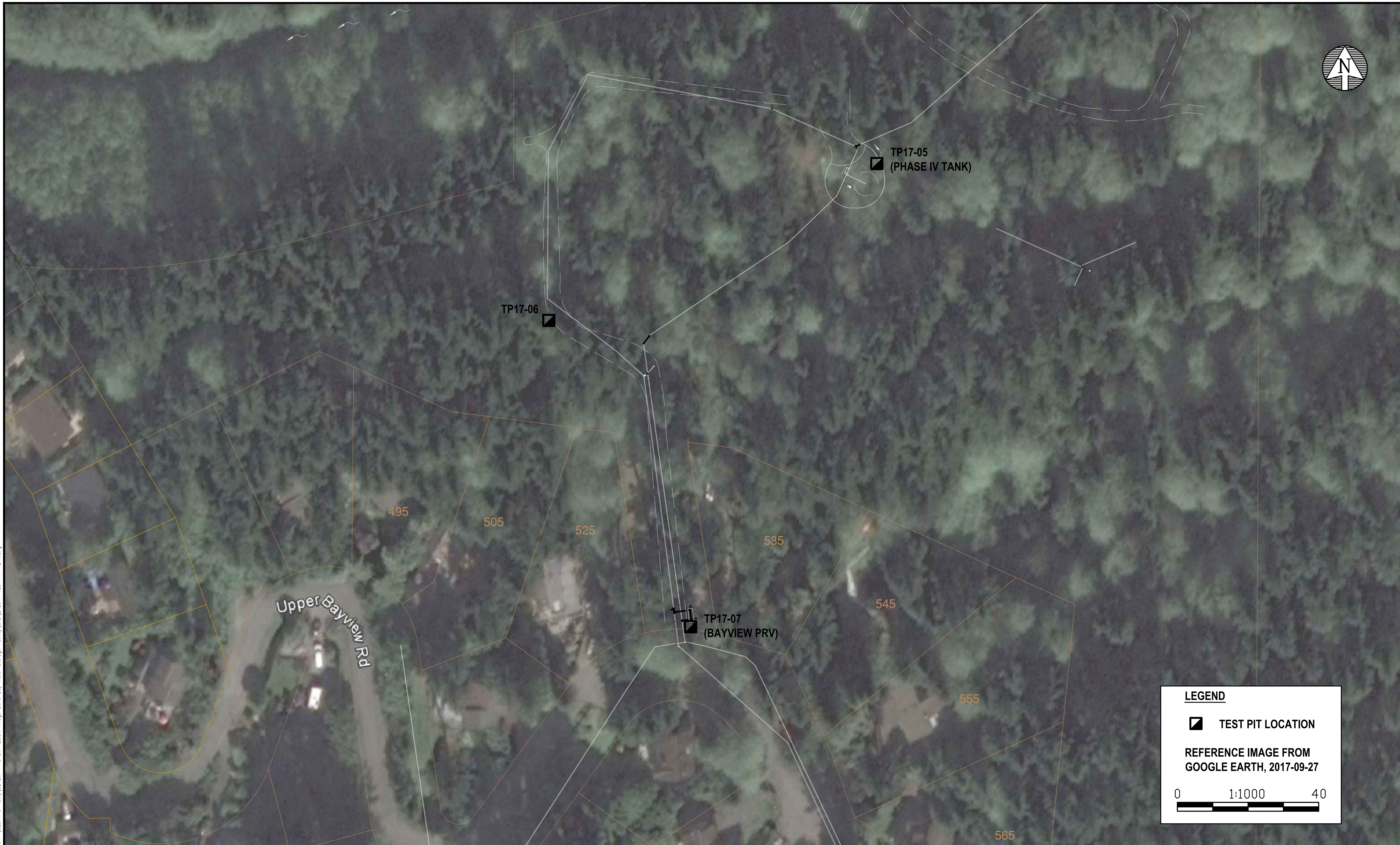
PROJECT: VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT

PROJECT NO.: VAN-00242641-A0

TITLE: TEST PIT LOCATION PLAN
HARVEY TANK

DATE	SCALE:	DWG NO.
2017-09-27	1:500	FIGURE 2

L:\2017 (0237475–A0...)\0242641–A0 BW AECOM Village Lions Bay Water Storage Facility\CAD\242641 TEST PIT PLAN.dwg
Oct 25, 2017 – 2:49pm



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DFTR.	REVISIONS		
DSGN.	No.	DESCRIPTION	DATE
CHK.			

CLIENT: AECOM CANADA LTD.

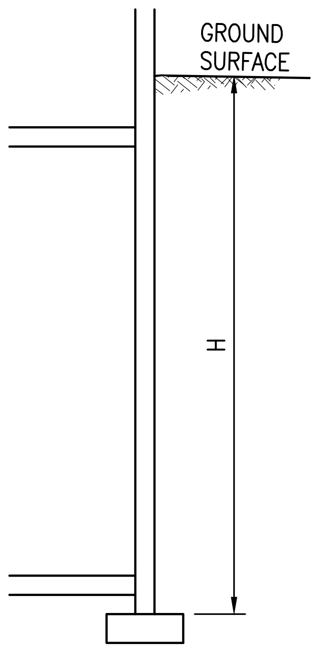
PROJECT: VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT

PROJECT NO.: VAN-00242641-A0

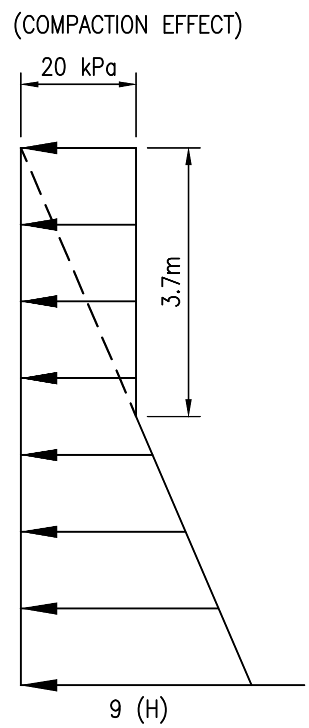
TITLE: TEST PIT LOCATION PLAN
BAYVIEW PRV AND PHASE IV TANK

DATE	SCALE:	DWG NO.
2017-09-27	1:1000	FIGURE 3

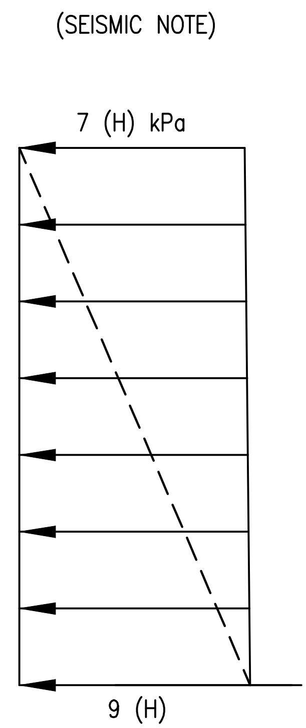
L:\2017 (0237475-A0...)\0242641-A0 BW AECOM Village Lions Bay Water Storage Facility\CAD\242641 TEST PIT PLAN.dwg
Oct 25, 2017 – 2:52pm



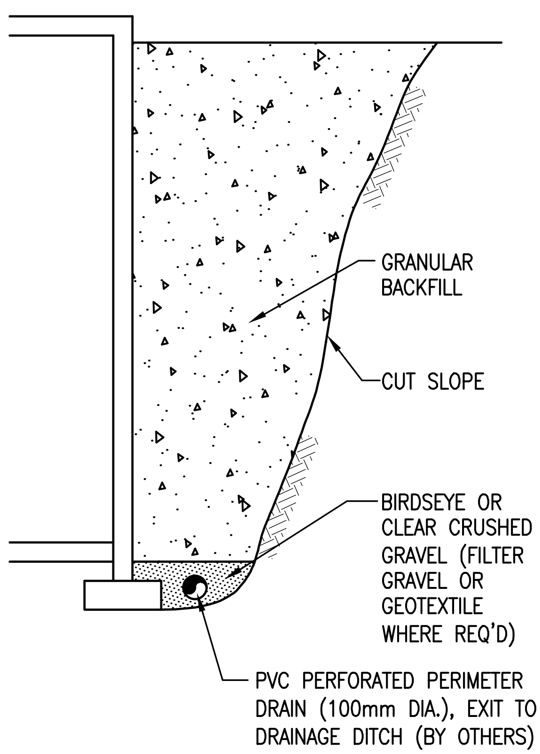
TYPICAL FOUNDATION WALL



STATIC



SEISMIC+STATIC



NOTES:

- ALL METRIC UNITS IN (m) AND (kPa)
- ACTIVE PRESSURE IS CALCULATED BASED ON ϕ=33 DEGREE AND γ =20kN/m^3
- EARTH PRESSURE AT REST COEFFICIENT Ko = 0.46
- THE PRESSURES GIVEN IN THIS DIAGRAM ARE UNFACTORED. USE APPROXIMATE LOAD FACTORS.
- ASSUMED DRAINED CONDITIONS WTIH NO HYDROSTATIC PRESSURE BUILDUP BEHIND WALL
- SEISMIC COMPONENT BASED ON: Kh = PGA = 0.40g
- ASSUMED GROUND SURFACE FLAT WITH DISTANCE H AT TOP OF WALL

exp.

CLIENT	AECOM CANADA LTD.
PROJECT	VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT
TITLE:	LATERAL EARTH PRESSURE ON NON-YIELDING WALLS, 2475 EQ

PROJECT NO.	DFTR.	DSGN.	CHK.	DATE	SCALE:	DWG NO.
VAN-00242641-A0	MG	RK	BW	2017-10-11	NTS	FIGURE 4

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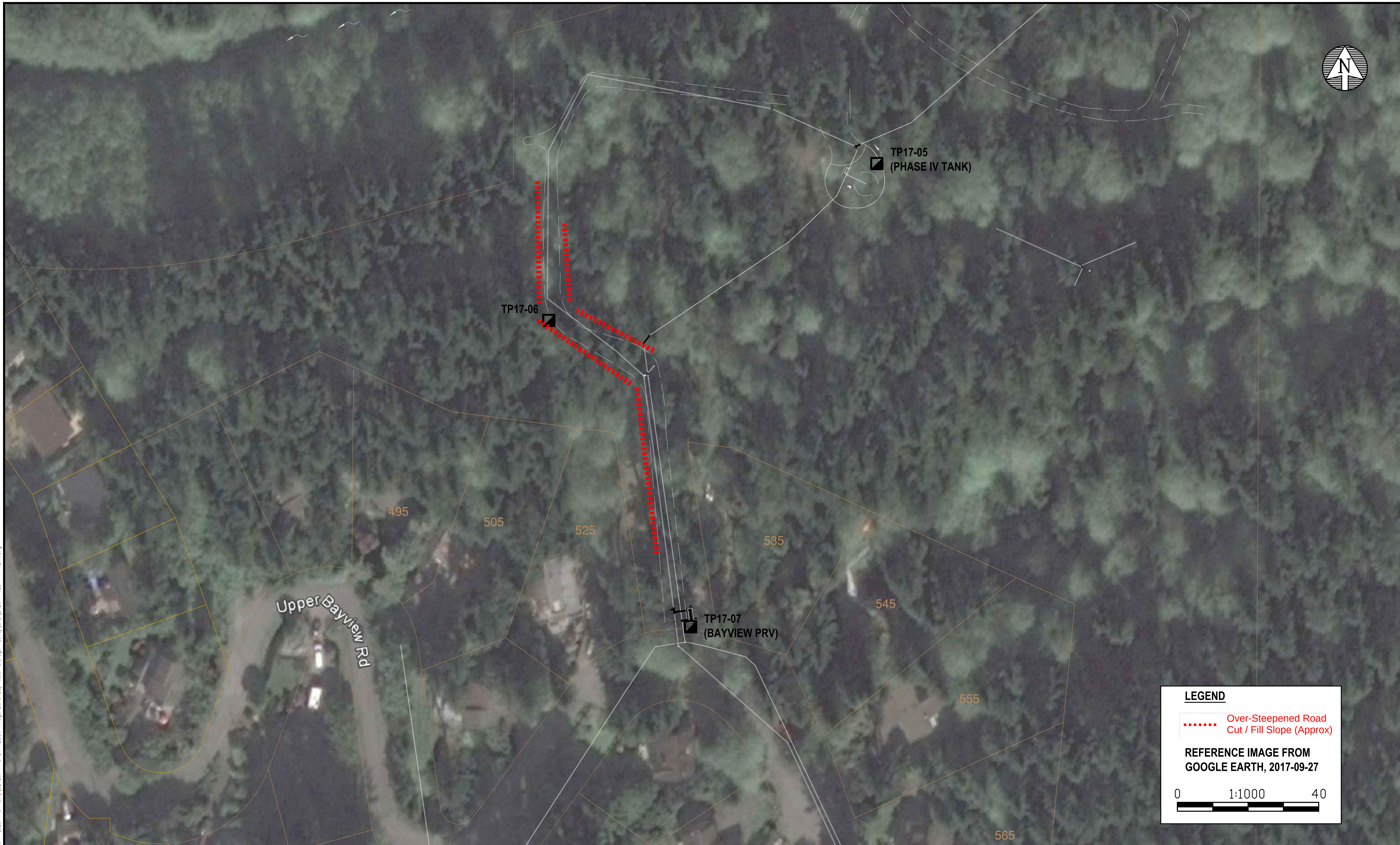
DFTR.	REVISIONS			CLIENT	AECOM CANADA LTD.
DSGN.	No.	DESCRIPTION	DATE	PROJECT	VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT
CHK.				PROJECT NO.	VAN-00242641-A0

TITLE:	TEST PIT LOCATION PLAN HARVEY TANK ACCESS ROAD		
DATE 2017-09-27	SCALE: 1:2000	DWG NO. Sketch 1	



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Telephone: 604–874–1245
Fax: 604–874–2358
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DFTR.	REVISIONS			CLIENT: AECOM CANADA LTD.	TITLE: TEST PIT LOCATION PLAN BAYVIEW PRV AND TANKS IV & V		
DSGN.	No.	DESCRIPTION	DATE	PROJECT: VILLAGE OF LIONS BAY WATER STORAGE FACILITIES REPLACEMENT			
CHK.				PROJECT NO. VAN-00242641-A0	DATE 2017-09-27	SCALE: 1:1000	DWG NO. Sketch 2

L:\2017 (0237475-A0...)\0242641-A0 BW AECOM Village Lions Bay Water Storage Facility\CAD\242641 TEST PIT PLAN.dwg
Oct 25, 2017 – 2:52pm

Appendix A

Test Pit Logs

TP17-01 through TP17-07

exp Services Inc.
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RECORD OF TEST PIT : TP17-01

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478418 E: 482911 Highway Tank
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS:
AT TIME OF EXCAVATION ---
EQUIPMENT TYPE 50 Series Mini Excavator
AT END OF EXCAVATION ---
LOGGED BY DGS **CHECKED BY** RK
AFTER EXCAVATION ---

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	POCKET PEN. (kPa) (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak Remold (40 80 120 160)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		PAVING STONES							
		SAND, some gravel, trace silt, grey, damp, (compact) well-graded (FILL)	0.1						
		SAND & GRAVEL, some silt to silty, frequent rootlets, brown, dry, (compact)	0.2	S1	GB				MC 2
		-layer of boulders and cobbles							
1		GRAVEL & COBBLES, some boulders, some sand, some silt, brown, dry, (compact) angular and coarse grained	0.9	S2	GB				MC 3
		-becomes more rocky with depth							

Refusal at 2.0m.

RECORD OF TEST PIT : TP17-02

exp Services Inc.
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Burnaby, BC V5G 4W3
Telephone: 1.604.874.1245
Fax: 1.604.874.2358

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478399 E: 482915 Highway Tank
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS: AT TIME OF EXCAVATION ---
EQUIPMENT TYPE 50 Series Mini Excavator
AT END OF EXCAVATION ---
LOGGED BY DGS **CHECKED BY** RK
AFTER EXCAVATION ---

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	POCKET PEN. (kPa) (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak Remold (40 80 120 160)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		VEGETATION							
		COBBLES & GRAVEL, some boulders, some sand, some silt, brown, dry, (compact)	0.1						
				S3	GB				2
1									
				S4	GB				2
2									
		- very hard digging							

Refusal at 2.3m.

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RECORD OF TEST PIT : TP17-03

PROJECT NUMBER VAN-00242641-A0
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
EXCAVATION DATE 2017-09-21
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
EXCAVATION METHOD Test Pit
EQUIPMENT TYPE 50 Series Mini Excavator
LOGGED BY DGS **CHECKED BY** RK

CLIENT AECOM Canada Ltd.
PROJECT LOCATION Lions Bay, BC
TEST PIT LOCATION N: 5478021 E: 483365 Harvey Tank
ELEVATION
GROUND WATER LEVELS: ▽ **AT TIME OF EXCAVATION** ---
▼ **AT END OF EXCAVATION** ---
▼ **AFTER EXCAVATION** ---

DEPTH (m)	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	POCKET PEN. (kPa) (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak / Remold (40 80 120 160)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
	SANDY GRAVEL, some silt, brownish grey, damp, (compact to dense) angular (ROADBASE FILL)		S5	GB				5
	SANDY GRAVEL, some cobbles and boulders, orangish brown, damp, (compact) sand was fine grained, gravel was angular (FILL)	0.2						
1			S6	GB				2
	-boulders/cobbles become more frequent with depth							
	SAND, trace to some gravel, light brownish grey, damp, (compact) medium grained	1.5						
	-cemented from 1.5 to 1.8m							
2			S7	GB				4

Bottom of test pit at 2.9m.

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RECORD OF TEST PIT : TP17-04

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478018 E: 483371 Harvey Tank
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS: AT TIME OF EXCAVATION ---
EQUIPMENT TYPE 50 Series Mini Excavator
AT END OF EXCAVATION ---
LOGGED BY DGS **CHECKED BY** RK
AFTER EXCAVATION ---

SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m	POCKET PEN. (kPa) (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak / Remold (40 80 120 160)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT PL MC LL (20 40 60 80)
VEGETATION							
GRAVELLY SAND, trace silt, light greyish brown, damp, (compact) sand was medium grained, gravel was angular to subangular (FILL)	0.1	S8	GB				MC 5
GRAVEL & SILT, some sand, some organics and roots, some cobbles, reddish brown, damp, (loose to compact) gravel was angular (FILL)	0.9	S9	GB				MC 11
SAND, some gravel, trace silt, occasional cobbles, orangish brown, damp, (compact)	1.5	S10	GB				MC 5
SANDSTONE, light greyish brown, damp, (hard) -alternating layers of fine and coarse grained	3.0	S11	GB				MC 6

Bottom of test pit at 3.7m.

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RECORD OF TEST PIT : TP17-05

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478633 E: 483344 Phase IV Tank
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS: **AT TIME OF EXCAVATION** ---
EQUIPMENT TYPE 50 Series Mini Excavator
AT END OF EXCAVATION ---
LOGGED BY DGS **CHECKED BY** RK
AFTER EXCAVATION ---

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SPT N VALUE BLOWS/0.3m (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	POCKET PEN. (kPa) (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak / Remold (40 80 120 160)	FINES CONTENT (%) (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		FOREST DETRITUS							
		COBBLES & BOULDERS with interstitial fine sand, some silt, reddish brown, dry, (compact to dense)	0.1						
1									

Refusal at 1.5m.

NOTES: Refusal on possible bedrock

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RECORD OF TEST PIT : TP17-06

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478605 E: 483276 Phase IV Access Road
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS: AT TIME OF EXCAVATION ---
EQUIPMENT TYPE 50 Series Mini Excavator
AT END OF EXCAVATION ---
LOGGED BY DGS **CHECKED BY** RK
AFTER EXCAVATION ---

DEPTH (m)	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	SPT N VALUE / DYNAMIC CONE	POCKET PEN. / FIELD VANE SHEAR	MOISTURE CONTENT (%)
	FOREST DETRITUS							
	GRAVELLY COBBLES & BOULDERS with interstitial sand, some silt, brown, damp, (compact to dense) gravel/cobbles were angular (FILL)	0.1	S12	GB				3
1								
	GRAVELLY SAND, some silt, occasional cobbles and boulders, brown, damp, (compact to dense)	1.5	S13	GB				5
2			S14	GB				4

Bottom of test pit at 2.7m.

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Fax: 1.604.874.2358

RECORD OF TEST PIT : TP17-07

PROJECT NUMBER VAN-00242641-A0
CLIENT AECOM Canada Ltd.
PROJECT NAME Village of Lions Bay Water Storage Facilties Replacement
PROJECT LOCATION Lions Bay, BC
EXCAVATION DATE 2017-09-21
TEST PIT LOCATION N: 5478515 E: 483279 Bayview PVR
EXCAVATION CONTRACTOR Atlas Leasing Ltd.
ELEVATION
EXCAVATION METHOD Test Pit
GROUND WATER LEVELS: ▽ **AT TIME OF EXCAVATION** ---
EQUIPMENT TYPE 50 Series Mini Excavator
▼ **AT END OF EXCAVATION** ---
LOGGED BY DGS **CHECKED BY** RK
▼ **AFTER EXCAVATION** ---

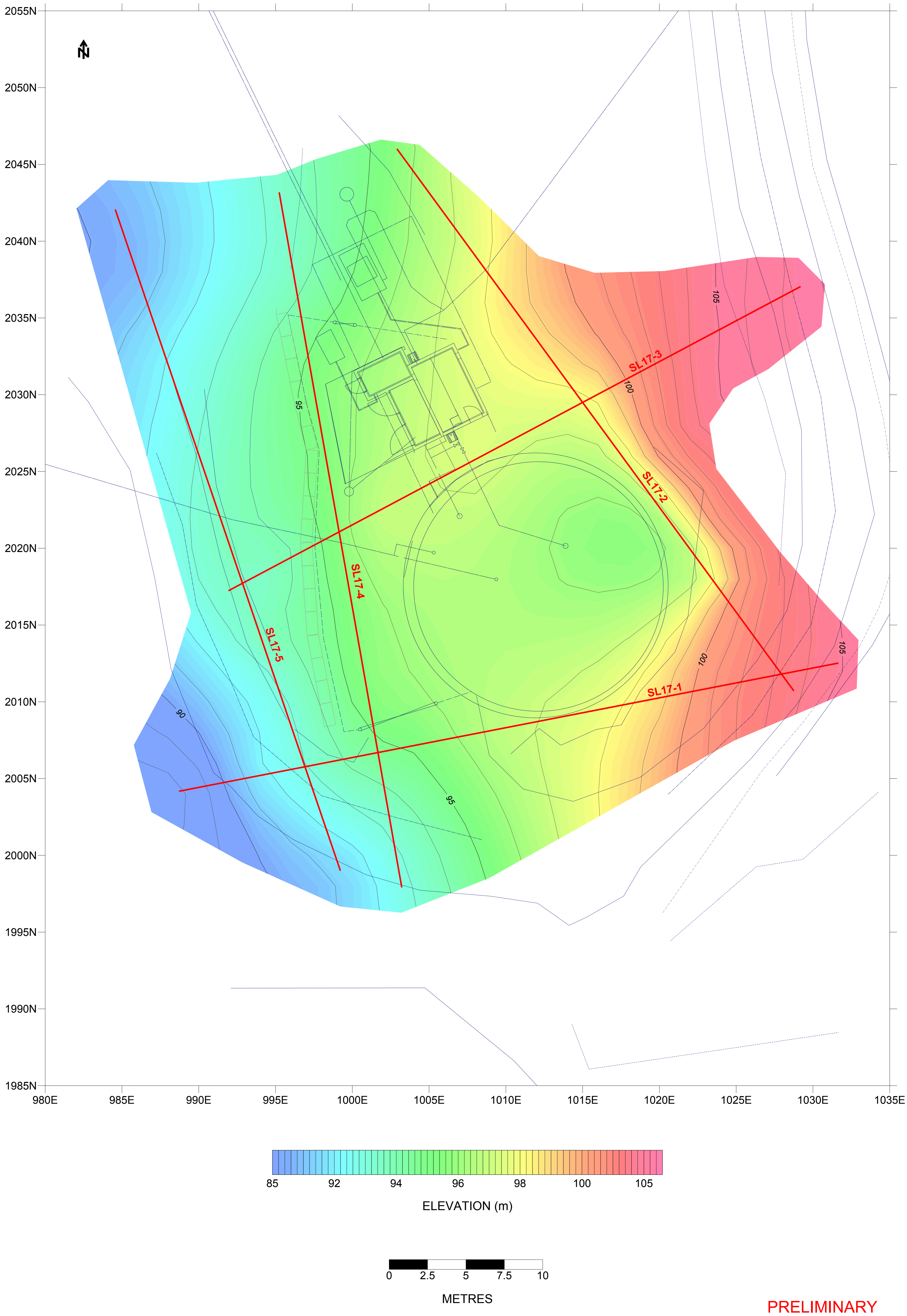
DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SPT N VALUE BLOWS/0.3m ▲ (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	POCKET PEN. (kPa) ⊙ (100 200 300 400) / FIELD VANE SHEAR (kPa) Peak ● Remold ○ (40 80 120 160)	FINES CONTENT (%) □ (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		VEGETATION							
		GRAVELLY COBBLES & BOULDERS with interstitial sand, some silt, brown, damp, (compact to dense) angular	0.1						
1									
				S15	GB				4
2		-silt content fluctuates with depth							

Bottom of test pit at 2.4m.

Appendix B

SEISMIC REFRACTION SURVEY RESULTS

Interpreted Bedrock Elevation, Site Plan & Interpreted Depth Sections SL-1 to SL-5



PRELIMINARY

EXP SERVICES INC.
WATER STORAGE REPLACEMENT PROJECT
LIONS BAY, BC

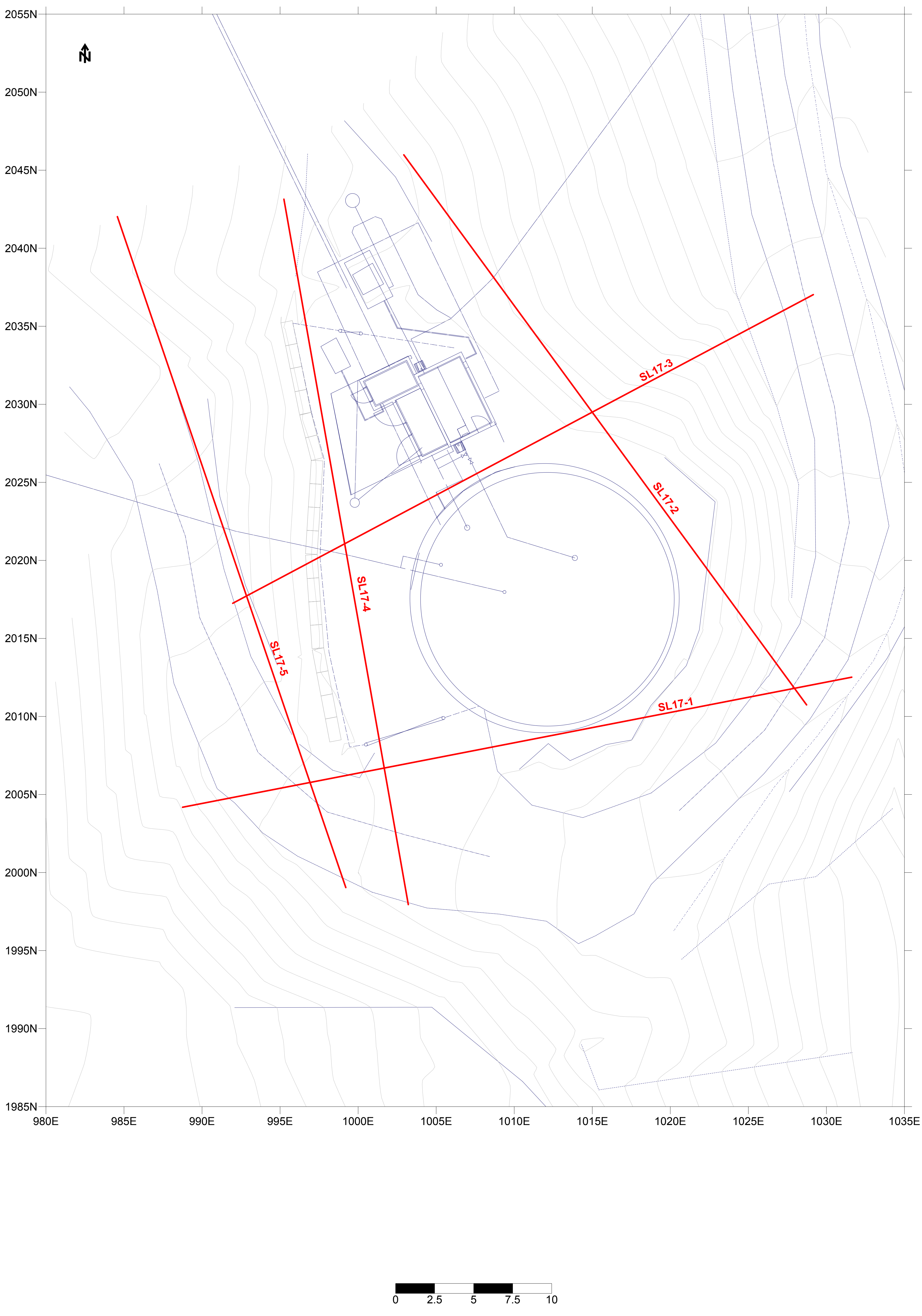
SEISMIC REFRACTION SURVEY

INTERPRETED BEDROCK ELEVATION CONTOUR PLAN

FRONTIER GEOSCIENCES INC.

DATE: OCT. 2017	SCALE 1:250	

COORDINATE SYSTEM: LOCAL
DATUM: LOCAL



PRELIMINARY

EXP SERVICES INC.
WATER STORAGE REPLACEMENT PROJECT
LIONS BAY, BC

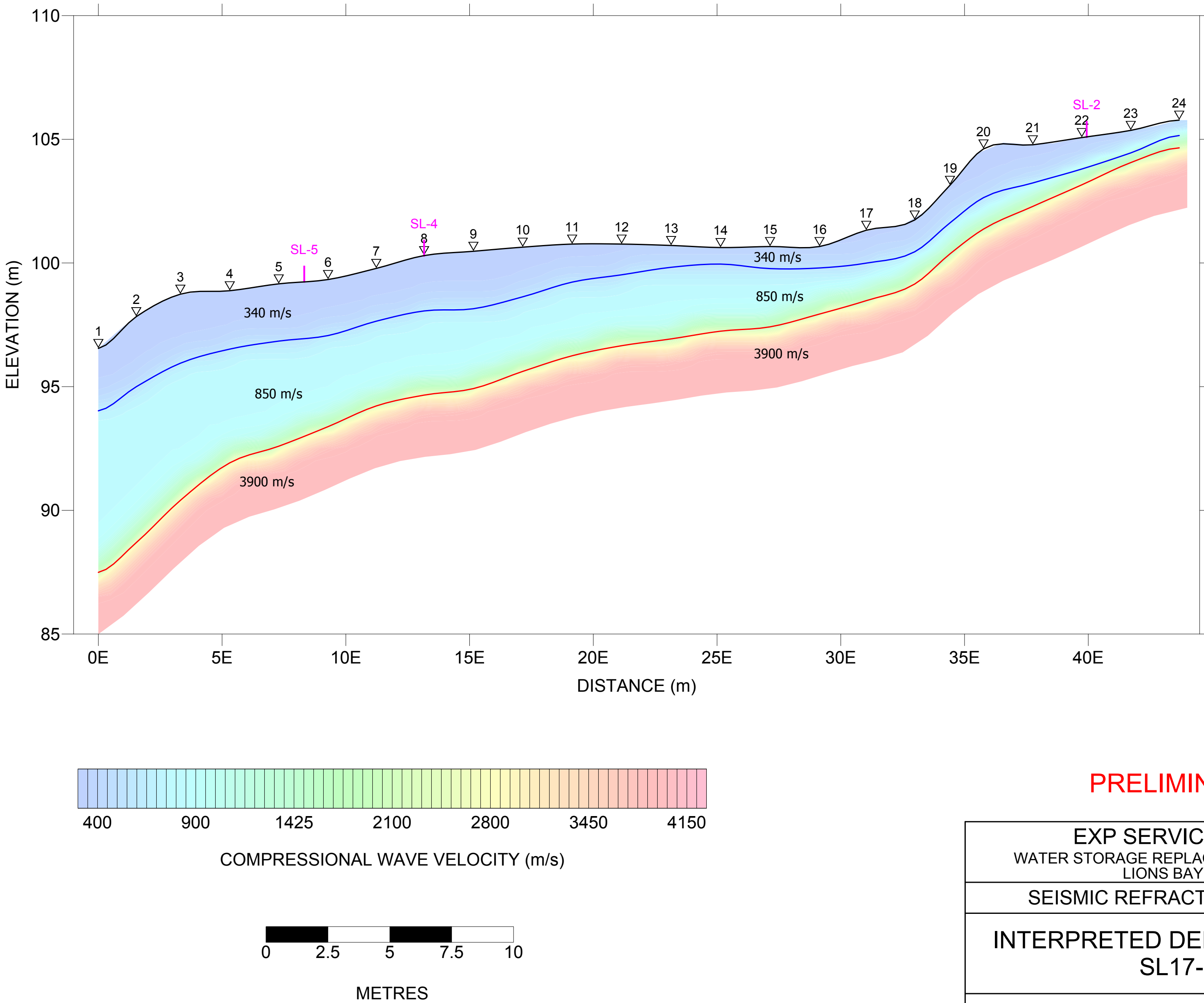
SEISMIC REFRACTION SURVEY

SITE PLAN

FRONTIER GEOSCIENCES INC.

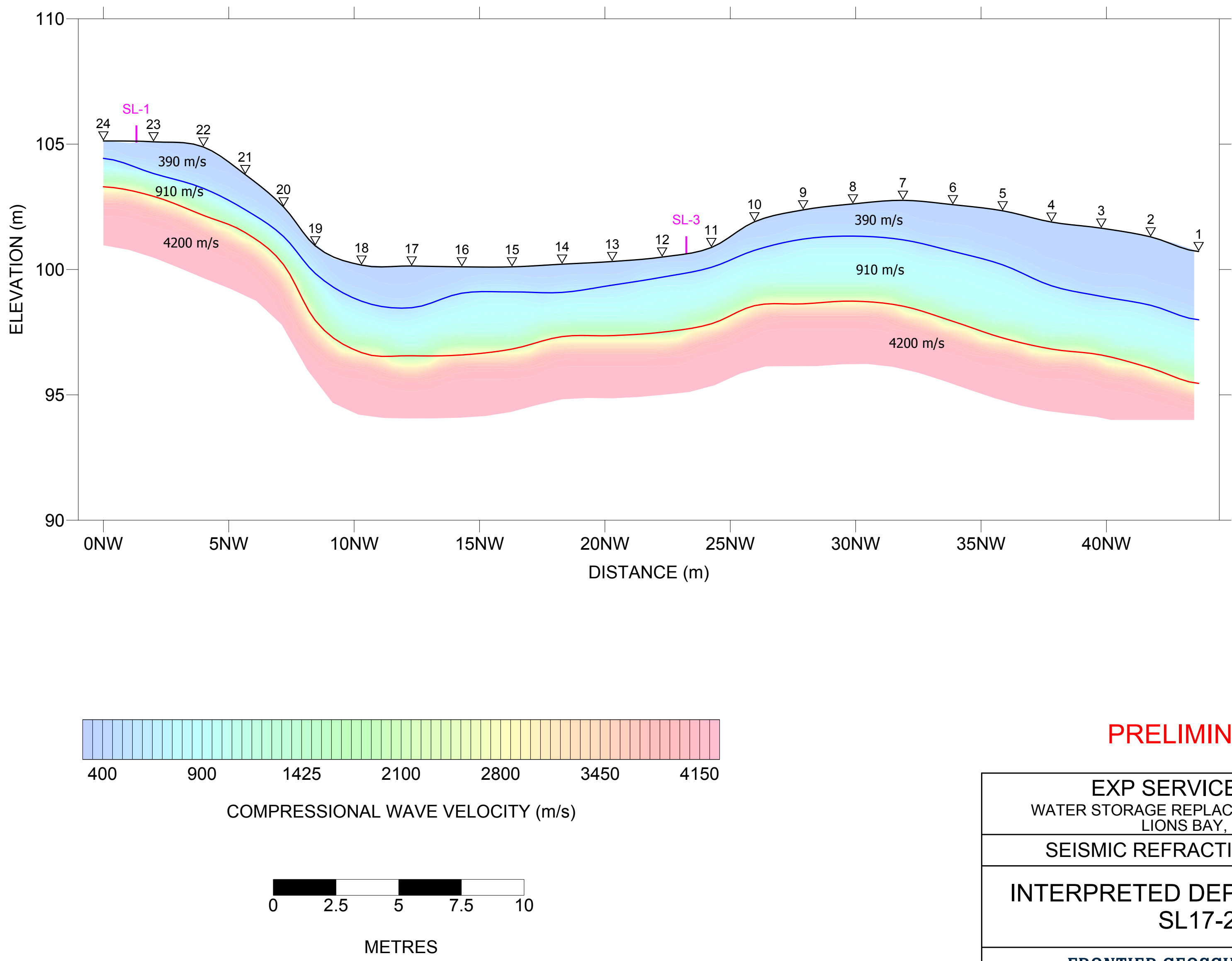
DATE: OCT. 2017 | SCALE 1:250 | FIG.

COORDINATE SYSTEM: LOCAL
DATUM: LOCAL



PRELIMINARY

EXP SERVICES INC. WATER STORAGE REPLACEMENT PROJECT LIONS BAY, BC
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL17-1
FRONTIER GEOSCIENCES INC.
DATE: OCT. 2017 SCALE 1:250



PRELIMINARY

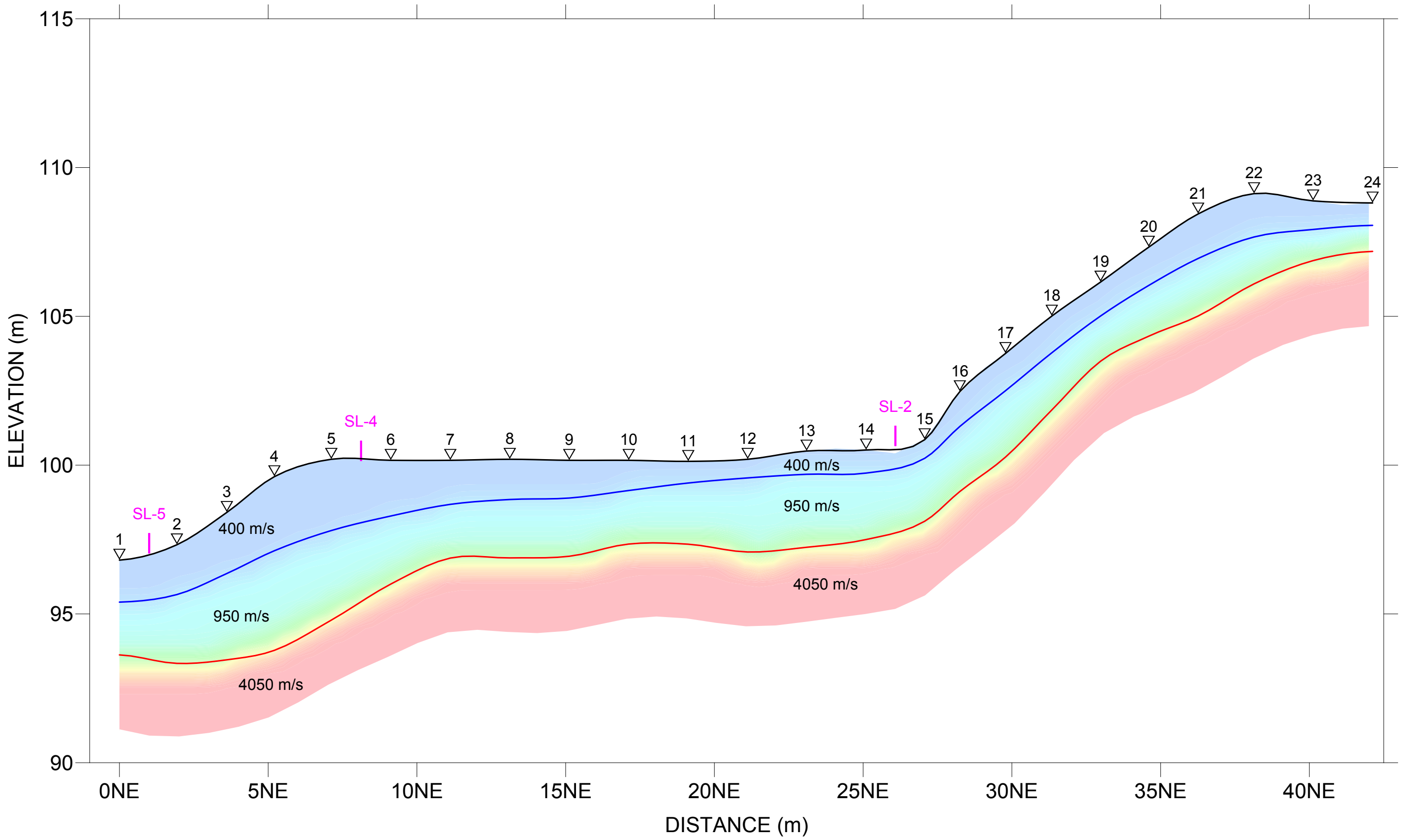
EXP SERVICES INC.
WATER STORAGE REPLACEMENT PROJECT
LIONS BAY, BC

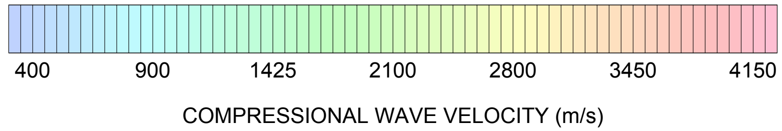
SEISMIC REFRACTION SURVEY

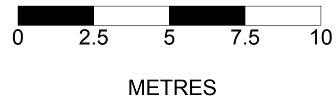
INTERPRETED DEPTH SECTION
SL17-2

FRONTIER GEOSCIENCES INC.

DATE: OCT. 2017	SCALE 1:250	

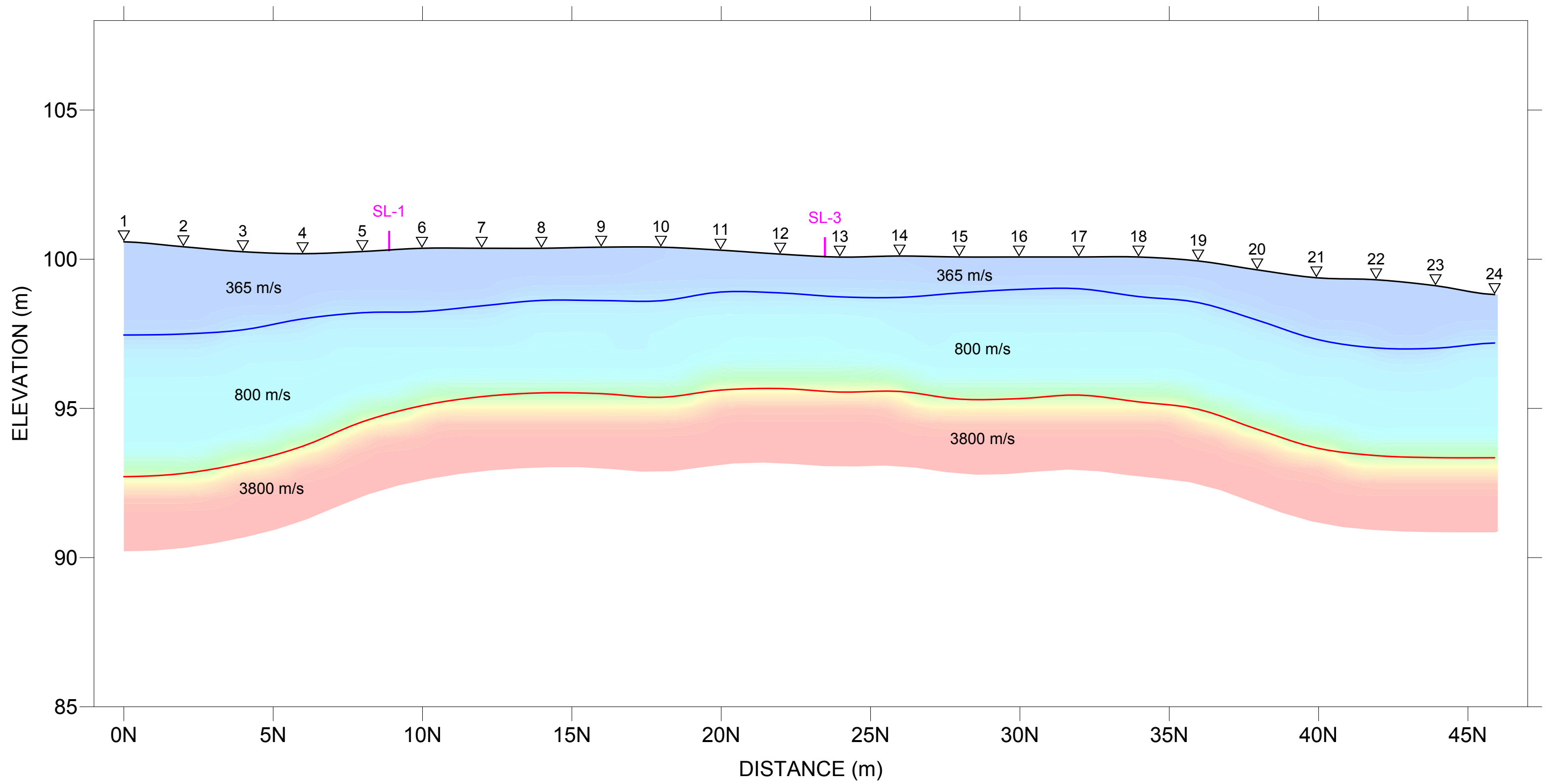


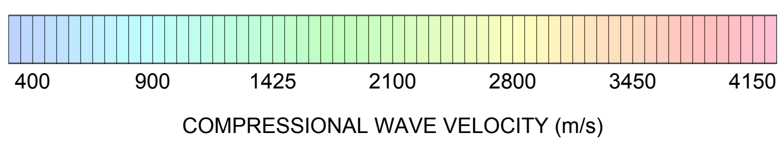


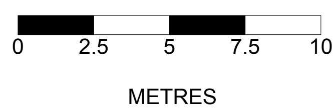


PRELIMINARY

EXP SERVICES INC. WATER STORAGE REPLACEMENT PROJECT LIONS BAY, BC
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL17-3
FRONTIER GEOSCIENCES INC.
DATE: OCT. 2017 | SCALE 1:250

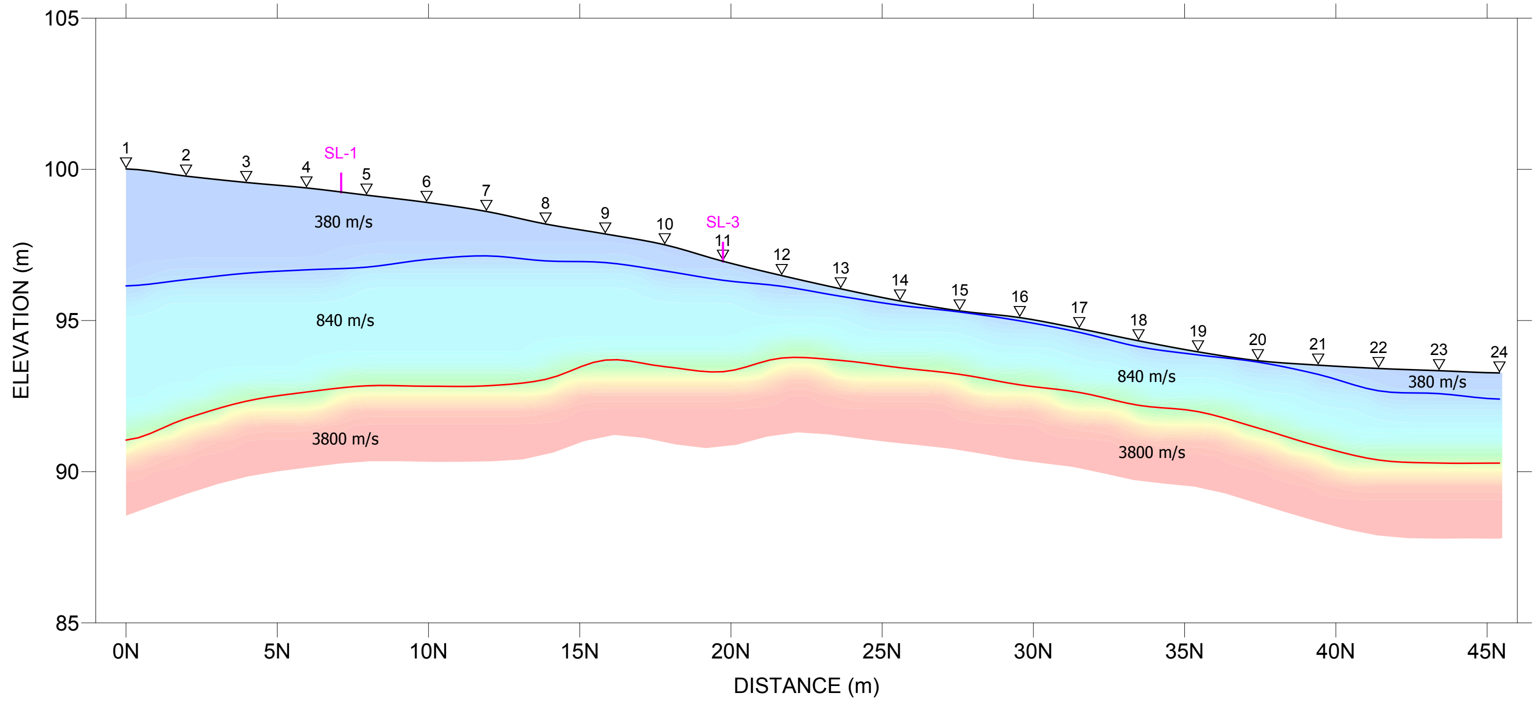


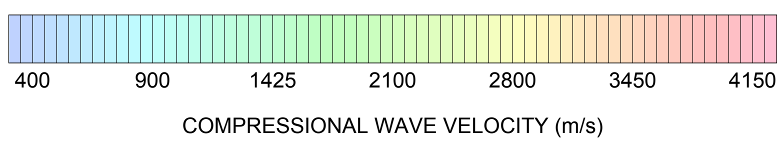


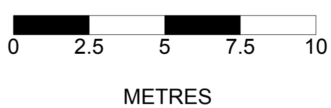


PRELIMINARY

EXP SERVICES INC. WATER STORAGE REPLACEMENT PROJECT LIONS BAY, BC
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL17-4
FRONTIER GEOSCIENCES INC.
DATE: OCT. 2017 | SCALE 1:250







PRELIMINARY

EXP SERVICES INC.
WATER STORAGE REPLACEMENT PROJECT
LIONS BAY, BC

SEISMIC REFRACTION SURVEY

INTERPRETED DEPTH SECTION
SL17-5

FRONTIER GEOSCIENCES INC.

DATE: OCT. 2017	SCALE 1:250	

APPENDIX B
ARCHAEOLOGICAL INVESTIGATION

Archaeological Overview Assessment (AOA) of Proposed Water Storage Facility Replacements in the Village of Lions Bay

Conducted under

Squamish Archaeological Investigation Permit 17-0162

and

Tsleil-Waututh Nation Cultural Heritage Investigation Permit 2017-097

Prepared on Behalf of:

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September 21st, 2017

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Field Archaeologists ....Chris Springer, M.A.

Field Personnel .... Kevin Rivers (Squamish Nation)
Darrell Guss (Tsleil-Waututh Nation)

Report Authors ....Dave Hall
Chris Springer

Report Graphics .... Chris Springer

Management Summary

This report presents the results of the Archaeological Overview Assessment (AOA) of the proposed replacement of four potable water storage facilities in the Municipality of the Village of Lions Bay, B.C: the Harvey Tank; Phase IV Tank; Phase V Tank; and the Highway Tank. The AOA was conducted at the request of AECOM/Village of Lions Bay in order to determine the potential of impacting archaeological sites as a result of the proposed developments. The AOA was conducted under the provisions of Squamish Archaeological Investigation Permit 17-0162 and Tsleil-Waututh Nation Cultural Heritage Investigation Permit 2017-097. The study area is located within the asserted traditional territories of the Squamish, Tsleil-Waututh, and Musqueam First Nations.

The objectives of the AOA were to:

- Identify areas within the study area with the potential to contain archaeological sites;
- Prepare predictions regarding archaeological site distribution, density, and variability within the project area; and
- Recommend the need and appropriate scope of future archaeological research within the project area.

The AOA took place in accordance with the *British Columbia Archaeological Impact Assessment Guidelines* (Apland and Kenny 1998) issued by the Archaeology Branch at the former Ministry of Sustainable Resources and *Archaeological Overview Assessments as General Land Use Planning Tools – Provincial Standards and Guidelines* (2009). The AOA was not concerned with identifying traditional use sites as the identification of traditional use sites is beyond the scope of an AOA. The AOA was conducted without prejudice to First Nations treaty negotiations, aboriginal rights, or aboriginal title.

For the current project, the AOA involved:

- A review of the archaeological, ethnographic, and historic literature pertaining to the study area;
- A review of biophysical and topographic data concerning the study area;
- An evaluation of archaeological site potential; and
- A Preliminary Field Reconnaissance (PFR), or ground-truthing, of the study area to confirm or refute the archaeological site potential of the study area derived from the literature review.

Based on the literature review conducted as part of the AOA, past, ongoing, and future developments within the study area were rated during the pre-field assessment as having moderate to low potential to impact archaeological sites.

The PFR of the study area took place on August 4, 2017 and consisted of a judgmental and systematic survey of the proposed developments. The field crew consisted of Chris Springer, M.A. (Arrowstone Archaeological Research and Consulting Limited), Kevin Rivers (Squamish First Nation), and Darrell Guss (Tsleil-Waututh First Nation). A representative of the Musqueam First Nation was unavailable to be part of the field crew.

The PFR was conducted: (1) to examine the terrain within the proposed development areas for landforms that might contain archaeological sites; (2) to look for evidence that supported or denied the potential evaluation made from the documentary research and the evaluations made from maps and air photos; and (3) to assess the amount of ground disturbance due to prior land altering activities and/or erosion within the proposed development areas. The results of the field assessment did not fully support the potential assessment derived from the documentary research, map, and air photo analyses.

The four proposed development locations are assessed as having low potential for impacting archaeological resources. This rating was as a result of the highly modified nature of the terrain encompassed by the four water tank facilities. Any archaeological sites that may have been present in the development area have been destroyed as a consequence of the original installation of the tanks and associated distribution system, and because the area has been logged at least once within the last 100 years.

As a result of the PFR and AOA, the potential of locating as-yet undiscovered archaeological sites is considered to be low at the four proposed water facility replacement locations. Accordingly, it is recommended that no further archaeological work is warranted for the proposed developments.

In the event that any unanticipated archaeological remains are discovered during construction activities, it is recommended that the proponent inform their personnel and all contractors of the following:

- Archaeological remains in the Province of British Columbia are protected from disturbance, intentional or accidental, by the *Heritage Conservation Act* (1994);

- In the event that archaeological remains are encountered, all activities which threaten the archaeological site(s) should be suspended at once; and

- It is the individual's responsibility to promptly advise the Archaeology Branch at the Ministry of Forests, Lands, and Resource Opportunities of the existence and location of the newly identified site(s). Mitigative measures or management options for the previously unidentified site(s) will be determined in consultation with the Archaeology Branch.

- It is further recommended that the Squamish, Tsleil-Waututh, and Musqueam First Nations be informed of any newly identified site(s).

This report provides background data regarding the context of the research in terms of its biophysical and cultural setting, describes the objectives of the research, describes the methods of the research, presents the results of the fieldwork, and provides recommendations regarding the need and appropriate scope of future archaeological research within the study area.

Acknowledgements

Arrowstone Archaeological Research and Consulting Limited (Arrowstone) would like to thank Nai Jaffer of the Village of Lions Bay and Graham Walker of AECOM for the opportunity to conduct this study. Arrowstone would also like to thank the Squamish, Tsleil-Waututh, and Musqueam First Nations for the opportunity to work within their asserted traditional territories. Arrowstone would also like to thank Kevin Rivers (Squamish First Nation) and Darrell Guss (Tsleil-Waututh First Nation) for their assistance and input during the preliminary field reconnaissance.

The opinions expressed in this document are those of the authors. The authors are solely responsible for its contents and any omissions and errors that it may contain. This report is intended for use by AECOM/the Village of Lions Bay to assess potential impacts to archaeological resources within the proposed development areas. The authors accept no responsibility for uses other than those intended and stated in this report.

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List of Figures

1.0 Introduction and Project Background

This report presents the results of the Archaeological Overview Assessment (AOA) of the proposed replacement of four potable water storage facilities in the Municipality of the Village of Lions Bay, B.C: the Harvey Tank; Phase IV Tank; Phase V Tank; and the Highway Tank. The AOA was conducted at the request of AECOM/Village of Lions Bay in order to determine the potential of impacting archaeological sites as a result of the proposed developments. The AOA was conducted under the provisions of Squamish Archaeological Investigation Permit 17-0162 and Tsleil-Waututh Nation Cultural Heritage Investigation Permit 2017-097. The study area is located within the asserted traditional territories of the Squamish, Tsleil-Waututh, and Musqueam First Nations.

The objectives of the AOA were to:

- Identify areas within the study area with the potential to contain archaeological sites;
- Prepare predictions regarding archaeological site distribution, density, and variability within the project area; and
- Recommend the need and appropriate scope of future archaeological research within the project area.

The AOA took place in accordance with the *British Columbia Archaeological Impact Assessment Guidelines* (Apland and Kenny 1998) issued by the Archaeology Branch at the former Ministry of Sustainable Resources and *Archaeological Overview Assessments as General Land Use Planning Tools – Provincial Standards and Guidelines* (2009). The AOA was not concerned with identifying traditional use sites as the identification of traditional use sites is beyond the scope of an AOA. The AOA was conducted without prejudice to First Nations treaty negotiations, aboriginal rights, or aboriginal title.

The assessment described in this report is concerned with the identification and management of archaeological sites. An archaeological site is any location that contains the remains of past human activity. Some examples of archaeological sites include habitation sites, stone tool manufacturing and maintenance sites, food storage or roasting pits, burials, fish weirs, rock art, Culturally Modified Trees (CMTs), and trails.

This report provides background data regarding the context of the research in terms of its biophysical and cultural setting, describes the objectives of the research, details the methods of the research, presents the results of the fieldwork, evaluates the research, and includes recommendations regarding the need and appropriate scope of further archaeological work within the study area.

Figure 1: NTS map showing the location of the study area and the approximate locations of the four water tanks (from map 92G/06; 1:50,000).

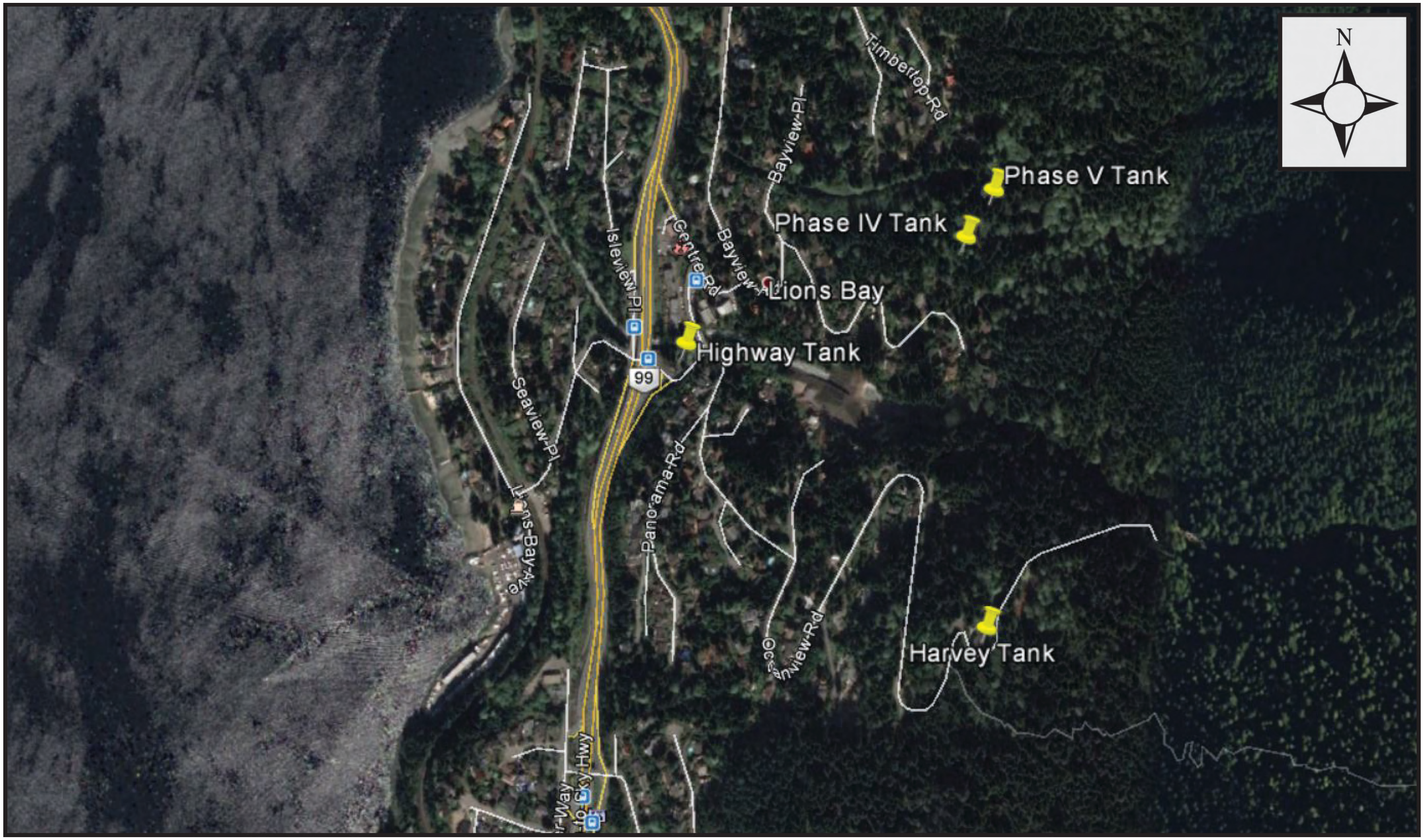

Figure 2: Google Earth image showing the locations of the four tanks within the Village of Lions Bay, B.C.

1.1 Definitions

An archaeological site can be defined as any location that contains identifiable physical traces of past human activities and/or behaviours. Many different types of archaeological sites may be found in the study area and more than one line of archaeological evidence may be present at these sites. The types of sites that may be found in the study area include village sites, temporary camps, lithic scatters, isolated finds, rock art sites (pictographs and petroglyphs), temporary shelters, lithic raw material quarry sites, burials, trails, and CMTs. The current AOA was not intended to identify areas in which no physical remains of past human activities can be found, such as berry picking sites and fishing locations, as the identification of these types of sites are more appropriately addressed in Traditional Use (TUS) and Traditional Knowledge Studies (TKS).

Archaeological sites that pre-date 1846 are automatically protected under the *Heritage Conservation Act* (*HCA*) whether on public or private land. Sites that are of an unknown age and that have a likelihood of dating to prior to 1846 (i.e., lithic scatters) as well as aboriginal pictographs, petroglyphs, and burials that are considered to have historical or archaeological value are also automatically protected. Sites that are protected under the *HCA* may not be altered, damaged, moved, excavated in, or desecrated in any way without a permit issued under Section 12 or 14 of the *HCA*.

Without Prejudice

The study area is located within the asserted traditional territories of the Squamish, Tsleil-Waututh, and Musqueam First Nations. Nothing in this report is intended to affect the scope or justify infringement of aboriginal title or rights or prevent the Squamish, Tsleil-Waututh, and Musqueam First Nations from exercising their aboriginal rights. This report is without prejudice to the positions any parties may assert in court proceedings or in treaty negotiations, and is not an admission of fact or liability for the purposes of such proceedings and processes. The archaeological investigations were undertaken solely for the purpose of gathering information about cultural heritage and archaeological resources. In no way will such studies replace the need for the Provincial Government to consult with the Squamish, Tsleil-Waututh, and Musqueam First Nations, nor do they attempt to address aboriginal rights issues.

Representatives of the Squamish, Tsleil-Waututh, and Musqueam First Nations participated in and/or contributed to and/or were invited to participate in this archaeological assessment. This participation in whatever means does not in any way represent their consent and/or consultation with respect to the construction of the study area. The sole purpose of this study was to identify archaeological sites, or the potential for sites, to be located within the assessment area. This study does not address Traditional Use Sites nor does it consider possible infringements of aboriginal rights and title within the assessment area.

2.0 Project Description

The Municipality of the Village of Lions Bay supplies potable water to the residents of Lions Bay via a water distribution system comprised of two raw water intakes located on Harvey and Magnesia Creeks, two water treatment plants, five storage tanks, 13 pressure reducing valve stations, and 13 kilometers of water mains including 16 pressure zones. Lions Bay's current population of approximately 1,300 is served through approximately 551 service connections. Four of the five distribution tanks require replacement: the Highway Tank; Harvey Creek Tank; Phase V Tank; and Phase IV Tank (Figure 3). The Harvey Tank, built in 1980, is the largest of the four. The three other tanks were installed in 1960.

The replacement of the four tanks is intended to increase the Village of Lions Bay's water reservoir storage capacity to the 2045 year population horizon, provide for emergency storage, prevent stagnant water development during low use periods, integrate and enhance controls of/and into the existing supervisory control and data acquisition (SCADA) system, and supply secure power and communications to the reservoir site(s).

2.1 Expected Impacts

Any archaeological sites that may be present within the study area could potentially be impacted by the replacement of the four water tank facilities. Expected machine impacts include the clearing, excavation, and grading of natural and imported landfill sediments and refuse. Machine excavation of subsurface deposits has the greatest potential to disturb any archaeological materials and/or features should they be present.

Figure 3: Locations of the four water tanks slated for replacement.

3.0 Definition of the Study Area and its Physiographic and Environmental Setting

3.1 Geologic Setting

The Municipality of the Village of Lions Bay is located on the eastern slopes of Howe Sound along the Sea-to-Sky Highway approximately midway between West Vancouver and Squamish, B.C. Its physiographic setting is defined by the Ministry of Forests Research Branch (Demarchi et al. 1990) as situated within the Southern Pacific Ranges Ecosection of the Pacific Ranges Ecoregion in the Georgia Depression Ecoprovince. The Southern Pacific Ranges Ecosection is characterized by rugged granitic mountains that rise abruptly above the Fraser Valley and Sunshine Coast. This ecosection is affected by westerly Pacific storms bringing heavy rain. Snow occurs from late fall to winter; summers can be dry and warm with occasional rainy periods. During periods of Arctic air outbreaks, outflow winds in the Squamish and Lillooet river valleys can be extreme. Except in several parts, intensive clearcut logging, with its attendant roads has occurred in all the valleys and lower slopes. The underlying bedrock in the study area is composed of Cretaceous age Hornblende diorite of the Gambier Group overlain with more recent flows of andesites, dacites, and other rocks of volcanic origin associated with the Garibaldi Volcanic Belt.

At the height of the last major glaciation (approximately 14,500 BP), the study area was buried under up to 1800 m of ice (Menounos et al. 2009; Slaymaker et al. 1992). Approximately 14,000 BP the glaciers began to recede, leaving the study area largely ice-free by 11,000 BP. As a consequence of the isostatic depression of the region caused by the massive weight of the ice, the early Holocene sea levels were in the order of 200+ m above modern relative sea levels (Clague et al. 1982; Kovanen and Slaymaker 2017). Subsequent to deglaciation, the study area rebounded from the weight of the ice-sheets culminating in sea levels that were roughly 13 m below present levels by 8780-9700 cal. BP (Kovanen and Slaymaker 2017:367). This was followed by eustatic change resulting in relative sea levels of 5 m below modern by circa 7000 radiocarbon years BP (Kovanen and Slaymaker 2017:367). With the emergence of the land surface during the mid-Holocene, previously glacially stored sediment loads were subjected to various non-glacial processes (marine, fluvial, mass movement, and aeolian) that led to the establishment of the modern coastline and local sediment conditions by 2330-1830 cal. years BP (Kovanen and Slaymaker 2017:367). Detailed reviews of current knowledge regarding paleoclimates, glacial history and changes in relative sea levels, and past and present land use practices in the study area can be found in Millennia Research (1997) and Slaymaker (2017).

3.2 Climatic Setting, Vegetation, and Wildlife

The study area lies within the Coastal Western Hemlock Biogeoclimatic Zone (CWH) as defined by the biogeoclimatic classification system utilized by the Ministry of Forests (see Meidinger and Pojar 1991; Pojar et al. 1991). More specifically, it is within the CWH subzone defined by Green and Klinka (1994) as the Coastal Western Hemlock dry maritime (CWHdm) variant. The CWH biogeoclimatic zone occurs at the low and middle elevations along the entire coast of the mainland, west of the Coast Mountains. In the southern portion of the CWH, the zone occupies elevations from sea level to 900 m on windward slopes. It is the wettest biogeoclimatic zone in B.C., characterized by cool summers and mild winters with a mean annual temperature ranging from 5.2°–10.5° Celsius. The mean annual precipitation ranges from 100–440 cm with less than 15% of the mean falling as snow.

The dominant tree species in the CWHdm subzone are Douglas-fir, western hemlock, and western red cedar. The shrub and herb layer is composed of salal, red huckleberry, dull Oregon-grape, vine maple, trailing blackberry, twinflower, sword fern, bracken, and bunchberry. The moss layer is primarily step moss and Oregon beaked moss with lesser amounts of flat moss and lanky moss.

The location and distribution of the CWH biogeoclimatic zone are the factors that most influence the wildlife population. Rising from sea level to 1050 m in some areas, the CWH zone has the greatest diversity and abundance of habitat elements than all other biogeoclimatic zones in the province. Black-tailed deer, black bear, grizzly bear, gray wolf, and mountain goat are the most common large mammals in the CWH zone. The former two occur throughout the zone while the latter three are specific to certain areas. The various smaller mammals and rodents include racoon, mink, river otter, marten, deer mouse, Columbian mouse, spotted skunk, gray squirrel, and the Douglas squirrel. There are also a number of marine mammals associated with the CWH zone as it pertains to the study area. Harbour seals are abundant in Howe sound while northern sea lions, and transient and resident orca pods are occasional visitors to the area (Pojar et al. 1991). Various species of salmon have been identified in many of the tributary streams that drain into Howe Sound and the Squamish and Mamquam Rivers. The littoral zone near the mouth of the Squamish River was a suitable habitat for shellfish such as clams, mussels, oysters, and chitons.

The majority of coastal, colony-nesting bird habitats on the B.C. coast are found in the CWH biogeoclimatic zone where the rocky coastline and coastal islands provide excellent protection from predation during the nesting months. The waterfowl most common to the zone are: black-legged Kittiwake, black oystercatcher, double-crested cormorant, pelagic cormorant, pigeon guillemot, glaucus-winged gull, Canada goose, and the mallard. The forested and grassy areas of the CWH zone also host a number of bird species including Cooper's hawk, red-tailed hawk, northwestern crow, northern harrier, osprey, Steller's jay, great horned owl, barred owl, common raven, ruffed grouse, among many others.

4.0 Methods

The AOA was conducted in accordance with the Guidelines and Objectives put forth in *Archaeological Overview Assessments as General Land Use Planning Tools – Provincial Standards and Guidelines* (2009). As outlined in the *Guidelines*, the purpose of an AOA is to:

- Identify and assess archaeological resource potential or sensitivity within the study area, and;
- Make recommendations concerning the appropriate methods and scope of work for subsequent studies.

For this project the AOA involved:

- A review of the archaeological, ethnographic, and historic literature pertaining to the study area;
- A review of biophysical and topographic data in the study area;
- An evaluation of archaeological site potential; and
- A preliminary field reconnaissance (PFR), or ground-truthing, of the study area to confirm or refute the archaeological site potential of the study area derived during the literature review.

4.1 Literature Review

Background data concerning known archaeological sites in the study area were obtained from the Provincial Heritage Register Database (PHRD) at the Ministry of Forests, Lands, and Natural Resource Operations in Victoria, B.C. Archaeological, ethnographic, and historic literature pertaining to the study area was gathered from a variety of institutions including: (1) various local and regional libraries; (2) the British Columbia Archives in Victoria; (3) the NRCan library (Earth Sciences); and (4) personal library collections. Published and unpublished reports relevant to the study area were also examined. The literature review was undertaken to assist in the development of a model to assess the archaeological site potential of the terrain encompassed by the study area.

General ethnographic sources that were examined include Ames and Maschner (1999), Barnett (1938, 1955), Boas (1894), Curtis (1911), Duff (1952, 1964), Hill-Tout (1902, 1905), Jenness (1955), Pickford and Flucke (1952), Rozen (1979), Suttles (1955, 1974, 1987, 1990), and Wells (1987). General syntheses of the prehistory of the Greater Vancouver Regional District include Borden (1950a, 1950b, 1961, 1968a, 1968b, 1975), R. Carlson (1983), Fladmark (1982, 1986), Hill-Tout (1895), Kenyon (1953), Matson (1976, 1981, 1996), Mitchell (1971, 1990), Morris (1993), and Porter and Copp (1993).

4.2 Review of Topographic and Biophysical Information

Topographic information was obtained from the 1:50,000-scale National Topographic Series Map 92G/06 (North Vancouver), and historic air photos. In addition to the library research, biophysical information was also obtained from the 1:250,000-scale Biogeoclimatic Ecosystem Classification Subzone/Variant Map for the Sea-to-Sky Resource District, South Coast Region, published by the Ministry of Forests, Lands and Natural Resource Operations (2016).

4.3 Archaeological Site Potential Assessment Methods

Archaeological sites in the study area may consist of one or a combination of several types of archaeological remains including habitation remains, lithic/artifact scatters, CMTs, rock art, trails, cultural depressions and other habitation features, and burial places, among others.

An assessment of archaeological site potential is based on a consideration of the locations of previously recorded archaeological sites, ethnographic and historic information, and topographical and biophysical characteristics. A correlation exists between particular biophysical characteristics and archaeological sites. The presence of these biophysical characteristics can be used to predict the likelihood of a location being used prehistorically. The biophysical characteristics considered were:

- vegetation and forest resources;
- wildlife and fish values;
- proximity to other natural resources (i.e. lithic resources);
- proximity to aquatic features;
- bedrock exposures (suitable for pictographs, burial caves, and shelters);
- aspect; and
- topography

Ethnographic studies relevant to the study area were utilized to evaluate archaeological site potential based on the correlation between archaeological site locations and biophysical characteristics. Archaeological potential values were assigned based on consideration of the following:

- topographic and biophysical characteristics;
- past historic land use and impacts;
- the results of the PFR; and
- the previous archaeological experience of the authors

4.4 Preliminary Field Reconnaissance Methods

A Preliminary Field Reconnaissance (PFR) is an optional part of an AOA. In this case, the PFR was conducted: (1) to examine the terrain within the proposed development areas for landforms that might contain archaeological sites; (2) to look for evidence that supported or denied the potential evaluation made from the documentary research and the evaluations made from maps and air photos; and (3) to assess the amount of ground disturbance due to prior land altering activities and/or erosion within the proposed development areas.

5.0 Results

5.1 Ethnographic Background

The Village of Lions Bay is located within the asserted traditional territories of the Squamish, Tsleil-Watuth, and Musqueam First Nations, all of which are part of the Coast Salish language family. The Squamish are a linguistically and culturally distinct group within the Central Coast Salish linguistic family (Barnett 1955; Suttles 1990). The Tsleil-Waututh and Musqueam Nations belong to a language group of related Central Coast Salish dialects—*Halq'eméylem*, upriver; *Hun'q'umin'um'*, downriver; and *Hul'q'umín'um'*, island—spoken in the Lower Fraser Valley, the southern Gulf Islands, and the southeastern coast of Vancouver Island (Hill-Tout 1902; Smith 2001:22; Suttles 1990). The three dialects are generically referred to as Halkomelem. The Tsleil-Waututh and Musqueam are *Hun'q'umin'um'* speakers.

There are shared areas in the asserted traditional territories of these First Nations. The asserted traditional territory of the Squamish Nation extends "from Point Grey on the south to Roberts Creek on the west; then north along the height of land to the Elaho River headwaters including all of the islands in Howe Sound and the entire Squamish valley and Howe Sound drainages; then southeast to the confluence of the Soo and Green Rivers north from Whistler; then south along the height of land to the Port Moody area including the entire Mamquam River and Indian Arm drainages; then west along the height of land to Point Grey" (Squamish Nation 2008). The Squamish Nation has recently updated their claim to include a portion of the lower Fraser River Valley.

The asserted traditional territory of the Tsleil-Waututh extends from Mount Garibaldi in the north to the Fraser River in the south, and from Coquitlam Lake in the east to Howe Sound in the west. The majority of the Tsleil-Waututh population is now centered on Burrard Inlet, between Maplewood Flats and Deep Cove in North Vancouver, B.C. (Tsleil-Waututh 2017). The name Tsleil-Waututh means 'people of the inlet.'

The asserted traditional territory of the Musqueam First Nation extends from Harvey Creek in Howe Sound southeast through Indian Arm and Burrard Inlet to the Fraser River between the Coquitlam and Brunette Rivers, west along the south bank of the Fraser to the Straight of Georgia, and is inclusive of all islands mainland and marine areas within this expanse (Musqueam Indian Band 1976). The name of the Musqueam people originates from the word *MəΘkʷəý (m-uh-th-kwi)* meaning People of the River Grass (Musqueam Indian Band 2014).

Understanding the traditional lifeways and land use systems of the Coast Salish peoples is of crucial importance towards comprehending the archaeological record of this culturally and physiologically unique region. Sources of information on these communities are generally derived from contemporary Coast Salish accounts of the past and the ethnographic record. Several caveats must be attached to the use of this latter source of information. Among the most important have to do with the historical context and the amount of exposure that ethnographers studying these groups experienced during the tenure of their research. With few exceptions, ethnographers spent relatively little time exposed to Coast Salish culture, spoke with relatively few informants, and constructed their understandings of aboriginal lifeways within academic and political frameworks that were affected by a number of ethnocentric and colonial assumptions (see Klassen 2002 and Wickwire 2005 for a more detailed review of bias within regional ethnographies). The following brief discussion is a generalized description of the Coast Salish seasonal round and material culture researched from a number of primary, and secondary works concerning the Coast Salish: Barnett (1935-1936, 1938, 1939, 1955)' Bouchard and Kennedy (1991); K. T. Carlson (1997, 2001); Carter (1966, 1972); Curtis (1911); Hill-Tout (1902, 1905); Jenness (1955); Maclachlan (2000); Pickford and Flucke (1952); Sparks and Border (1989); and Suttles (1955, 1974, 1987, 1990, 2000). It is by no means intended to serve as a comprehensive review of these cultures or lifeways, past or present.

Similar to most other groups on the Northwest Coast, the Coast Salish practiced a semi-sedentary hunting-gathering-fishing economy incorporating well-established forays by specialized task groups ranging over wide territorial areas in order to acquire specific resources. This practice followed an annual cycle with dispersal from communal winter villages, sometimes ranging distances greater than 320 km (Burley 1980:6) to temporary camps in order to acquire seasonally available resources (Barnett 1938:119; Grier 2003; Sanders 2006; Sanders and Ritchie 2008), gathering again at the end of fall in winter villages. Subsistence for the Coast Salish was based on hunting terrestrial mammals (e.g., elk, deer and bear) and marine mammals (e.g. sea lions, harbour seals, and porpoises), gathering various floral resources (e.g., cedar bark, berries, camas, as well as various roots and shoots), fishing (e.g., the various available species of salmon, herring, eulachon, rockfish, lingcod, flounder and sturgeon), and gathering various species of shellfish (e.g., mussels, clams) and other intertidal resources according to a complex annual cycle (Barnett 1938:122; Pickford and Flucke 1952). In addition, western redcedar, western hemlock, western yew, willow, and Douglas-fir trees were also utilized by the Coast Salish for a variety of implements, clothing, and construction materials.

Typically, Coast Salish winter villages were located near sheltered bays with easy access to fresh water (Suttles 1990). These villages consisted of semi-permanent and permanent structures constructed from large cedar logs and planking. Seasonal campsites often consisted of cedar post frames covered by rush mats or cedar planks (Barnett 1955:40).

Documented accounts of Coast Salish burial practices during the ethnographic and ethnohistorical period report the use of baskets, boxes, and canoes to inter the remains of single or multiple persons. Mortuary containers were suspended from trees at heights of up to four meters (Menzies 1790-1795; Vancouver 1801). Mound and cairn burials have been documented in the Fraser Valley particularly at, and around, the site of Scowlitz (**DhRl-0016**), and in the Strait of Juan de Fuca on the Rocky Point Peninsula, the southern most tip of Vancouver Island. However, the temporal and geographical extent of this suite of mortuary practices are not well understood (see Mathews 2014 for an extensive review of Coast Salish ethnographic and archaeological burial practices).

Similar to most groups along the south coast, the material culture of the Coast Salish peoples was, at the time of contact, dominated by the extensive use of products derived from western redcedar (Stewart 1984; Turner 1998). Products fashioned from western red cedar included large ocean-going canoes, large rectangular plank houses, house posts, ceremonial masks, complex latticework fish weirs and fish traps, mats, intricate basketry, and various forms of clothing (Stewart 1977). Raw material for planks, posts, canoes, and boxes were procured by felling trees and subsequently splitting the logs. Stone mauls, antler, and wood wedges, nephrite adzes, and chisels with bits fashioned from stone, bone, shell, and antler were the traditional woodworking tools of the Coast Salish. Cedar bark for clothing and other items was harvested by pulling long narrow strips of bark beginning from a small incision about waist high near the base of the tree with the subsequent extraction of the inner bark from the outer bark before transportation away from the harvesting site. In addition to material derived from western red cedar, a number of implements within Coast Salish material culture were fashioned from stone and bone. At the time of contact, polished and ground, bone, antler, and stone implements played a dominant role in material culture.

One further and important aspect of Coast Salish material culture was the processing and use of wool for weaving blankets and other textiles. The Coast Salish wool weaving tradition relied until at least the mid-19th century on a regional species of dog for its hair—the woolly dog (Howay 1918). Wool from dog's hair was supplemented by mountain goat hair, waterfowl down, and fireweed cotton (Pojar and Mackinnon 1994:206) when available (Kissel 1916; Orchard 1926; Turner 1998:175-176). The woolly dog became extinct by the middle of the 19th century. Dogs were also used for a variety of other activities throughout the northwest coast including hunting (Kennedy and Bouchard 1990:445; De Laguna 1990:190, 209; Hamori-Torok 1990:308; McLaren et al. 2005; Suttles 1990:458) and packing (De Laguna 1990:208).

The Coast Salish emphasized prestige and rank, participated in secret societies and slavery, and performed a variant of the potlatch. Coast Salish societies were stratified, with high status families claiming rights to resources, names, and ceremonial activities and regalia. The primary socio-economic group was the household, consisting of several kin-related families occupying a single plank house. The household of an established kin group and several dependent households made up the local group (Suttles 1990). Villages were usually composed of one or more houses occupied by families who cooperated economically. Villages were linked through ties of marriage and kinship providing a social network. Marriages arranged between socially equal families in different villages helped to establish systems for resource procurement, including shared access to specific resource locations and shared labour.

Precisely how far back into prehistory the ethnographic pattern described above extends is open to question. A full account of the ethnographic subsistence pattern of the Coast Salish is beyond the scope of this report. Further accounts of Coast Salish ethnography, mythology, language, subsistence practices, cultural practices, and material culture can be found in a number of primary and secondary works including, but not limited to Barnett (1935-1936, 1938, 1939, 1955), K. T. Carlson (1997, 2001), Curtis (1911), Duff (1952), Elmendorf (1960, 1961, 1971), Hill-Tout (1895, 1897, 1902, 1905), Gunther (1927), Jenness (1955), Matthews (1955, 2011), Pickford and Flucke (1952), and Suttles (1955, 1974, 1987, 1990, 2000).

5.2 Historical Background of the Capilano Watershed

The first record of Europeans in Howe Sound occurred on June 14, 1792 when George Vancouver entered the sound with a small crew using the HMS *Discovery's* yawl and launch. Vancouver named the body of water Howe Sound after Lord Howe of the Royal Navy. Spanish explorers, on the schooner *Santa Saturnina* under the command of Jose Maria Narvaez, had observed and named the sound *Boca del Carmelo* the previous year, but did not enter it. Narvaez is believed to have been the first European to enter the Gulf of Georgia (Kendrick 1986:48). When Vancouver and his crew entered Howe Sound the following year, they met and traded with approximately 40 members of the Squamish First Nation on Friday, June 15:

> [I]nto the spirit of which they entered with infinitely more avidity than any of our former acquaintances, not only in bartering amongst themselves the different valuables they had obtained from us, but when that trade had become slack, in exchanging those articles again with our people; in which traffic they always took care to gain some advantage, and would frequently exult on the occasion. Some fish, their garments, spears, bows and arrows, to which these people wisely added their copper ornaments, comprised their general stock and trade. Iron, in all its forms, they judiciously preferred to any other article we had to offer (Lamb 1984:585).

The sound was surveyed in the mid-19th century during the third commission of the HMS Plumper under the command of George Henry Richard. This survey also included surveys of the lower Fraser River, Burrard Inlet, the Sunshine Coast, and Victoria and Esquimalt.

Non-Native presence and settlement within the study area began slowly with the first residents settling at Brunswick Beach around 1911 after it was surveyed in 1908. In the early 1900s, private Japanese logging companies had logged the area around Lions Bay, which precipitated more people to the area. Prior to the initial settling of the study area, the Sea-to-Sky corridor along the eastern slope of Howe Sound was used in the 1800s as a trail connecting the North Shore with Pemberton and Lillooet. At this time the route was known as the Pemberton Trail and was an expansion of a pre-exiting First Nations trade route (The Lions Bay Historical Society 2001). For much of the first half of the 20th century there was little development of the study area. During this time, the Lions Bay/Brunswick Beach area was a stopping point for commercial and private boats running between Vancouver and Squamish.

The opening of the Pacific Great Eastern rail line between North Vancouver and Squamish in August 1956 and the extension of Highway 99 to Britannia Beach in 1958 allowed for greater access to the study area (The Lions Bay Historical Society 2001). In addition to access upgrades, electricity and telephone services were established in Lions Bay in the late 1950s. Following improvements to the local infrastructure, settlement of the area began to increase with the first development lots selling in the spring of 1958. Lions Bay was incorporated as a Village in 1971 and Brunswick Beach amalgamated with Lions Bay in 1999 (The Lions Bay Historical Society 2001).

Additional details regarding the historic period of the study area can be found in Akrigg and Akrigg (1975), Gough (1971, 1980), Harris (1992, 1997), Lamb (1984), The Lions Bay Historical Society (2001), and Ormsby (1971).

5.3 Previous Land Use

Whereas the preceding section gives a basic chronology of historic events associated with Lions Bay, this section is dedicated to specific examples of First Nations land use and other high potential land use patterns in the study area, whether related to habitation, subsistence-related activities, or spiritual values.

The study area is located along the eastern slopes of Howe Sound, extending from sea level to approximately 300 m above sea level. Considering the presence of three significant drainages (Harvey, Alberta, and Magnesia Creek), a shell midden site on Brunswick Beach

(**DiRt-0003**), and the pre-contact use of the Sea-to-Sky corridor as a land-based travel route, the study area was likely used as a short-term camping location during hunting and gathering trips for marine, and mid- and high-elevation resources (Reimer 2003:57-58).

The animals sought after during these forays were used for multiple purposes: food (mountain goat, deer, elk, marmot, grouse, black and brown bear, various rodents, snow goose, Canada goose); clothing (mountain goat); bone/antler/horn raw material (mountain goat, deer, elk, black and brown bear Canada goose), medicine (skunk), and feathers (bald and golden eagle). A number of different plant resources would have been available within close proximity to the study area for construction materials, clothing, containers, and food. These include western redcedar, Douglas-fir, western hemlock, and amabilis fir. Plant gathering within proximity to the study area would have focused on a variety of species such as, Alaskan blueberry, oval-leaved blueberry, red huckleberry, salal, deer fern, bunchberry, and bracken fern.

There is a place name in close proximity to the study area associated with the shell midden site (**DiRt-0003**) at Brunswick beach and the long point at the end of Alberta Bay. The place name, Kéİetstn translates as “sometimes they fight” (Kwi Awt Stelmexw 2016), suggesting the area was a defensive location.

5.4 Air Photo Analysis

A series of aerial photographs taken between 1939 and 2004 inclusive were analyzed to assess recent changes to the study area over time. The use of historic aerial photographs (see Figures) indicates the rate and type of landscape changes affecting the study area, which in turn provide context for the archaeological reconstruction of past lifeways and understanding of archaeological potential in present landscapes. The following is a brief description of changes to the study area recorded in the aerial photographs. The photographs showing significant change are included.

In the first photograph (1939), Harvey and Alberta Creeks are visible as well as the Pemberton trail that later became Highway 99 (the Sea-to-Sky Highway) running north-south through the middle of the photograph (Figure 4). The Village of Lions Bay is non-existent and the locations of the future water tanks are fully treed with second growth timber. The old growth had, by this time, been removed by Japanese logging concerns earlier in the century. There is no noticeable change to the landscape until 1957 when roadways become visible above and below what will soon become Highway 99, and a jetty can be seen extending out into Howe Sound near the mouth of Alberta Creek (Figure 5).

By 1969, Lions Bay has become substantially developed with numerous roads and housing clearly visible, the Pacific Great Eastern rail line and a paved Highway 99 are also in place by this time (Figure 6). Three of the four water tanks that are to be replaced had been installed by 1969—Phase IV Tank, Phase V Tank, and the Highway Tank—but they are not visible in the photograph. Development of the Village of Lions Bay continues through to 1975 (Figure 7). The Highway Tank is visible in the 1975 photograph. All four of the water tanks marked for replacement are in place above and within the village by 1982; however, as with the previous photograph, only the Highway Tank is visible (Figure 8). Residential development continues through the 1980s and 1990s without any significant change to the tank locations. In the final 2004 photograph the Harvey Tank and Highway Tank are visible (Figure 9).

Figure 4: 1939 aerial photograph showing the study area (scale 1:22,000).

Figure 5: 1957 aerial photograph showing the study area (scale 1:15,000).

Figure 6: 1969 aerial photograph of the study area (scale 1:13,000).

Figure 7: 1975 aerial photograph of the study area (scale 1:15,000).

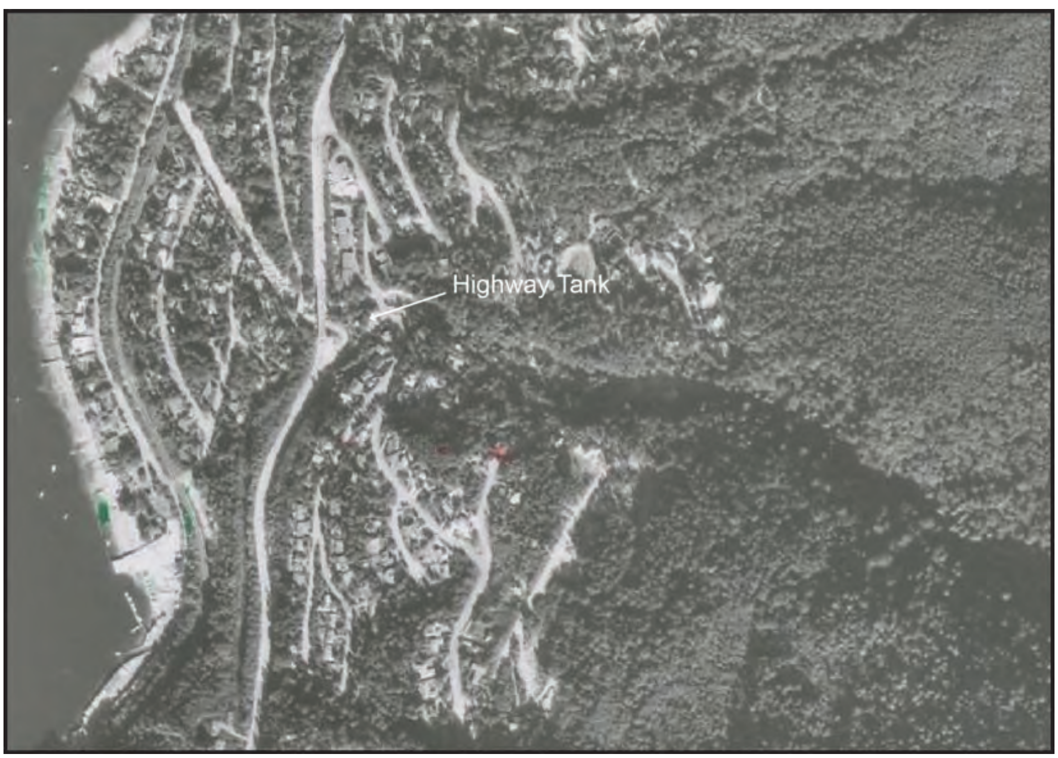

Figure 8: 1982 aerial photograph of the study area (1:20,000).

Figure 9: 2004 aerial photograph of the study area.

In summary, the most significant early disturbance to the study area visible in the photographs is associated with the initial infrastructure development in 1957 followed by the laying down of the Pacific Great Eastern rail line and the paving of Highway 99, both of which were complete by 1969. In addition, three of the four tanks were in place by 1969. The next major change to the study area is in 1982, by which time all four tanks are in place. Any archaeological sites within the footprints of the four water tanks would have been heavily impacted during installation. Development of the Village of Lions Bay would have also seriously impacted any archaeological sites within the area.

5.5 Previous Archaeological Research in and near the Study Area

The Greater Vancouver Regional District and Sea-to Sky corridor have been studied by archaeologists and anthropologists, beginning in the late 19th century with Boas (1890, 1891, 1892, 1894) and Hill-Tout (1895, 1902, 1905), through to the early 20th century, see Barnett (1935-1936, 1938, 1939, and 1955), Duff (1952), Borden (1950a, 1950b, 1961, 1968a, 1968b, 1970, 1975), Suttles (1949a,b, 1951, 1955, 1958, 1960, 1963, 1974, 1987, 1990, 2000), Mitchell (1971, 1990), and Winram (1975) to note a few of the major contributors. In 1996, Millennia Research Limited completed the Archaeological Overview Assessment of the Squamish Forest District (Millennia Research Limited 1997). The Squamish Forest District Overview was developed to assist with the management of archaeological resources within the forested environments of the Squamish Forest District, which includes the subject property. The AOA produced a model and series of 1:20,000-scale archaeological potential maps that delineated areas of high-low potential within the Squamish Forest District. The model used to produce archaeological potential polygons for each site type (habitation, rock art, sub-alpine camps, and CMTs) was based upon sets of variables drawn from data on the physical world, that were assumed to be consistent for a particular site type. These variables were loaded into a Geographic Information System (GIS) and using TRIM data as a base layer expressing topographic and elevation information; the interactive GIS was used to produce maps that detailed areas of high and moderate archaeological potential. The utility of the Squamish Forest District AOA is that it summarizes physical characteristics of the study area across time, and considers patterns within previous archaeological and to a degree ethnographic data that are pertinent to the study area. The model's predictions regarding the association of biophysical characteristics and archaeological sites requires further community-based ethnographic research (interviewing) and ground-truthing (archaeological survey and subsurface testing).

In addition to the Squamish AOA, a number of academic projects have been undertaken in the region. Recent dissemination of these projects include Peter Locher's (2006) study of early human occupation in southwestern coastal British Columbia using data collected from the Pitt River Valley, Duncan McLaren's (2003) research in the Stave Watershed and his 2001 (2002) survey of archaeological sites in the Salmon River region of Langley, Bill Angelbeck's (2009) analysis of Coast Salish warfare, Jesse Morin's (2012) study on stone celt exchange among ancestral Coast and Interior Salish people, Terence Clark's (2010) re-assessment of the Marpole Phase, David Schaepe's (2009) study on pre-colonial Stó:lō-Coast Salish community organization, and the previous archaeological research conducted at Fort Langley by Porter and Copp (1993), Porter et al. (1995), Steer et al. (1980), and Steer and Porter (1984). Specific to the study area, Rudy Reimer (2000, 2003, 2004, 2006, 2007, 2011, 2014) has conducted a substantial amount of academic research within Squamish traditional territory. His research has greatly expanded the number and types of sites that have been identified within traditional Squamish territory and has contributed greatly to a better understanding of the nature of the ancestral occupation of the Squamish River watershed and Howe Sound, and the subsistence resource procurement and logistical mobility strategies of the region's ancestral inhabitants.

Long-standing archaeological evidence suggests that the Greater Vancouver Regional District, and the lower Fraser Valley and Fraser Canyon region have been inhabited for at least the past 9,000 years (Borden 1968a, 1975). More recent data have pushed this period of human occupation back to the terminal Pleistocene-Holocene transition, prior to 10,000 BP (McLaren and Storey 2010). General syntheses on the prehistory of the region can be found in Ames and Maschner (1999), Borden (1970, 1975), R. Carlson (1983), Fladmark (1982, 1986), Matson and Coupland (1995), Millennia Research Limited (1997), and Mitchell (1971, 1990).

5.6 Previously Recorded Archaeological Sites near the Study Area

As part of the current study, a search of the Remote Access to Archaeological Data (RAAD) was conducted. This online archaeological site database is operated by the Archaeological Branch of the Ministry of Forests, Lands, and Natural Resource Operations in Victoria, B.C. The search of RAAD found two previously recorded archaeological sites in the vicinity of the study area: **DiRt-0003** and **DiRt-0013** (Figure 10). The two sites are described below.

DiRt-0003 is located in Alberta Bay at Brunswick Beach. It is composed of shell midden and a surface lithic scatter. The point of land that juts west out into the sound from Brunswick Bay has a place name associated with it that translates as “sometimes they fight.” The place name is Kéİetstn

DiRt-0013 is located on the west side of Highway 99 about 0.7 kms north of Newman Creek and 0.5 kms south of Lone Tree Creek. It is presently situated adjacent to a house, between the southern edge of a gravel driveway and a small garden along the southern portion of the house. The site consists of a single petroglyph.

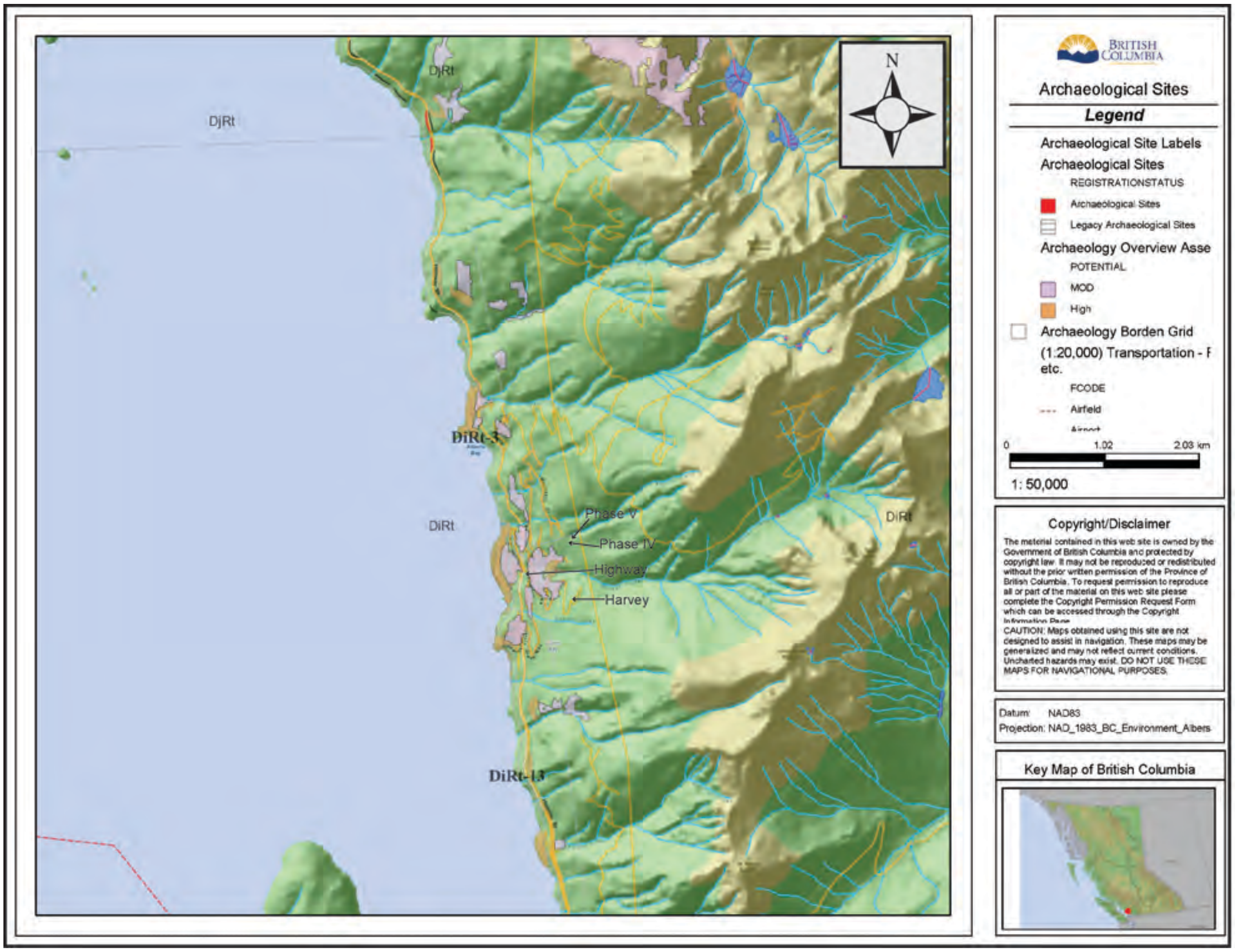

Figure 10: Map showing locations of **DiRt-0003** and **DiRt-0013** in relation to the study area.

5.7 Prefield Archaeological Potential Assessment

Archaeological sites within the Greater Vancouver Regional District and Sea-to-Sky corridor tend to be scattered unevenly throughout the region. This may have occurred due to resource availability, defensibility, preferred navigational corridors, and taboos surrounding certain types of land use practices in particular areas. The number of recorded archaeological locales in the area suggests that it was heavily utilized in precontact times and was favoured for aboriginal use. Direct evidence of disturbance of archaeological deposits through industrial, agricultural, and residential developments and/or natural processes such as erosion, flooding, mass wastage events, and boat waves have destroyed numerous archaeological sites in the region.

The types of archaeological sites that may be expected within the general study area include settlements, seasonal camps, rock shelters, lithic and/or artifacts scatters, fishing stations, land mammal hunting and trapping camps, special use campsites (sweat lodges, menstrual huts, vision quest sites, plant resource processing sites, etc.), burial sites, rock art sites (petroglyphs/pictographs) trails, CMTs, among other possibilities.

Based on the assessment of resources known to have been utilized ethnographically by the Squamish, Tsleil-Waututh, and Musqueam First Nations, and their availability in and near the location of the study area, it is surmised that the terrain encompassed by the study area was likely utilized seasonally for gathering various floral resources (e.g., berries, roots, tree bark, lumber), toolstone material, fishing, hunting, and trapping at various times during the year. However, given the impact of various forms of development within and around Lions Bay over the last century, the study area is assessed as having medium to low potential for the presence of unrecorded archaeological resources.

5.8 Results of the Preliminary Field Reconnaissance

The PFR of the study area took place on August 4th, 2017 and consisted of a judgmental and systematic survey of the proposed locations (Figures 11-26). The PFR was conducted: (1) to examine the terrain within the proposed development areas for landforms that might contain archaeological sites, (2) to look for evidence that supported or denied the potential evaluation made from the documentary research and the evaluations made from maps and air photos, and (3) to assess the amount of ground disturbance due to prior land altering activities and/or erosion within the study area.

The fieldcrew for the PFR consisted of Chris Springer (Arrowstone Archaeological Research and Consulting Limited), Kevin RIvers (Squamish Nation), and Darrell Guss (Tsleil-Waututh Nation). Unfortunately, a representative of the Musqueam First Nation was not available to be part of the field crew. Existing paved and gravel roads allowed convenient access to the four water tanks. Ground exposures were examined for the presence of cultural materials and other evidence of past human settlement and land use. Shovel testing and subsurface testing were not conducted since the PFR was not undertaken under a permit issued under the *Heritage Conservation Act*. Landforms, vegetation (and lack thereof), and aspect were noted in the field.

Paved and gravel access roads extend throughout the study area. Three of the four water tanks—Phase IV, Phase V, and Harvey Creek Tanks—all sit at approximately 250 masl, directly above and to the east of the Village of Lions Bay (Figures 11-23). The fourth tank—the Highway Tank—is located within the Village proper, just east of the Sea-to-Sky Highway (Figures 24-26). All four tanks have been built on raised platforms to function as level surfaces, in some areas the manufactured surface is two meters above the original sloped surface. The platforms consist of both local and imported fill. Piping to move the water from the tanks is buried and extends from the tank locations to the distribution system.

The Phase IV, Phase V, and Harvey Tanks are surrounded by second growth forest composed primarily of Douglas-fir, Hemlock, and western redcedar. Alberta Creek is the primary drainage associated with the Phase IV and V Tanks. It runs to the north of the tanks flowing west into Howe Sound. Harvey Creek is the primary drainage associated with the Harvey and Highway Tanks. It flows west into Howe Sound to the north of both tanks. At the Harvey Tank location some degree of blasting of the exposed bedrock was conducted to make additional room for the large tank (Figure 23). The exposed bedrock is basalt, which was commonly used as a toolstone in the production of flaked stone tools in the past. If this was used ancestrally as a quarry location, the extensive modification to the slope for the purpose of installing the Harvey Tank will have obliterated any archaeological evidence of quarrying behaviour. Similarly, the Highway Tank is in a location that has undergone significant modification to the landscape as it is located within the Village of Lions Bay proper (Figures 24-26).

Figure 11: Phase IV Tank, facing southeast.

Figure 12: Phase IV Tank, facing north by northeast.

Figure 13: Phase IV Tank, facing north.

Figure 14: Phase IV Tank, facing west.

Figure 15: Phase V Tank, facing north.

Figure 16: Phase V Tank, facing north by northwest.

Figure 17: Phase V Tank, facing east.

Figure 18: Phase V Tank, facing south by southeast.

Figure 19: Harvey Tank, facing north by northwest.

Figure 20: Possible location for new Harvey Tank above current location, facing south.

Figure 21: Harvey Tank, facing southeast. Darrell Guss in foreground.

Figure 22: Harvey Tank, facing northeast. Kevin Rivers in foreground.

Figure 23: Basalt exposure behind Harvey Tank. Blasting tube visible in middle of photograph, facing east.

Figure 24: Highway Tank, facing north.

Figure 25: Highway Tank, facing north.

Figure 26: Looking out from the entrance to the Highway Tank location toward Highway 99, facing west.

In summary, the four proposed development locations are assessed as having low potential for impacting archaeological resources. This rating was as a result of the highly modified nature of the terrain encompassed by the four water tank facilities. Any archaeological sites that may have been present in the development area have been destroyed as a consequence of the original installation of the tanks and associated distribution system, and because the area has been logged at least once within the last 100 years.

6.0 Recommendations

The results of the field assessment partly concurred with the potential assessment derived from the documentary research, map, and air photo analyses. Accordingly, as a result of the highly modified nature of the terrain encompassed by the water tank storage facilities, the proposed development locations at Phase IV Tank, Phase V Tank, Harvey Tank, and Highway Tank are rated as having low potential for impacting archaeological sites. It is therefore recommended that no further archaeological work is warranted prior to the start of any future development activities provided that the study area is not expanded to include unassessed areas.

In the event that any unanticipated archaeological remains are discovered during construction activities, it is recommended that the proponent inform their personnel and all contractors of the following:

- Archaeological remains in the Province of British Columbia are protected from disturbance, intentional or accidental, by the *Heritage Conservation Act* (1994);

- In the event that archaeological remains are encountered, all activities which threaten the archaeological site(s) should be suspended at once; and

- It is the individual's responsibility to promptly advise the Archaeology Branch at the Ministry of Forests, Lands, and Resource Opportunities of the existence and location of the newly identified site(s). Mitigative measures or management options for the previously unidentified site(s) will be determined in consultation with the Archaeology Branch.

- It is further recommended that the Squamish, Tsleil-Waututh, and Musqueam First Nations be informed of any newly identified site(s).

7.0 Discussion of Results

The ethnographic review and prefield archaeological potential assessment suggested that the ancestral and descendant Squamish, Tsleil-Waututh, and Musqueam First Nations communities utilized the study area. There are abundant resources that would have made the area attractive for First Nations groups. These resources include deer, bear, elk, wolf, smaller fur-bearing animals, and fish. Numerous ethnographically utilized roots, plants, and berries would have also been available. Suitable western red cedar for construction materials may also have been present within certain portions of the study area prior to timber harvesting.

Based upon the literature review and the results of the PFR, the study area is assessed as having low potential for archaeological sites. The methods utilized within the current study are in accordance with the *Archaeological Impact Assessment Guidelines* (Apland and Kenny 1998) and are considered suitable for the study area.

It should be noted that the relative lack of previously recorded archaeological sites in the general study area should not be interpreted to mean that there was a relative lack of ancestral use of the study area. Rather, it is more likely that the relative lack of previously recorded archaeological sites in the study area reflects the fact that few archaeological investigations have occurred in the study area and/or that considerable land altering activities have already taken place within the study area without the benefit of archaeological studies preceding the development activities.

7.1 Data Gap Analysis of the Literature Consulted

Detailed information concerning how First Nation populations utilized the study area and interacted with other groups in the area is rare in the ethnographic literature. Part of the reason for this lack of information may be due to the fact that many of the ethnographers arrived after First Nation groups had been heavily impact by smallpox and other epidemics that swept through the Province following contact (see Duff 1964; Harris 1992, 1997). As such, much of the traditional knowledge of the area may have died with the people who succumbed to these epidemics. In addition, many of the ethnographers working in the area did not start their work until well into the 20th century after many of the First Nation groups had been in contact with Europeans for more than a century after the effects of the fur trade, a cash economy, missionaries, and firearms had already heavily impacted traditional lifeways. Moreover, many of the ethnographic accounts that do exist tend to concentrate on the more permanent village settlements and do not pay as much attention to only seasonally occupied areas such as the study area.

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APPENDIX C
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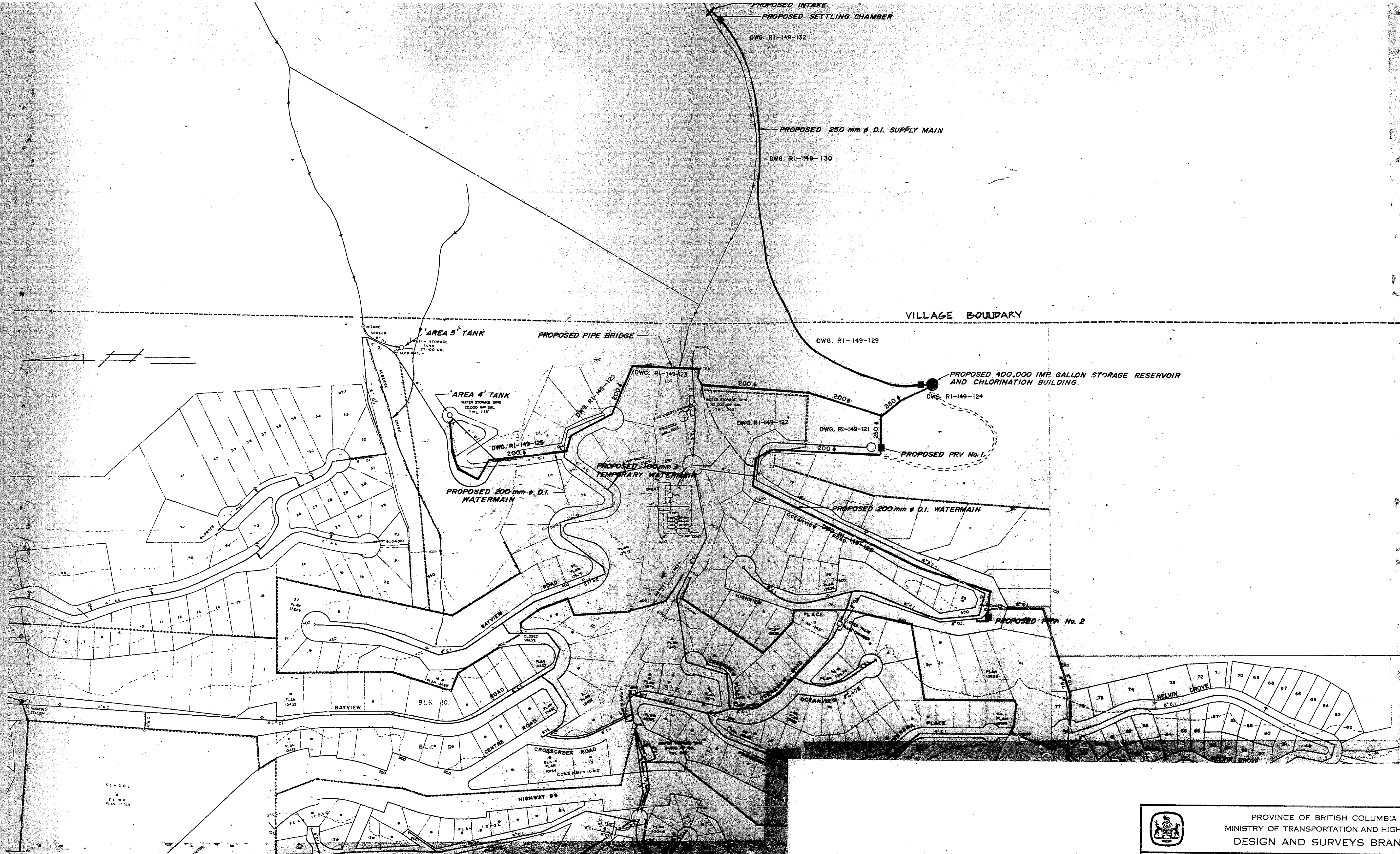

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PROVINCE OF BRITISH COLUMBIA
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VILLAGE OF LIONS BAY

WATERWORKS

KEY PLAN

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DATE	DIRECTOR OF HIGHWAY DESIGN AND SURVEYS DATE 84-05-01	M G Elston EXECUTIVE DIRECTOR ENGINEERING DATE 1984 05 01

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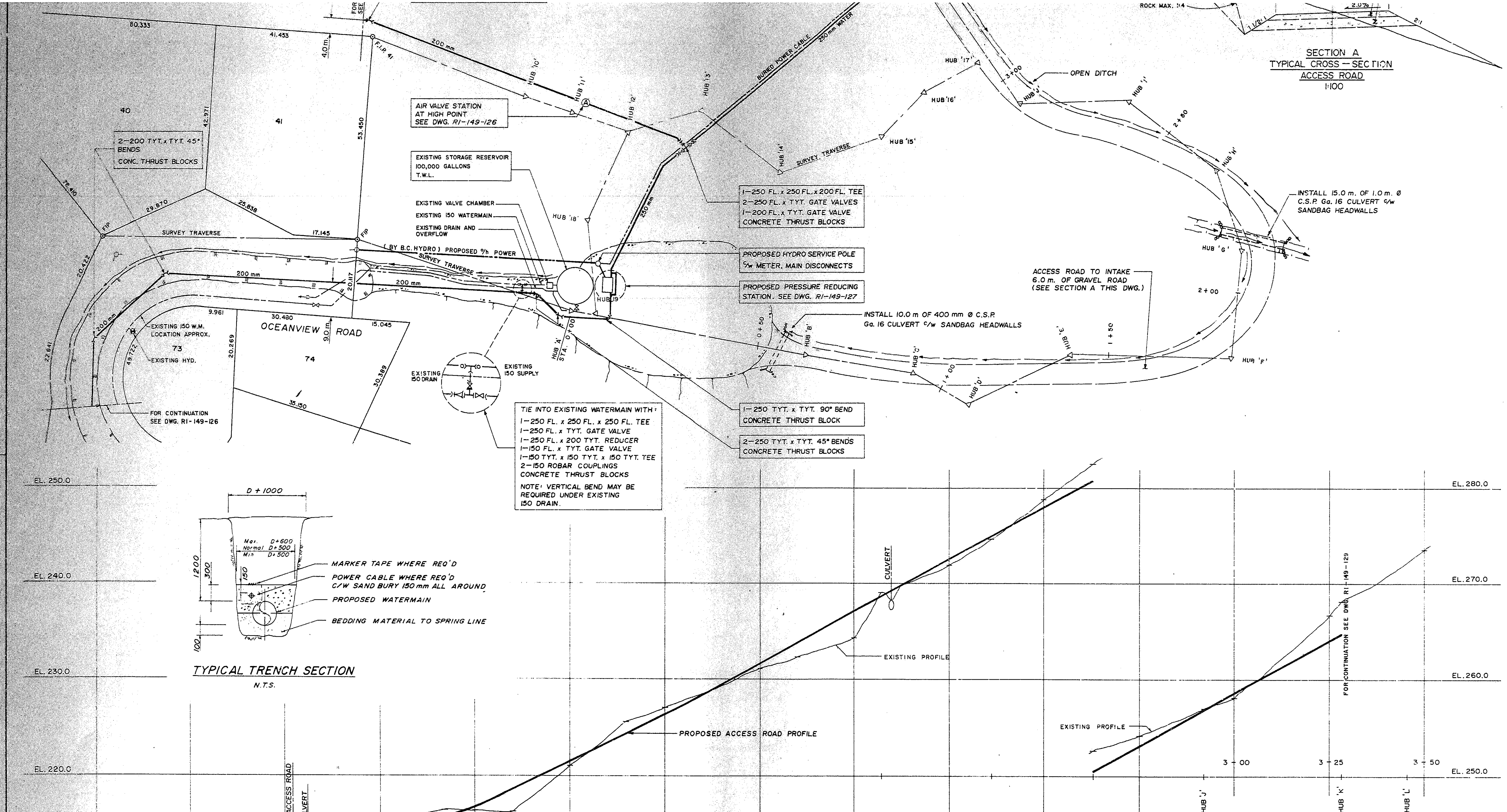

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OCEANVIEW ROAD — RESERVOIR SITE

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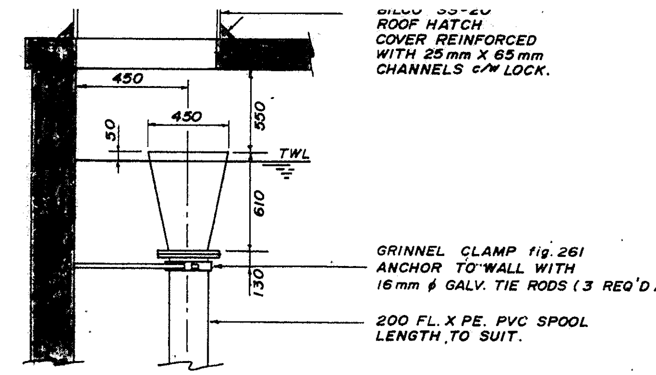

OVERFLOW DETAIL
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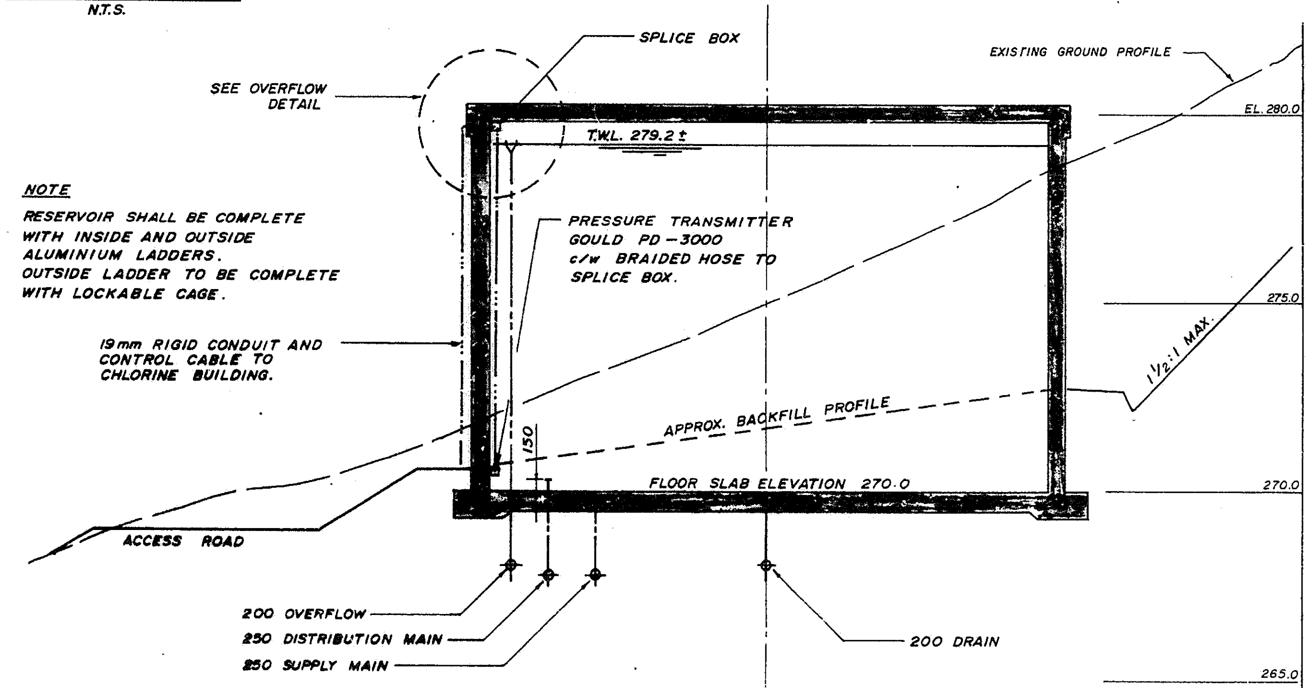

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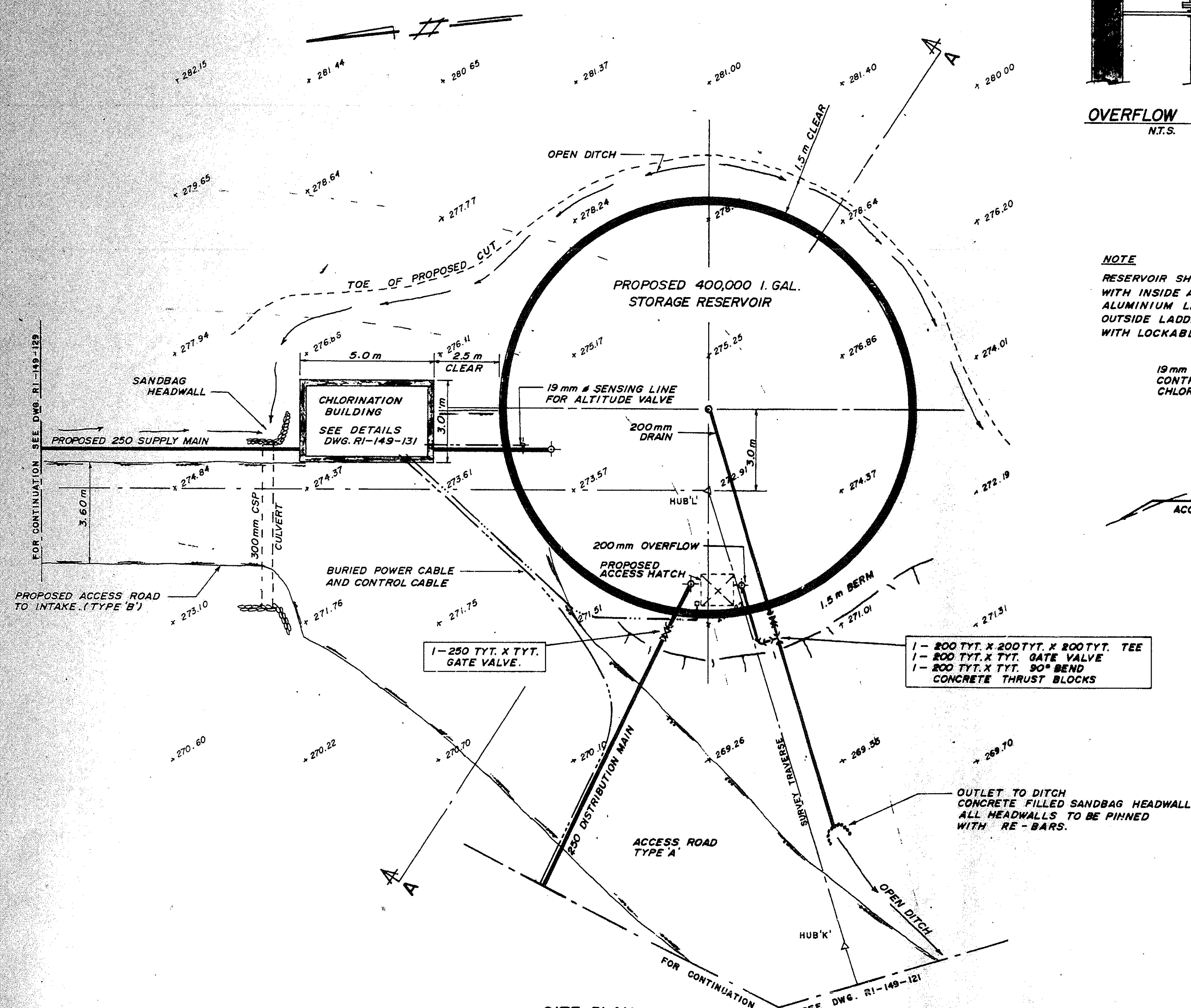

SITE PLAN
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PROPOSED 400,000 IMP. GAL. RESERVOIR

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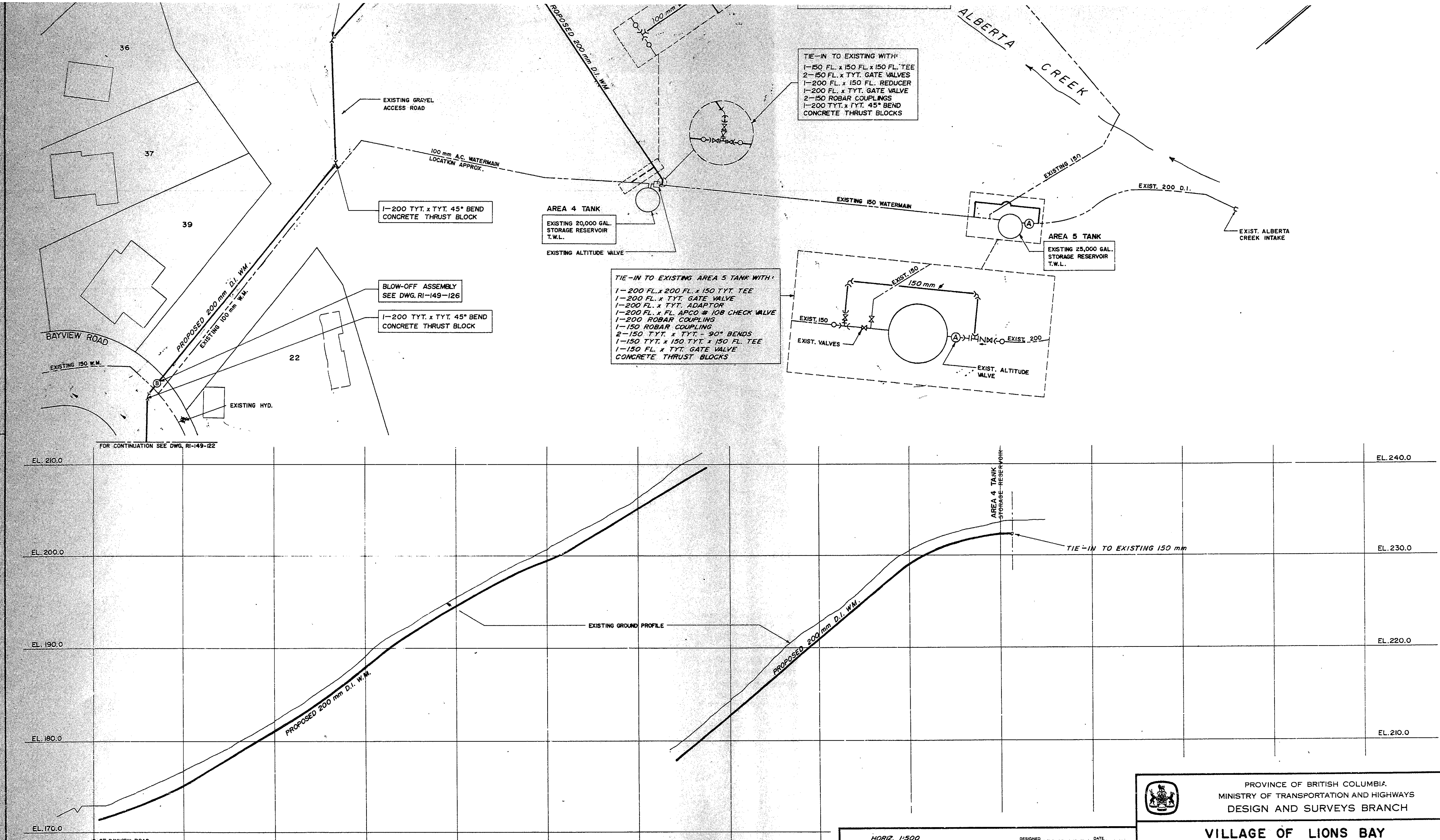

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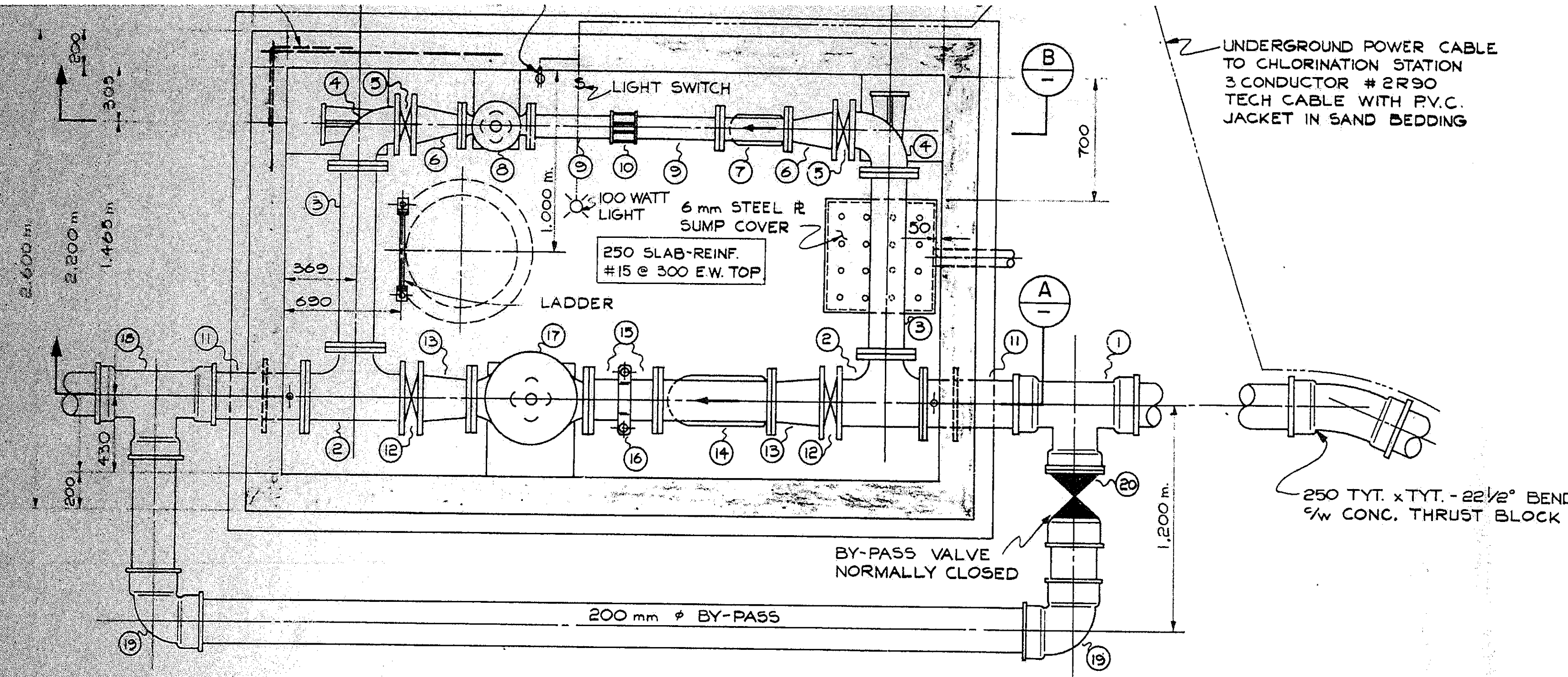

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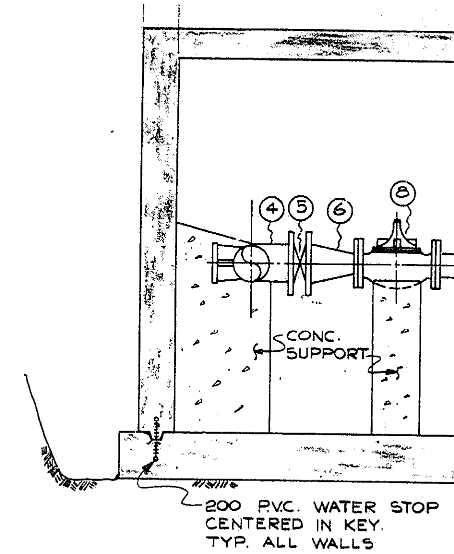

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(MINUS REINF. DETAIL)

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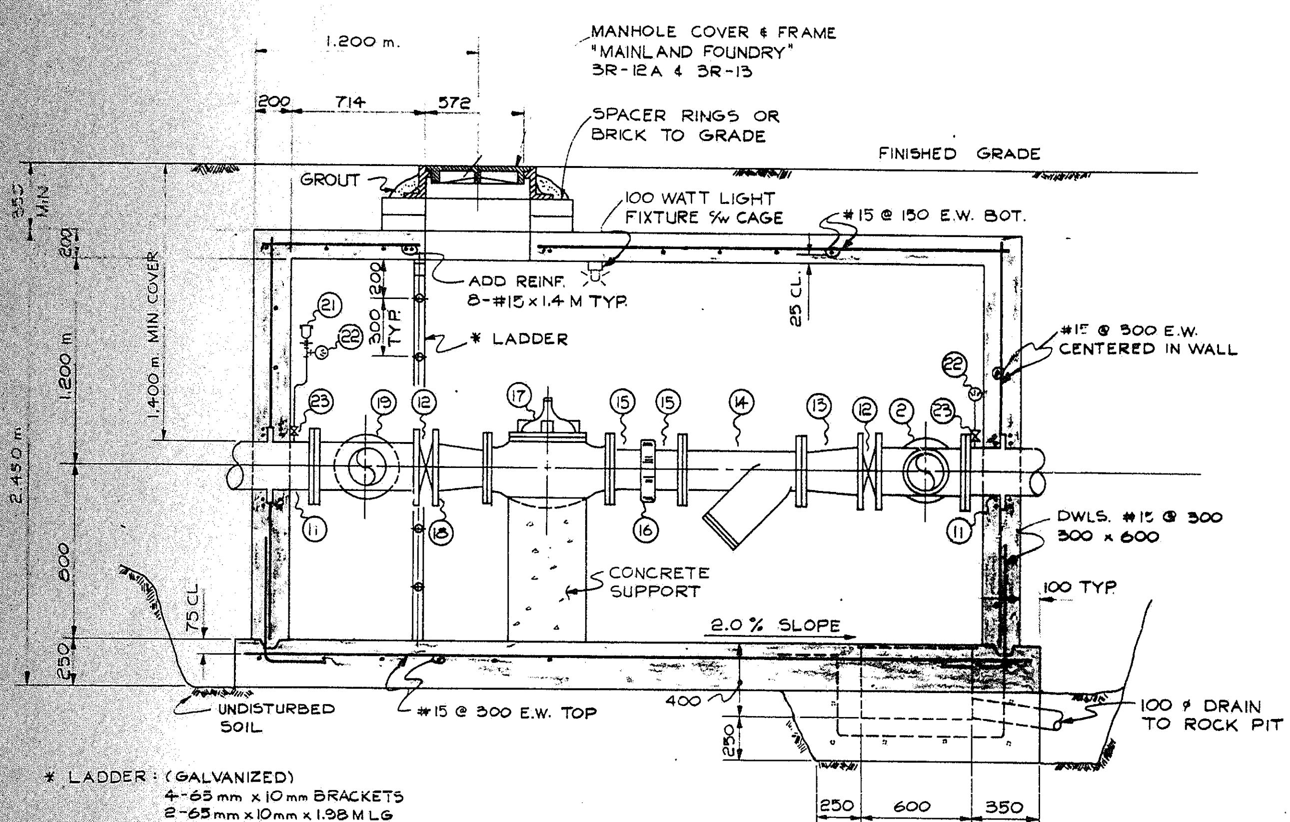

* LADDER: (GALVANIZED)
4-65 mm x 10 mm BRACKETS
2-65 mm x 10 mm x 1.98 M LG BAR RAILS
6-19 mm ⌀ RUNGS

SECTION A

EQUIPMENT & PIPING MATERIAL LIST

MARK NO.	NO. REQ'D	DESCRIPTION
1	1	250 TYT. x 250 TYT. x 200 FL. TEE c/w THRUST BLOCKS.
2	2	250 FL x 250 FL x 200 FL. TEE.
3	2	200 FL. x FL. C.I. SPOOL - 957 LG.
4	2	200 FL. x FL. - 90° BASE ELBOW
5	2	200 WAFER BUTTERFLY VALVE, "DRESSER" # 450 c/w U/G OPERATOR, OR APPROVED EQUAL.
6	2	200 FL. x 100 CL. FL. REDUCER.
7	1	100 FL. Y-STRAINER MUESSCO" # 751 c/w BLOWOFF PLUG.
8	1	100 PRV. "CLAYTON" 90G-01, CL. 125.
9	2	100 FL. x P.E. C.I. SPOOL, LENGTH TO SUIT.
10	1	100 ROBAR CAST STRAIGHT COUPLING CI. TO CI.
11	2	250 FL x P.E. x 500 MM LG CI. SPOOL c/w CASTING RING 200 MM FROM FL. FACE.
12	2	250 WAFER BUTTERFLY VALVE "DRESSER" # 450 c/w U/G. OPERATOR, OR APPROVED EQUAL.
13	2	250 FL. x 200 FL. REDUCER
14	1	200 FL. Y-STRAINER, "MUESSCO" # 751 c/w BLOWOFF PLUG.
15	2	200 FL. x "VICTAULIC" GROOVED END C.I. SPOOL LENGTH TO SUIT.
16	1	200 "VICTAULIC" STYLE 31 COUPLING.
17	1	200 PRV. "CLAYTON" 90G-01 CL. 125.
18	1	250 TYT. x 250 TYT. x 200 TYT. TEE c/w THRUST BLOCKS.
19	2	200 TYT x TYT - 90° BEND c/w THRUST BLOCKS.
20	1	200 FL. x TYT GATE VALVE
21	2	25 AIR-RELEASE VALVE, "APCO" # 200A OR EQUAL, c/w UNION.
22	2	PRESSURE GUAGE, "WEISS" 4 PG-B RANGE 0-1040 KPa (0-150 PSI.)
23	2	25 CORP. STOP, "FORD" TYPE F400, OR EQUAL.

PROVINCE OF BRITISH COLUMBIA
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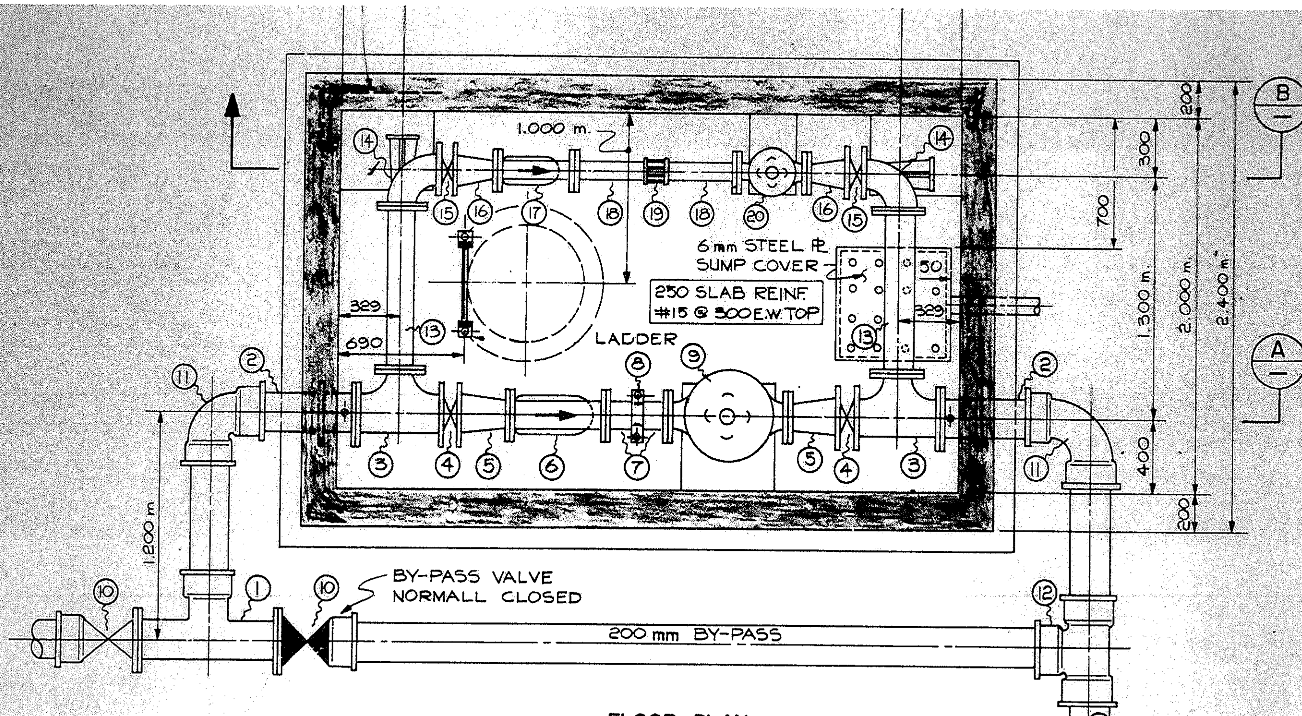

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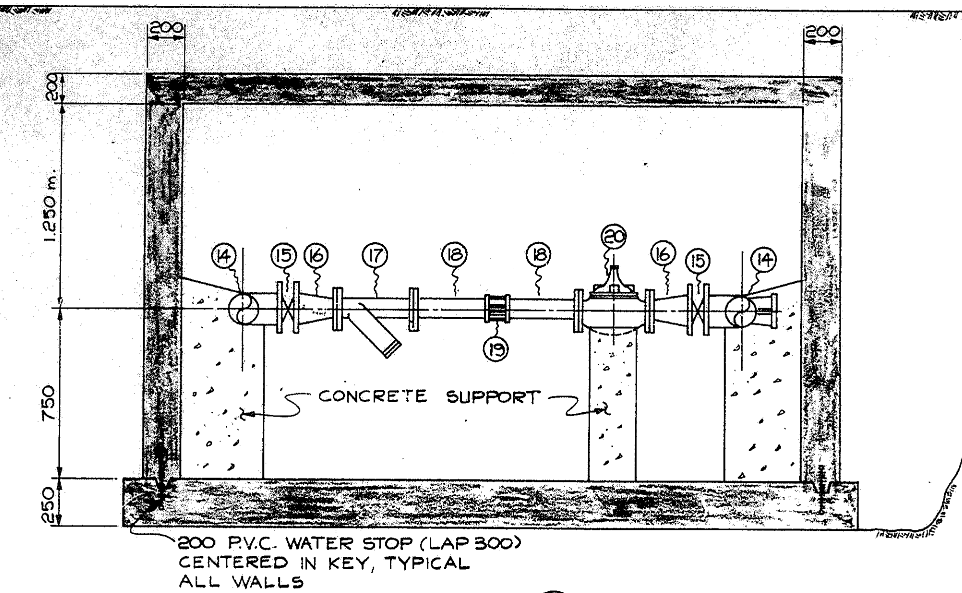

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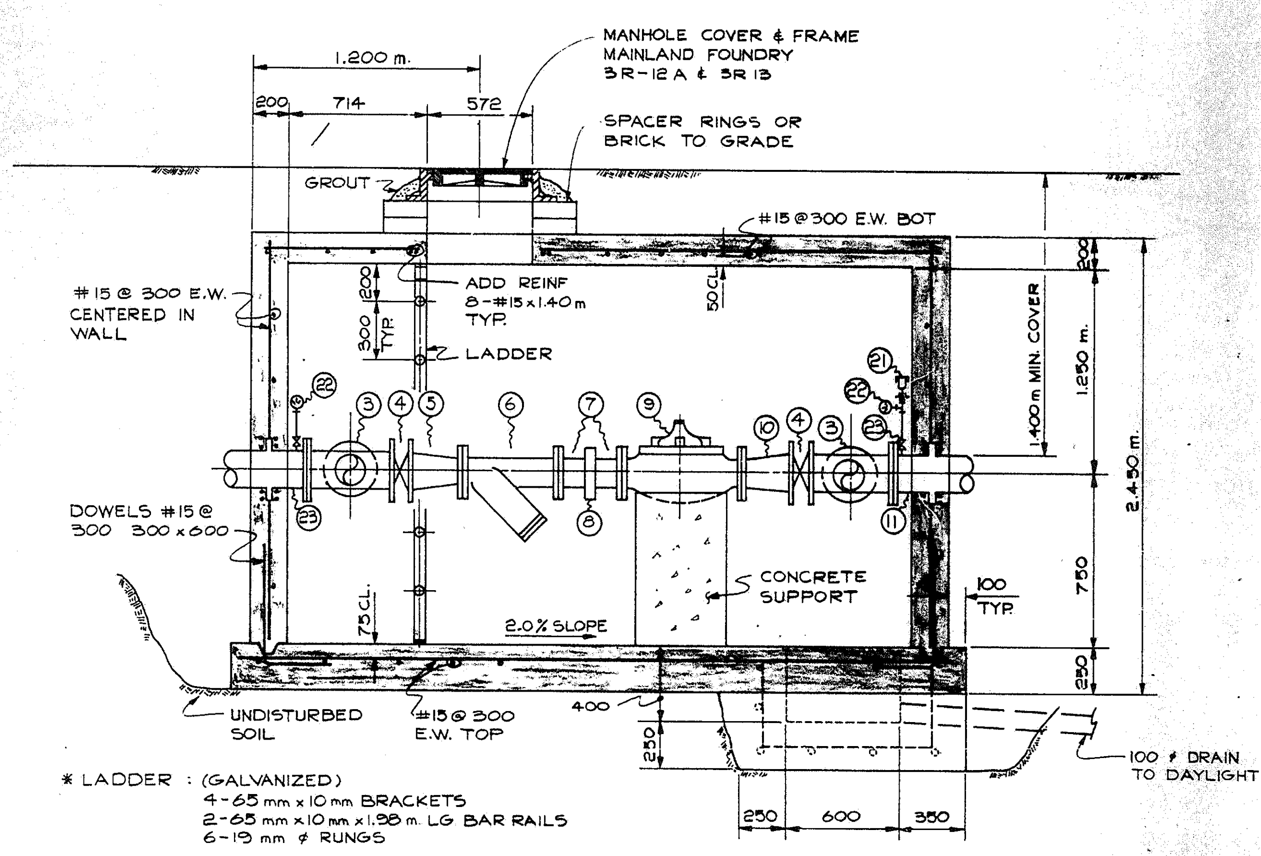

SECTION (A)

NOTE : UNLESS OTHERWISE NOTED, ALL FLANGES SHALL BE CLASS 125.

EQUIPMENT & PIPING MATERIAL LIST

MARK NO.	NO. REQ'D	DESCRIPTION
1	1	200 FL. x 200 FL. x 200 TYT. TEE c/w THRUST BLOCKS.
2	2	200 FL. x FL. x 500 mm LG. C.I. SPOOL c/w CASTING RING 200 mm FROM FLANGE FACE
3	2	200 FL. x 200 FL. x 100 FL. TEE
4	2	200 WAFER BUTTERFLY VALVE "DRESSER" # 450 c/w U/G OPERATOR, OR APPROVED EQUAL.
5	1	200 FL. x 150 FL. REDUCER.
6	1	150 FL. Y-STRAINER "MUESSCO" # 751 c/w BLOWOFF PLUG
7	2	150 FL. x "VICTAULIC" GROOVED END C.I. SPOOL LENGTH TO SUIT.
8	1	150 "VICTAULIC" STYLE 31 COUPLING
9	1	150 P.R.V. "CLAYTON" 90 G-01 CL. 125
10	2	200 FL. x TYT. GATE VALVES
11	2	200 TYT x TYT. 90° BENDS c/w CONCRETE THRUST BLOCKS
12	1	200 TYT. x 200 TYT. x 200 TYT. TEE c/w CONCRETE THRUST BLOCKS.
13	2	100 FL. x FL. x 906 mm LG. C.I. SPOOL.
14	2	100 FL. x FL. - 90° BASE ELBOW.
15	2	100 WAFER BUTTERFLY VALVE "DRESSER" # 450 c/w U/G OPERATOR, OR APPROVED EQUAL.
16	2	100 FL. x 75 FL. REDUCER.
17	1	75 FL. Y-STRAINER "MUESSCO" # 751 c/w BLOWOFF PLUG.
18	2	75 FL. x THREADED C.I. SPOOL, LENGTH TO SUIT.
19	1	75 UNION
20	1	75 P.R.V. "CLAYTON" 90 G-01 CL. 125.
21	1	19 mm APCO # 65 AIR RELEASE VALVE.
22	2	(4 1/2") WEISS 4 PGAN-1 PRESSURE GUAGES.
23	2	19 mm CORP. STOP "FORD" TYPE F400 OR EQUAL.

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MINISTRY OF TRANSPORTATION AND HIGHWAYS
DESIGN AND SURVEYS BRANCH

VILLAGE OF LIONS BAY
WATERWORKS
PRESSURE REDUCING STATION No.2

PREPARED UNDER THE DIRECTION OF	APPROVED FOR USE IN CONSTRUCTION	EXAMINED AND ACCEPTED
DATE	DIRECTOR OF HIGHWAY DESIGN AND SURVEYS DATE 84-05-01	M G Elston EXECUTIVE DIRECTOR ENGINEERING DATE 1984-05-01

INDEX	NEG No	FILE No	PROJECT No	REGION	DRAWING No
			C-2593		RI-149-128 0

CANCEL PRINTS BEARING EARLIER LETTER

SCALE 1:20 DESIGNED .... DATE .... CHECKED .... DATE ....

REVISIONS	
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E	
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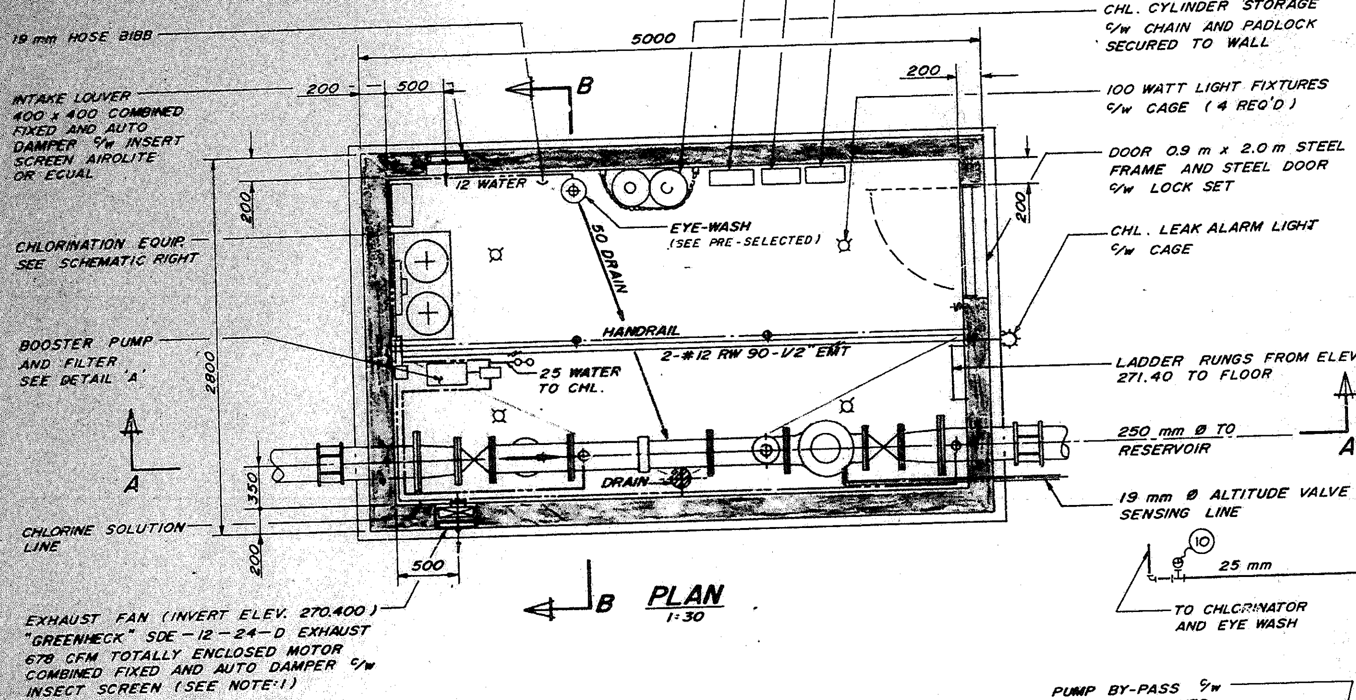
WEB No. 087-28 REVISIONS

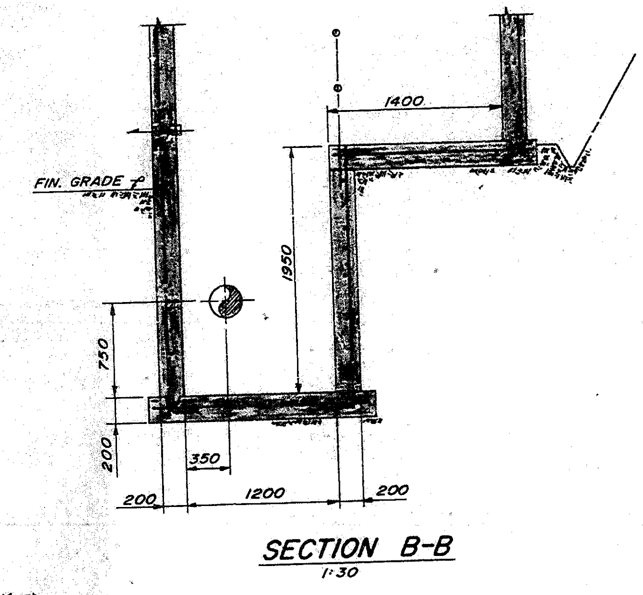
WEB ENGINEERING LTD.
consulting civil engineers
STE. 101 1861 WELCH ST.
North Vancouver, B.C.

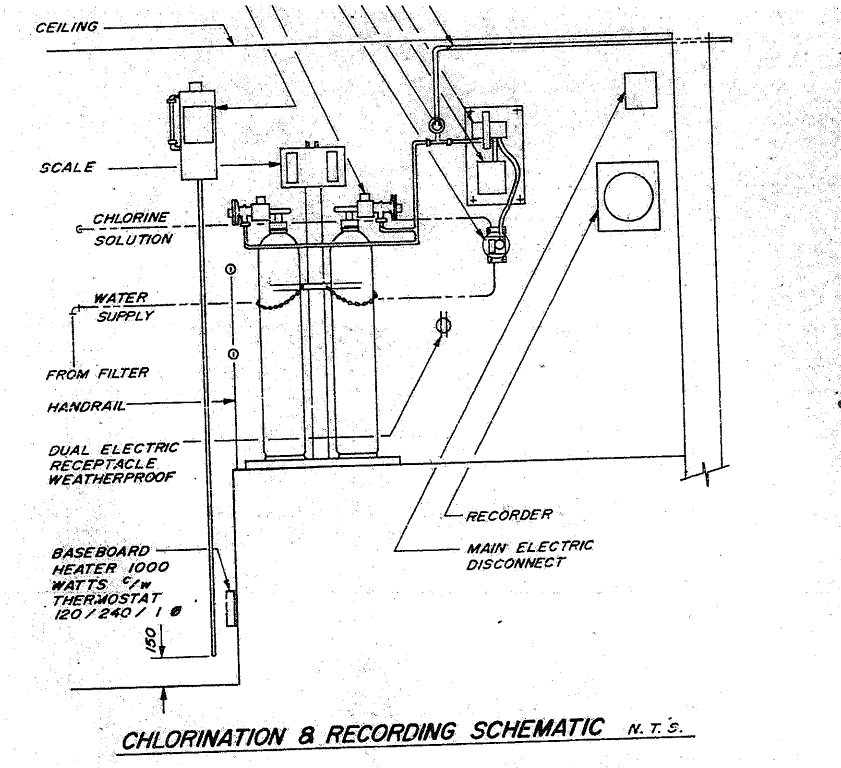
DRWN: D.B.
DSGN: R.P.
CHKD: R.D.
DATE: APR./84

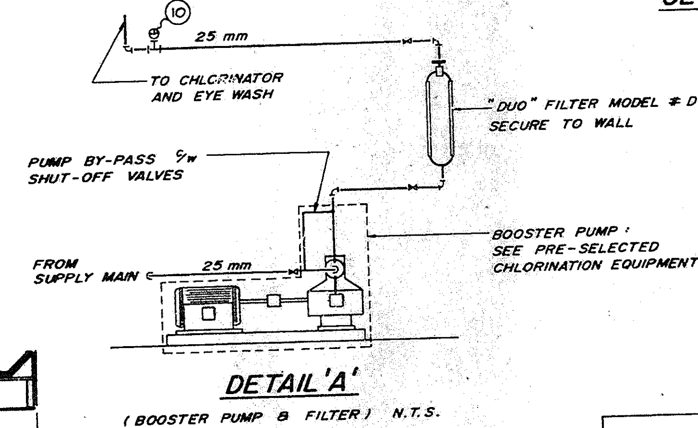
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA R. F. U...

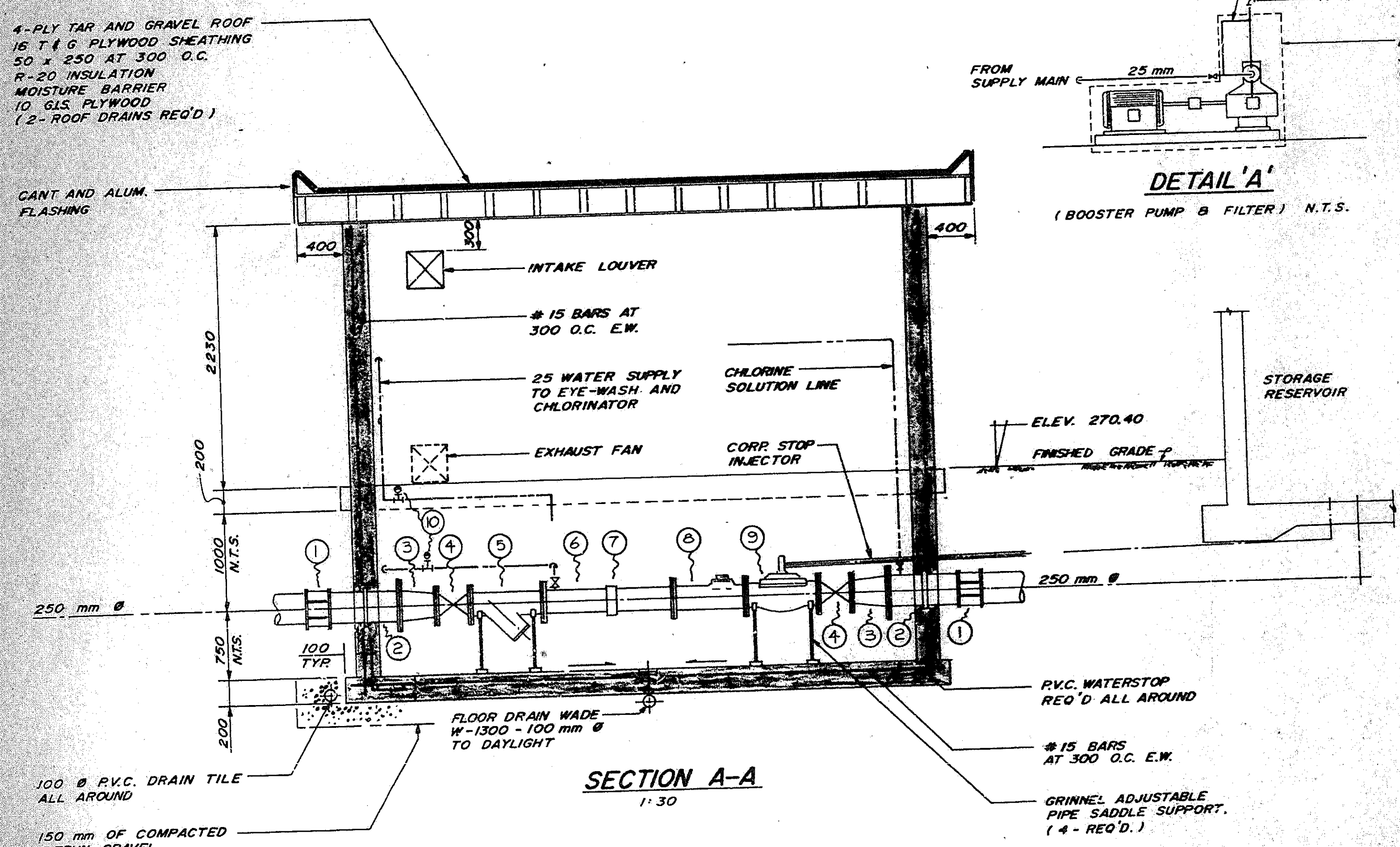
FORM H 3081











FITTING LIST

1. 250 ROBAR TRANSITION COUPLING.
2. 250 FL. x 250 P.E. x 760 LG. STEEL SPOOL c/w CASTING RING @ 300 mm FROM FLANGE FACE.
3. 250 FL. x 200 FL. REDUCER
4. 200 FL. x FL. GATE VALVE.
5. 200 FL. Y-STRAINER "MUESSCO" #751.
6. 200 FL. x VIC. GROOVE x 550 LG. C.I. SPOOL.
7. 200 VICTAULIC STYLE 31 COUPLING.
8. 200 "SPARLING" F.M. 103 FLOW METER.
9. 200 CLAYTON #210-01 ALTITUDE VALVE.
10. PRESSURE GAUGE "WEISS" 4 PG-B RANGE 0-1040 KPa (0-150 P.S.I.) 25 CORP. STOP "FORD" TYPE F400.

NOTES:

1. CHLORINE GAS LEAK DETECTOR SHALL BE WIRED TO ACTIVATE ALARM LIGHT AND EXHAUST FAN.
2. FOR CONCRETE, REINFORCING STEEL, HANDRAIL AND PAINTING SEE NOTES ON DWG. R1-149-133.
3. INTERIOR CONCRETE SURFACES SHALL BE PAINTED WITH 2 COATS OF LOW LUSTER WHITE EXTERIOR PAINT.

PRE-SELECTED EQUIPMENT

CHLORINATION (WALLACE & TIERNAN)

1 - V-500 REMOTE CHLORINATOR.
1 - AUTOMATIC SWITCHOVER, VACUUM REGULATOR CHECK UNIT SET.
1 - 25 mm FIXED THROAT INJECTOR
1 - ELECTRIC V-NOTCH POSITIONER FOR 4-20mA.
1 - SERIES 50-125 CHLORINE LEAK DETECTOR.
1 - 19 mm CORP. COCK MAIN CONNECTION.
1 - SERIES 50-345 TWO-CYLINDER SCALE.
1 - AURORA TURBINE PUMP SERIES 110, MODEL # E4 SINGLE STAGE 3/4 H.P.

CONTROL SYSTEM (B.C.A. INDUSTRIAL CONTROLS)

METER - 200 'SPARLING' F.M. 103-081-110-0 OUTPUT 4-20mA AND PULSE.
RECORDER - HONEYWELL MODEL AR100 RECORDER c/w 7-DAY CHARTS.
ALTITUDE VALVE - 200 mm CLAYTON # 210-01.
PRESSURE TRANSMITTER - GOULD PC 3000 c/w LIGHTNING ARRESTOR IN RESERVOIR.
LEVEL INDICATOR - CEMA 4 CONTROL PANEL CONTAINING LEVEL INDICATOR, POWER SUPPLY, ALARM INDICATING LIGHTS.

MISCELLANEOUS
EYE-WASH - TWIN EYE-WASH "HAWS" MD. 7761 OR APPROVED EQUAL.

PROVINCE OF BRITISH COLUMBIA
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DESIGN AND SURVEYS BRANCH

VILLAGE OF LIONS BAY
WATERWORKS
CHLORINATION BLDG.

SCALE AS NOTED   DESIGNED ____ DATE ____   CHECKED ____ DATE ____

	REVISIONS
F	
E	
D	
C	
B	CHLORINATION SYSTEM REVISED
A	GRINNEL PIPE SUPPORT ADDED

WEB No. 087-31

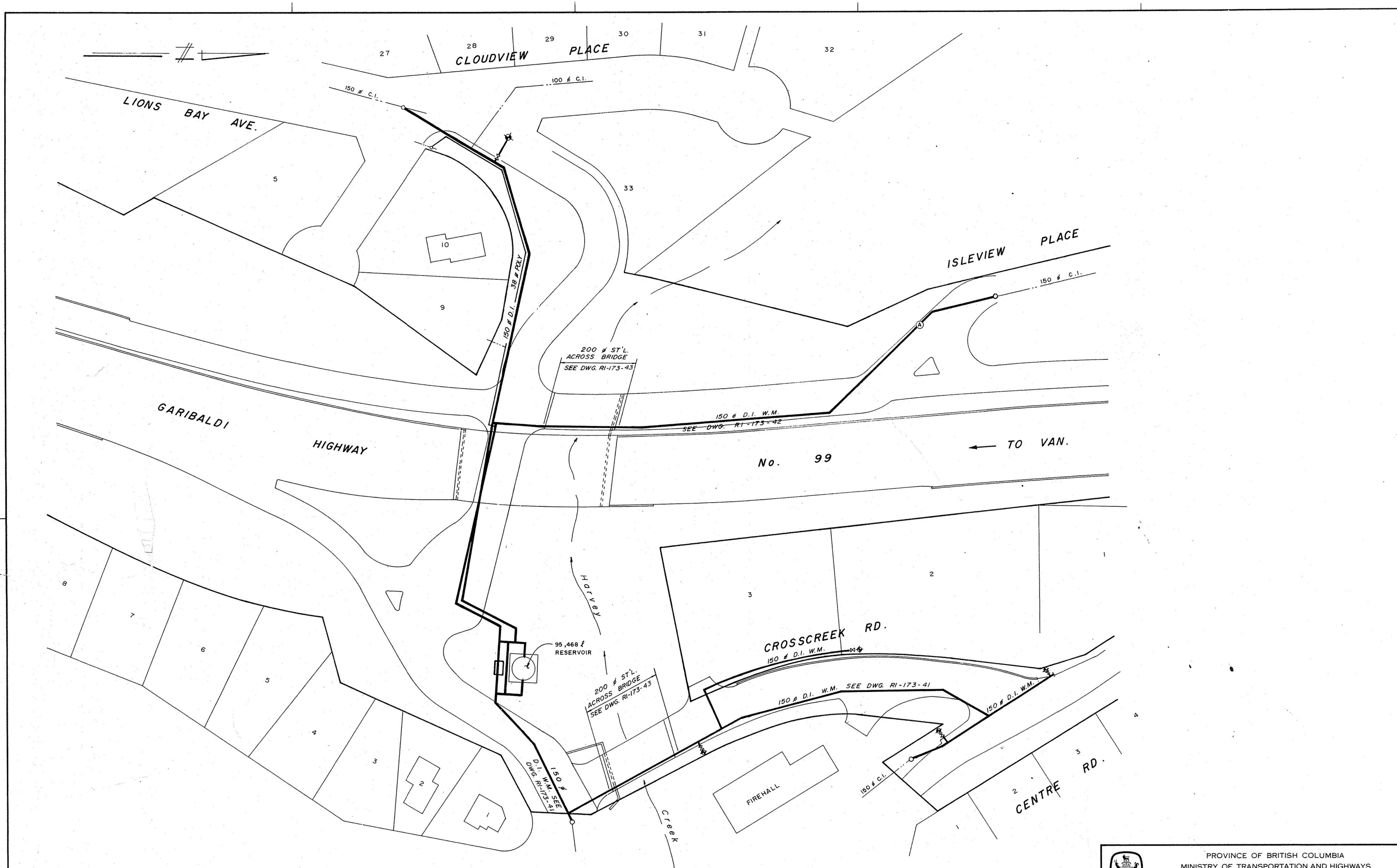
WEB ENGINEERING LTD.
consulting civil engineers
STE. 101 1861 WELCH ST.
North Vancouver, B.C.

DRWN: D.B.
DSGN: R.P.
CHKD: R.D.
DATE: APR./84

PREPARED UNDER THE DIRECTION OF — DATE
APPROVED FOR USE IN CONSTRUCTION — DIRECTOR OF HIGHWAY DESIGN AND SURVEYS — DATE May 14 '84
EXAMINED AND ACCEPTED — EXECUTIVE DIRECTOR ENGINEERING — DATE May 14 /84

INDEX	NEG. No.	FILE No.	PROJECT No.	REGION	DRAWING No.
					R1-149-131 B

CANCEL PRINTS BEARING EARLIER LETTER



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A	AS CONSTRUCTED	JAN. 1987

WEB No. 425-33 REVISIONS

WEB ENGINEERING LTD.
consulting civil engineers
STE. 101 1861 WELCH ST.
North Vancouver, B.C.

DRWN: DJB
DSGN: R.P.
CHKD: R.P.
DATE: APR./85

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND HIGHWAYS
DESIGN AND SURVEYS BRANCH

VILLAGE OF LIONS BAY

GARIBALDI HWY. No. 99 - LIONS BAY INTERCHANGE

WATERWORKS KEY PLAN

PREPARED UNDER THE DIRECTION OF	APPROVED FOR USE IN CONSTRUCTION	EXAMINED AND ACCEPTED
DATE	DIRECTOR OF HIGHWAY DESIGN AND SURVEYS DATE	EXECUTIVE DIRECTOR ENGINEERING DATE

INDEX	NEG. No.	FILE No.	PROJECT No.	REGION	DRAWING No.
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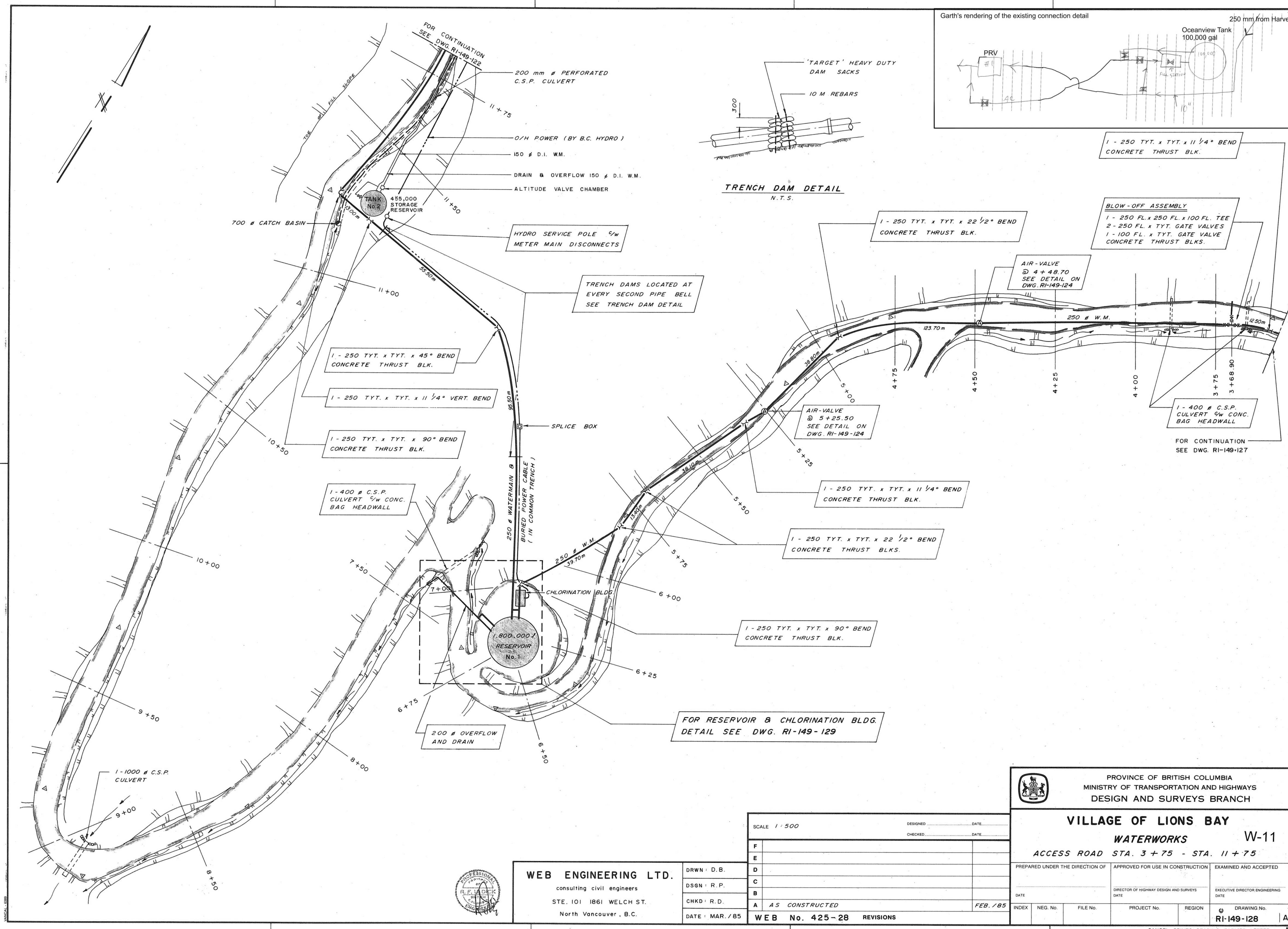
FORM H3081

CANCEL PRINTS BEARING EARLIER LETTER



FOR CONTINUATION SEE DWG. RI-149-122
200 mm ø PERFORATED C.S.P. CULVERT
11 + 75
O/H POWER (BY B.C. HYDRO)
150 ø D.I. W.M.
DRAIN & OVERFLOW 150 ø D.I. W.M.
ALTITUDE VALVE CHAMBER
TANK No.2
455,000 STORAGE RESERVOIR
700 ø CATCH BASIN
11 + 50
HYDRO SERVICE POLE c/w METER MAIN DISCONNECTS
11 + 00
TRENCH DAMS LOCATED AT EVERY SECOND PIPE BELL SEE TRENCH DAM DETAIL
1 - 250 TYT. x TYT. x 45° BEND CONCRETE THRUST BLK.
1 - 250 TYT. x TYT. x 11 1/4° VERT. BEND
1 - 250 TYT. x TYT. x 90° BEND CONCRETE THRUST BLK.
10 + 50
SPLICE BOX
250 ø WATERMAIN & BURIED POWER CABLE (IN COMMON TRENCH)
1 - 400 ø C.S.P. CULVERT c/w CONC. BAG HEADWALL
10 + 00
7 + 50
7 + 00
CHLORINATION BLDG
1,800,000 l RESERVOIR No. 1
250 ø W.M.
6 + 00
1 - 250 TYT. x TYT. x 90° BEND CONCRETE THRUST BLK.
6 + 25
6 + 75
200 ø OVERFLOW AND DRAIN
FOR RESERVOIR & CHLORINATION BLDG. DETAIL SEE DWG. RI-149-129
6 + 50
9 + 50
8 + 00
1 - 1000 ø C.S.P. CULVERT
9 + 00
8 + 50
'TARGET' HEAVY DUTY DAM SACKS
10 M REBARS
300
TRENCH DAM DETAIL
N.T.S.
1 - 250 TYT. x TYT. x 22 1/2° BEND CONCRETE THRUST BLK.
AIR-VALVE @ 4 + 48.70 SEE DETAIL ON DWG. RI-149-124
123.70 m
250 ø W.M.
5 + 00
4 + 75
4 + 50
4 + 25
4 + 00
3 + 75
3 + 68.90
AIR-VALVE @ 5 + 25.50 SEE DETAIL ON DWG. RI-149-124
5 + 25
1 - 250 TYT. x TYT. x 11 1/4° BEND CONCRETE THRUST BLK.
5 + 50
1 - 250 TYT. x TYT. x 22 1/2° BEND CONCRETE THRUST BLKS.
5 + 75
1 - 250 TYT. x TYT. x 11 1/4° BEND CONCRETE THRUST BLK.
BLOW-OFF ASSEMBLY
1 - 250 FL. x 250 FL. x 100 FL. TEE
2 - 250 FL. x TYT. GATE VALVES
1 - 100 FL. x TYT. GATE VALVE
CONCRETE THRUST BLKS.
1 - 400 ø C.S.P. CULVERT c/w CONC. BAG HEADWALL
FOR CONTINUATION SEE DWG. RI-149-127
Garth's rendering of the existing connection detail
250 mm from Harvey
Oceanview Tank 100,000 gal
PRV
PROVINCE OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND HIGHWAYS
DESIGN AND SURVEYS BRANCH
VILLAGE OF LIONS BAY
WATERWORKS
W-11
ACCESS ROAD STA. 3 + 75 - STA. 11 + 75
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DIRECTOR OF HIGHWAY DESIGN AND SURVEYS
EXECUTIVE DIRECTOR ENGINEERING
INDEX
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PROJECT No.
REGION
DRAWING No.
RI-149-128
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DESIGNED
CHECKED
A AS CONSTRUCTED FEB. /85
WEB No. 425-28 REVISIONS
DRWN: D.B.
DSGN: R.P.
CHKD: R.D.
DATE: MAR. /85
WEB ENGINEERING LTD.
consulting civil engineers
STE. 101 1861 WELCH ST.
North Vancouver, B.C.
CANCEL PRINTS BEARING EARLIER LETTER

APPENDIX D
REFERENCE REPORTS

April 24, 2017

Project No.: 171-02740-00

The Municipality of the Village of Lions Bay
P.O. Box 141, 400 Centre Road
Lions Bay, BC V0N 2E0

Attention: Mr. Nai Jaffer, Public Works Manager

Subject: Harvey Creek Water Reservoir Wall Review

Dear Mr. Nai,

The Municipality of the Village of Lions Bay (Municipality) retained WSP Canada Inc. (WSP) to perform a preliminary condition assessment of the post-tensioned concrete reservoir wall of the Harvey Creek water reservoir operated by the Municipality. The intent of this review is to establish the current condition of the wall, and to determine if additional detailed condition assessment work is necessary. The following presents our findings.

1. BACKGROUND

The Harvey Creek Reservoir was built circa 1984 and it is located on a gravel road, which is accessed from the end of the Oceanview Road in Lions Bay. The reservoir wall is approximately 200 mm in thickness, 10.1 m in height, and has an internal diameter of 15.8 m, with a storage capacity of 400,000 Imperial gallons. General views of the reservoir are shown in Photos 1 and 2.

The wall of the reservoir comprises sixteen precast concrete panels. Each wall panel is joined together by approximately 100 mm wide infilled strip of concrete over its full height as part of the original construction, as shown in Photo 3. The wall is post-tensioned both in the vertical and circumferential directions.

Earth Tech Inc. (Earth Tech) performed a structural assessment of several reservoirs, including the Harvey Creek Reservoir operated by the Municipality in September 2004. As part of this assessment, Earth Tech identified some critical defects, such as extensive water leakage, which reportedly required urgent attention. Earth Tech was subsequently retained by the Municipality to complete an engineering analysis on the structural integrity of this reservoir. As part of this work, Earth Tech also performed a strengthening and seismic review of the reservoir in

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150-12791 Clarke Place
Richmond, BC V6V 2H9

Tel: 604-278-1411
Fax: 604-278-1042
www.wspgroup.ca

relation to the seismic code requirements at the time. Please refer to the enclosed report dated March 21, 2006 prepared by Earth Tech.

A review of Earth Tech's report indicates that extensive water leakage was occurring between the precast panels as observed from the outside of the reservoir. Upon further review of inside of the tank by Earth Tech indicated that the seals between the precast panels had deteriorated. A repair plan was then developed to seal the gap between the precast panels. WSP understands that some repairs were undertaken; however, WSP does not have any information on the type of repair, or extent of the completed remedial works. Please refer to the enclosed inspection report dated March 27, 2006 prepared by Earth Tech.

WSP understands that no subsequent remedial work was undertaken to seal the gap between the precast panels since the initial attempt made in 2006. It is also understood that strengthening and seismic retrofit work was not completed.

WSP was retained by the Municipality to assess the current condition of the Harvey Reservoir, including any remedial work conducted in 2006. All of our review was conducted from the outside of the reservoir.

2. INTRODUCTION

As part of a preliminary assessment of the reservoir wall, WSP performed a visual review of the outside of the reservoir, and a delamination survey in areas accessible from the ground to identify areas of corrosion-related deterioration; this review was conducted on March 8, 2016.

Delaminations are typically cracks within the concrete slab along the plane of the outer mat of reinforcement that are caused by corrosion (rusting) of the reinforcing steel. The corrosion products of the steel are five to seven times larger than the steel that is consumed and this volume change exerts expansive forces on the concrete, causing it to crack. Often delaminations are not visible from the surface, but can be detected by sounding with a hammer or chain as they produce a different sound from intact concrete. Spalls are areas where delaminated concrete has broken off.

In addition, WSP extracted powder samples at one location from the wall for laboratory analyses to determine water-soluble chloride ion content and pH.

3. VISUAL REVIEW AND DELAMINATION SURVEY

Visually, the precast concrete wall panels are in generally fair to good condition with areas of minor crazing, and minor shrinkage cracking. Crazing is a network of fine random cracks on the surface of concrete caused by shrinkage of the surface layer. These types of cracks typically manifest within days after finishing of the concrete has been completed and typically do not pose a structural or durability concern.

The infilled concrete at the joint between the precast concrete panels, however, is in fair to poor condition at a few locations due to significant leakage (Photo 4). This leakage has resulted in deterioration of the concrete where active leakage was observed at the time of the review (Photos 5 and 6). Several of the joints are leaking indicating that the joint detail at the interior of the wall has failed. It is noted that the as-built drawings of the reservoir are unavailable; therefore, the specified joint detail is unknown. The joint detail repair plan prepared by Earth Tech was not available for our review.

There is minor loss of surface paste at a few locations which has exposed fine aggregate, and in a few instances coarse aggregate, particularly adjacent to the leaking joints.

Areas of efflorescence are also visible at the joints indicating that the water is passing through them (Photo 7). Efflorescence is a salt deposit, usually white, on the surface of concrete. When water passes through concrete through cracks, voids, or gaps some salts within the concrete are dissolved and transported by the water to the surface of the concrete. Water then evaporates, leaving these salt deposits (efflorescence) on the surface of the concrete. Apart from the appearance, efflorescence is generally harmless; however, it is indicative that water is moving through the concrete which may induce corrosion of the reinforcing steel.

Spalls are visible at the top of the wall at several infilled joint locations as observed from the ground (Photos 8 to 10). However, a close review in these areas was not possible.

WSP notes that the reinforced concrete roof, and the reinforced concrete ring beam which provides lateral restraint to the reservoir walls were not part of the current assignment, and these elements were covered with snow at the time of our review.

4. LABORATORY ANALYSES

We extracted concrete powder sample at one location from the wall adjacent to an actively leaking joint; the sample location is shown in Photo 4. We removed the samples from two depths: from the surface to 20 mm, and from 20 mm to 35 mm. These samples were analyzed for water-soluble chloride ion concentrations in accordance with CSA A23.2-4B. The samples were also analyzed for pH to determine if carbonation induced corrosion may be a concern. The test results are presented in Table 1.

Table 1 – Laboratory Analyses of Concrete Samples

Sample #	Sample Location	Cover (mm)	Depth (mm)	Water-soluble Chloride Ions (% mass of concrete)	pH
1	Wall adjacent to an area of water leakage	35	0 – 20	<0.005	12.1
			20 – 35	<0.005	12.2

The chloride threshold value necessary to initiate corrosion of reinforcing steel ranges from approximately 0.03 to 0.05% by mass of concrete. The threshold value is typically stated as a range as it depends on several factors, such as the cement content, pH, humidity, and temperature of the concrete.

Corrosion of reinforcing steel can have several adverse effects on reinforced concrete structures including but not limited to: spalling of concrete cover, reduced bond between the steel and the concrete, and reduction in cross-sectional area of the steel which decreases the load bearing capacity of the structural element.

As shown in Table 1, the chloride ion concentrations at the depth of the reinforcing steel are well below the corrosion initiation threshold. Therefore, the corrosion observed at the roof/wall joint location is not a result of exposure to chloride ions.

The alkalinity of the concrete pore solution in new concrete (pH > 12) passivates the steel at the steel/concrete interface and reduces corrosion rates to negligible levels. Carbonation of the concrete will result in a lower pH and causes breakdown of the passive layer. At pH values of approximately 10 or lower, the steel is no longer passivated and active corrosion may be initiated.

Laboratory results show that the pH is greater than 12 which indicates that the alkalinity of the concrete is sufficiently high to conclude that carbonation-induced corrosion mechanism is not a concern at this time.

The spalling of the concrete observed is not a result of elevated chloride levels, nor a result of lower pH of concrete. The spalling observed, therefore, is related to ingress of moisture through poorly detailed joints.

5. DISCUSSION AND RECOMMENDATIONS

The reservoir wall is in generally fair condition except in areas of leakage. There is leakage of water through the joints between the precast panels at several locations indicating that the joint seals have likely failed. This ongoing leakage also indicates that past remediation efforts to seal the joints have been unsuccessful. We recommend that a full condition assessment of the reservoir wall be undertaken sometime this year. This review would require access to both the inner and the outer surfaces of the wall, including safe access to the upper portions of the reservoir wall. The roof slab may also be included as part of this condition assessment work.

The ongoing leakage may have initiated corrosion of the post-tensioned cables and other reinforcement. WSP recommends that the reinforcement be exposed by chipping at a few locations to visually review their condition.

We recommend that spalls and delaminations be repaired by patching. In general, the patch repairs would entail removal of the deteriorated concrete by chipping, augmenting any bars with cross-sectional loss, thoroughly cleaning the patch area, and reinstating the area with a high-quality cementitious patching material.

If the Municipality wishes to complete the seismic upgrades proposed by Earth Tech, WSP recommends the study carried out by Earth Tech be updated to account for any changes in the structure and/or the code since 2006. WSP would be pleased to provide a proposal for the detailed condition assessment and update of the seismic review.

6. CLOSURE

We have presented a brief summary of the present condition of the wall of the reservoir. We trust this meets your requirements. Please advise if you require anything further in this regard.

Yours truly,

WSP Canada Inc.

Reviewed by:

[Original signed by M. Abrar]

[Original signed by D. Smith]

Mohammed Abrar, P.Eng.
Laboratory Supervisor – Richmond, BC
Mohammed.Abrar@wspgroup.com

David Smith, MScE, P.Eng.
Director, Materials (BC)
David.E.Smith@wspgroup.com

MA

Enclosure: *Earth Tech report dated March 21, 2006*
Earth Tech report dated March 27, 2006

APPENDIX A
PHOTOGRAPHS

Photo1: General view of the Harvey Creek Reservoir.

Photo 2: General view of the Harvey Creek Reservoir.

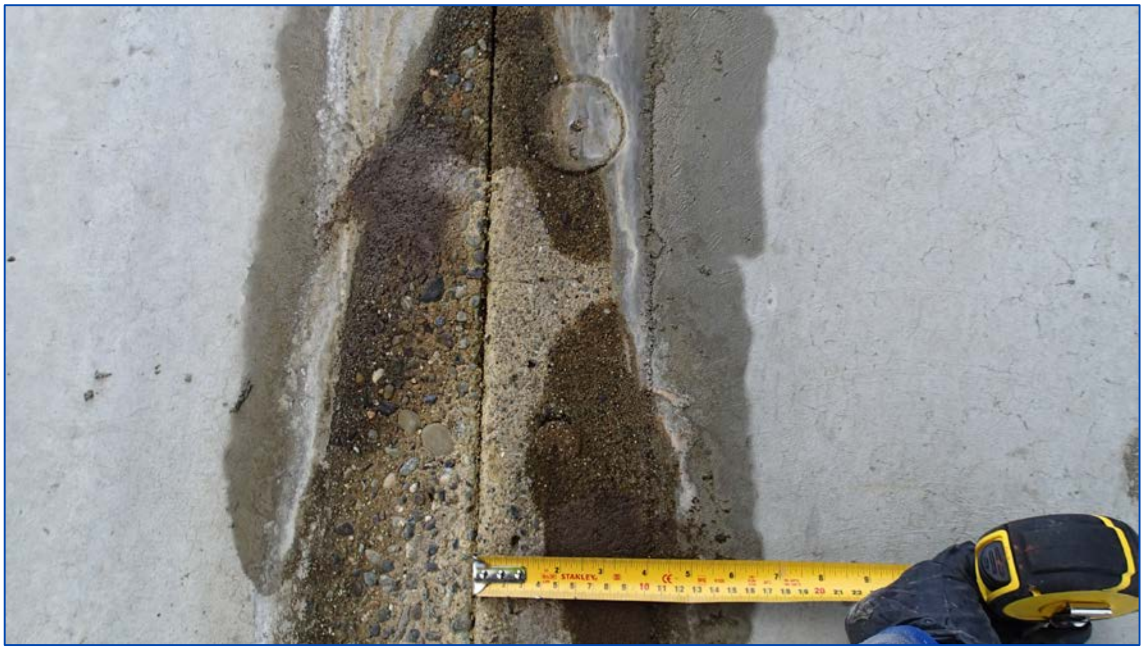

Photo 3: Infilled concrete strip at the joint between the precast wall panels.

Photo 4: Leaking joints between the precast wall panels.

Photo 5: Close-up of Photo 4 showing deterioration of the joint.

Photo 6: Close-up of Photo 5 showing deterioration of the joint.

Photo 7: Presence of efflorescence at the joint between the precast wall panels.

Photo 8: Spalls at the precast wall panel joints at the top of the reservoir wall.

Photo 9: Close-up of Photo 8 showing a spall.

Photo 10: Presence of spall at the joint at the top of the reservoir wall.

March 21, 2006 Refer to File: 87833-03

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The Village of Lions Bay
PO Box 141, 400 Center Road
Lions Bay, BC
Canada V5C 6S3

Attention: Lori Pilon
Administrator
Village of Lions Bay

Dear Ms. Pilon:

Re: Harvey Creek 400,000 Gallon Reservoir Preliminary Structural Assessment

INTRODUCTION

The Village of Lions Bay retained Earth Tech (Canada) Inc. to carry out an assessment of the existing reservoirs in the Lions Bay area in Sept. 2004. During the assessment of the Harvey Creek 400,000 imperial gallon reservoir it was noted that the structure has some critical defects, such as extensive water leakage, which require urgent attention (See Earth Tech's report titled "Village of Lions Bay Reservoir Assessment"). Earth Tech (Canada) Inc. has been retained by the Village of Lions Bay to complete an engineering analysis on the structural integrity of the Harvey Creek 400,000 gallon reservoir to determine the cause of these defects.

This letter report summarizes the work listed in Phase 1-b of the project(as identified in our email proposal dated July 25, 2005) and a recommendation on the strengthening and seismic retrofitting required to repair the defects in the reservoir and meet the current code requirements.

STRUCTURE DESCRIPTIONS

The Harvey Creek 400,000 imperial gallon reservoir is located approximately 250 m past the end of Oceanview Road (on a gravel access road), in the Village of Lions Bay. The reservoir is approximately 500 m south of Harvey Creek.

In accordance with the recorded drawings provided by the Village of Lions Bay, the Harvey Creek reservoir is a circular pre-cast concrete structure with an internal diameter of 15.780 m.

Its wall is 0.200 m thick by 10.125 m high, reinforced with post-tensioned strand tendons in both the vertical and circumferential directions. The reservoir roof is composed of 16 pre-cast concrete T-beams consisting of a 0.125 m thick slab supported on 0.475 m by 0.200 m beams spanning from a column in the center of the reservoir to the reservoir wall. The reservoir is supported on a 0.150 m thick reinforced concrete slab foundation, with a 0.680 m by 0.500 m reinforced concrete ring beam around the perimeter of the base slab. The ring beamwas supposed to lateral restraint for the bottom of the reservoir wall.

RESERVOIR INSPECTION

Earth Tech (Canada) Inc. inspected the Harvey Creek reservoir on Sept. 9, 2004 and on Feb. 11, 2005. During the inspection of the tank it was noticed that extensive water leakage was occurring between the pre-cast panels. Further inspection of the inside of the tank revealed that the seals between the pre-cast panels have deteriorated. The leaking between the wall panels is a concern because it could cause rapid deterioration of the post-tensioning steel. A repair plan has been developed to seal the cracks, and it was recommended that an analysis be preformed on the structure to determine the cause of the cracks and leakage. During the inspection of the reservoir and review of the structural drawings, it was also noted that the foundation ring beam appears to be inadequate to support the hoop tension at the base of the wall.

STANDARDS, REFERENCES AND RECORDED DRAWINGS

The assessment was performed in accordance with the following codes and references:

- ACI 318M "*Building Code Requirements for Structural Concrete*".
- ACI 350M "*Environmental Engineering Concrete Structures*".
- ACI 344 *"Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons"* by American Concrete Institute.
- PCA Journal "*Circular Concrete Tanks without Prestressing*".
- CSA A23.3 "*Design of Concrete Structures*".
- PCI Journal *"Recommended Practice for Precast Prestressed Concrete Storage Tanks"*.

- PCA's Journal *"Design of Liquid Containing Concrete Structures for Earthquake Forces"*

- CAN/CSA S6-00 *"Canadian Highway Bridge Design Code"*.

- British Columbia Building Code 1998

The assessment was also based on the following recorded drawings provided by the Village of Lions Bay, drawings with the assumptions that the reservoir was built as per the drawings:

- Crosier, Kilgour & Partners Ltd. File No. 44018 As Built Drawings S1, S2, S3 and S4.

It should be noted that neither design criteria, codes & standards, nor load combinations are explicitly indicated on the above-noted recorded drawings. The recorded drawings only depict dimensions of the structure, size and spacing of normal reinforcement, and locations and size of the post-tensioning tendons.

LOADS AND LOAD COMBINATIONS

The following loads and load combinations were considered to analyze the reservoir:

- Dead Loads – self weight of the roof slab, roof beams and walls.

- Snow Load – Ss =2.32 kPa plus Sr =0.6 kPa acting uniformly over the entire roof slab or on half the roof slab.

- Pre-compression forces acting on the wall from vertical and circumferential post-tensioning.

- Hydrostatic pressure on the interior of the tank wall acting over the full height (10.125m) of the wall.

- Earthquake in accordance with BC Building Code 1998, 1 in 475 year return and with the parameters as follows: -

    - v = 0.20 (West Vancouver)
    - I = 1.5
    - S*F = 3.0 (Max. response used since soil properties are unknown)
    - R = 2.0 (assume nominal ductility)

The seismic forces excited by the earthquake motion include:

- Inertia forces due to self-weight of the structure.
- Hydrodynamic forces including impulsive & convective pressure due to movement of liquid inside the tank.

With the above-noted probable load cases, many loading combinations could be developed. In this assignment, we have considered the following two (2) loading conditions:

1) At normal operating condition:
Dead Load + Post-Tensioning + Hydrostatic.

2) At earthquake condition:
Dead Load + Post-Tensioning + 25% balanced Snow Load + Hydrostatic Load + sqrt[(inertia forces +impulsive forces)^2 +(convective forces)^2].

All earthquake forces are assumed to be acting in one direction and they are unbalanced forces.

MATERIALS

The following material strength and properties were assumed for this analysis:

- Concrete Strength, Walls: f'c = 40 MPa.; Roof: f'c = 35 MPa.
- Reinforcing Yield Strength, fy = 400 MPa.
- Circumferential Prestressing Strands – 0.6" Dia. 270 Grade Low Relaxation Strands.
- Vertical Prestressing Strands – 0.5" Dia. 270 Grade Low Relaxation Strands.

ANALYSIS SUMMARY AND CRITERIA

The reservoir was analyzed in three dimensions for normal and seismic loading conditions (as described above) using the "STAAD PRO" program. The reservoir structure was considered as an integral structure with an assumption that the cast-in-place foundation, pre-cast walls and pre-cast roof were erected and the post-tensioning was subsequently applied after all concrete work was in place. Plate elements were utilized to represent the walls in conjunction with beam elements for the roof beams. The roof slab was represented as a distributed load supported along the roof beams. Both ends of the beams were modeled as a pinned connection representing the tie between the reservoir walls and the center column. It was assumed that the roof slab would not provide diaphragm action due to the limited connections between the precast roof panels. The bottom of the reservoir wall was rested on pinned supports without modeling the base slab. It was assumed that the ring beam along the base slab has adequate capacity to restrain the bottom of the reservoir wall and provide a pin connection.

It was assumed that the shear forces at the bottom of the reservoir wall will be transmitted to the ring beam along the perimeter of the base slab. The shear forces will be carried by the continuous, circumferential reinforcing in the ring beam. The capacity and demand of the ring beam were determined in accordance with PCA's publication "*Circular Concrete Tanks Without Prestressing*". In determining the ring beam capacity only two-15M and two-20M reinforcing bars in the beam around the outside of the foundation were considered.

The hoop tension and vertical tension in the wall are counteracted by the circumferential and vertical post-tensioned tendons, respectively. In accordance with ACI 344, *"Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons"*, the circumferential pre-stressing tendons shall provide a minimum of 200 psi (1.38 MPa) residual compressive stress in the pre-compressed elements under normal service load conditions (with the tank filled to the design level, after all short and long term prestress losses). This residual axial pre-compressive stress is intended to prevent cracking, leakage of the contents inside the tank and corrosion of the pre-stressing steel.

To model the circumferential post-tensioning, the tendon force was represented as a pressure acting on the exterior face of the wall plate elements. The vertical post-tensioning tendon force was represented as a compressive stress in the vertical direction in the wall elements. The "STAAD Pro" program does not allow pressures to be input onto the edges of plate elements, therefore the vertical post-tensioning stress was input, by hand into the load combination calculations. Drawing numbers S2 and S4 provide detailed post-tensioning information, such as the size and grade of the strands and number of tendons. The losses in the post-tensioning tendons were calculated according to the CSA-S6-00 *"Canadian Highway Bridge Design Code"*. The minimum effective pre-stressing forces in the circumferential and vertical strands were determined to be 127 kN and 123 kN per strand, respectively. This minimum effective pre-stressing force was used to determine the post-tensioning pressures in the model.

Seismic force from the reservoir self-weight was calculated in accordance with British Columbia Building Code (BCBC) 1998 and UBC 1997. The reduced base shear for the structure (with R=2.0) is about 0.270*W calculated from BCBC 1998 compared to 0.3125*W obtained from UBC 1997. Hydrodynamic forces, including Impulsive and Convective responses, acting on the reservoir inside face, were estimated in accordance with PCA's *"Design of Liquid Containing Concrete Structures for Earthquake Forces*". It should be noted that the periods of the impulsive and convective responses are generally widely separated, i.e. the impulsive period being much shorter than the convective period. Therefore, PCA recommends that the impulsive and convective responses be combined together using square root of the sum of the squares method. Subsequently, all seismic responses from different components were added together assuming all responses are acting in one direction.

The demand of the roof beams was determined using the previously described "STAAD Pro" model. The roof beam capacities were determined by hand calculation using the beam reinforcing details provided on the recorded drawings. The roof beams were assumed to be simply supported between the center column and the reservoir wall. The effects of hydrostatic loads, earthquake loads, post-tensioning pressure, dead load and snow loads were considered in the analysis of the roof beams.

ANALYSIS RESULTS

The critical stresses in the wall elements for normal service load condition and in the event of an earthquake are summarized in Table 1 below.

Table 1: Critical Element Stresses in the Reservoir Walls

Critical Element Stresses in the Walls			
Load Combinations	**Horizontal Hoop Stress** *MPa*	**Vertical Stress** Outside Face *MPa*	Inside Face *MPa*
Case 1: Normal Operating Conditions	0.13 Comp.	2.13 Comp.	2.22 Comp.
Case 2: Earthquake Conditions	0.01 Comp.	2.08 Comp.	2.18 Comp.

<u>Reservoir Walls</u>

At the normal service condition, the analyses results show that the circumference stress (horizontal hoop stress) of the reservoir wall is in compression, indicating that the existing lateral post-tensioning force in the wall is adequate to balance the applied hydrostatic pressure inside the reservoir. However, the residual compressive stress in the bottom 1/3 of wall, which is approximately 0.13 MPa, does not meet the minimum residual stress requirement of 1.38 MPa as recommended by ACI 344 to prevent leaks.

Post-tensioning was placed in the vertical direction in each face of the reservoir wall to resist the vertical flexural tensile stresses. The analysis results show that the vertical stress of the reservoir wall is in compression, with a minimum stress of 2.13 MPa, which exceeds the minimum requirements of 1.38 MPa pre-compression as recommended by ACI 344.

In the event of an earthquake, it should be noted that the reservoir circumference would deform in an elliptical shape caused by the unidirectional earthquake forces. The reservoir circumference is subject to both hoop tensile stress and horizontal bending stress. Our analyses indicate that, taking into account the post tensioning force of 127 kN per tendon, the reservoir circumference will remain in compression. However, the reservoir is critically close to experiencing tension stress since the minimum compression stress is only 0.01 MPa on the exterior face of the wall and in the vicinity of the long axis of the ellipse. The reservoir wall remains in compression in the vertical direction when subjected to earthquake forces with a minimum compression force of 2.08 MPa.

Ring Beam

The ring beam around the perimeter of the base slab was also analyzed for hoop Tension. In order to achieve the assumed boundary conditions, the ring beam must have adequate strength to carry the shear forces at the base of the reservoir wall caused by the hydrostatic pressure. If the ring beam does not have adequate capacity to carry these forces, the use of pin connections along the bottom of the reservoir wall in the analysis model becomes invalid. The analysis of the ring beam determined that the hoop tension demand was approximately 2020 kN, which is significantly greater than the capacity of 360 kN (Capacity/Demand ratio = 0.18). The inadequate capacity of the ring beam will cause much higher tensile forces in the reservoir wall. The leaking evident on the existing tank wall could have been caused by the structural deficiency in this ring beam.

Reservoir Roof

At the normal service condition, the roof slab has a critical bending moment of 10 kNm/m, which is equivalent to a crack control parameter of 49.1 kN/mm. This is significantly greater than the maximum crack control parameter of 20.0 kN/mm as recommended by CSA A23.3 "Design of Concrete Structures".

The beams supporting the roof slab were analyzed for strength as well as serviceability. The bending and shear capacities of the roof beams are 198 kNm and 202 kN, respectively. These capacities are well above the moment and shear demands of 150 kNm and 94 kN. Since the tank was modeled assuming that the roof beams are tied between the walls and the center column, it was necessary to determine the tensile demand and capacity of the beams. It was assumed that when the beams are under tension the concrete will crack and only the reinforcing bars will contribute to the tensile capacity. The tensile capacity of the 4-20M bars was determined to be 432 kN, which is significantly greater than the maximum tensile demand of 55 kN (which occurs under seismic loading).

It was noted that currently the only connection between the reservoir roof and the walls is a single 20M bar in a PVC pipe located at the joint between each pre-cast roof panel. Also, at the center of the roof, the only connection between the roof beams and the center column is a single 15M bar projecting from each beam into the column. It is felt that during a seismic event these connections will not be adequate to hold the roof in place. If these connections fail, there is a possibility that the roof could collapse. The integrity of the reservoir wall depends on the tension tie action provided by the roof beams, therefore, the roof beam must be adequately connected to both the center column and the reservoir wall.

The overall stability of the reservoir was also analyzed. It was determined (according to PCA's Journal *"Design of Liquid Containing Concrete Structures for Earthquake Forces"*) that the reservoir has adequate stability to resist both sliding and overturning during earthquake conditions with factors of safety of 2.25 and 8.02, respectively.

COST ESTIMATES

Table 2: Seismic Upgrade Cost estimate

Item	Unit Cost		Quantity		Total Cost
Ring Beam					
Concrete Ring Beam	$1,000	/m^3	85	m^3	$85,000
Reinforcing	$2	/kg	2600	kg	$5,200
Formwork	$150	/m^2	170	m^2	$25,500
Surface Preparation					$5,000
Drill in Dowels	$25	/dowel	340	dowel	$8,500
Excavation and Backfill	$40	/m^3	45	m^3	$1,800
Mobilization - Add 10%					$13,100
Roof Upgrade					
Waterproofing membrane	$30	/m^2	225	m^2	$6,750
Beam to Wall brackets (plates and angles)	$5,000	/tonne	0.040	tonnes	$200
Steel Plates @ center column	$5,000	/tonne	1.7	tonnes	$8,500
Bolts (includes drilling)	$75	/bolt	192	bolts	$14,400
Engineering					$30,000
Add 15% Contingency					$30,000
Total Cost :					**$233,950**

RECOMMENDATIONS

Based on the analysis results above, it can be concluded that the reservoir wall requires strengthening in order to increase the circumferential residual stress to an acceptable level. Also, since the structural integrity of the reservoir depends on the capacity of the base slab ring beam, it is imperative that the ring beam is strengthened to have adequate capacity to support the shear forces transferred from the base of the reservoir wall. The construction of a reinforced concrete beam along the bottom of the reservoir wall is recommended to strengthen the ring beam and increase the residual stress of the reservoir wall. The strengthened ring beam should extend up to a height of approximately 2.50 m to correct the inadequate residual stresses in the wall. See attached drawing for the recommended ring beam strengthening.

Since the integrity of the reservoir depends on the roof beams remaining connected to the reservoir walls, it is recommended that steel brackets be installed to adequately fasten the roof beams to the reservoir wall. It is also recommended that a circular steel plate be installed at the center of the roof to provided additional anchorage between the roof beams and the center column. See attached drawing for anchorage details.

Due to the inadequate crack control of the reservoir roof, it is recommended that a waterproofing membrane be installed over the entire roof area. This will prevent contaminants from entering the reservoir through cracks which may form in the roof slab.

The total estimated cost to complete the recommended seismic upgrades is $235,000.

I trust this report satisfies your requirements at this time. If you have any further questions, please do not hesitate to contact the undersigned.

Yours truly,

EARTH TECH (CANADA) INC.
Per:

Amber Ringer, EIT

Eric de Fleuriot, P.Eng.

Celebrating 100 years in Canada

EarthTech

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March 27, 2006

Refer to File: 87833 (04a)
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Village of Lions Bay
Box 141
Lions Bay, BC
V0N 2E0

Attention: Lori Pilon, Administrator

Dear Lori:

Re: Harvey Creek Reservoir

Post construction inspection of the Harvey 400,000 Gal Reservoir Repairs

Chronology of events:

1. A preliminary inspection of the outside of the tank was carried out on the 20th of March 2006 by Eric de Fleuriot of Earth Tech, Grant Raeburn of Retro Specialty Contractors, Paul Gair of Sika and Joe Canning of the Village of Lions Bay.

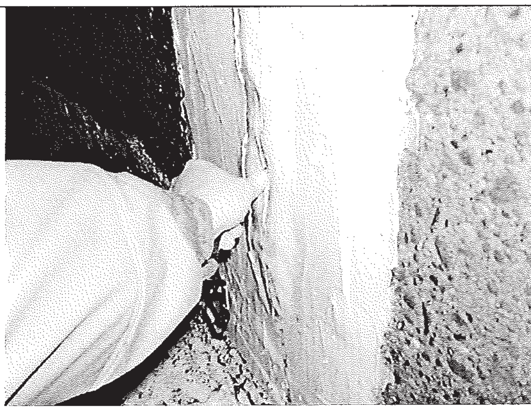
   The following was noted:

   Leaks were found along some of the vertical joints and along a portion of the horizontal joint at the base of the walls. This prompted a further inspection of the inside of the reservoir. The leaks however appeared to be significantly less than previously observed prior to the repairs.

2. The tank was emptied to enable the inspection of the inside of the reservoir on the 24th March 2006. The following persons were present at this site inspection: Joe Canning from the Village, Scott Neuman and Eric de Fleuriot from Earth Tech, Grant Raeburn and his foreman from Retro and Paul Gair from Sika.

The following was noted:

	
1. A number of tears were found in the hypalon material. The above photo shows one such tear. This was located in the hypalon along the base of the wall	2. A large hole sufficient to push a pen through was observed at one of the vertical joints between precast panels



3. Water was found to be located behind the hypalon in many areas. When pressing onto the hypalon one could hear the water squishing behind the repair material

4. At this particular joint, the hypalon was stretched and ballooning out to the extent that indicated the water behind the hypalon was under pressure. This could be due to the head of water above the area of ballooning.

5. At a number of the joints, the material was observed to be unconnected along edges. It is uncertain whether this would have affected the water-tightness of the joint, but nevertheless indicated poor workmanship. It is uncertain whether the joints are water-tight. It is however noted that at one of these joints, the joint appeared to be breathing along the joint edge when pressing on the hypalon approximately ½ m above the joint. Air bubbles appeared along the joint edge during pressing on a ballooned area of the joint.

6. The epoxy material was also present on areas of the hypalon which is expected to stretch under load and during opening of the crack. This is not good practice, neither is it indicated in the joint material manufacturers brochure on the Combiflex System that this should be done. The epoxy will crack when the hypalon is stretched and deformation of the hyperlon will be concentrated along the future cracks. The effects of this on the performance of the hypalon is unknown.

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EarthTech

A tyco International Ltd. Company

It is suggested that the contractor carry out a further more detailed inspection of the whole area of repair and positively identify all defects and propose a procedure for remedial work to reinstate the integrity of the Combiflex System.

Yours truly,

EARTH TECH (CANADA) INC.
Per:

Eric de Fleurlot, P.Eng.
Manager, Bridge Group

VILLAGE OF LIONS BAY	WATER RESERVOIR FIELD INSPECTION SHEET	Harvey Creek Tank

Current inspection				Inspector	Firm	Date (dmy)
Principle	✔	Monitoring		Eric de Fleuriot & Garth Begley	Earth Tech	9 Sep 2004 11 Feb 2005
Last Principle inspection						
Last Monitoring inspection						

Reservoir type: Circular precast concrete post-tensioned tank constructed above ground (16 panels)
Purpose: Drinking water
Design volume: 400,000 Gals (1,514,160 litres)
Dimensions: 55’ dia. x 32.5’ high (16.764 m dia. x 9.9 m high)

Built in: ≈1980
Air temperature: 16 °C
Top of water level: 29’ (8.84m)
Date last cleaned: No records

1. Tank	1.1 Walls				1.2 Roof				1.3 Wall Fdn				1.4 Floor				1.5 Column				1.6 Column foundation				1.7 Wall stability				1.8 Drain sump			
	R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)			
Panels	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
AP			1		50					2			E				E				N				E				E			
Panels	1.9 Guardrail				1.10 Access hatch				1.11				1.12 Miscellaneous				**2. Joint bet. panels**				2.1 Walls				2.2 Roof				2.3 Floor			
AP	5				20								X									55	40	**5**			100				100	

3. Auxiliary items	3.1 Check valve chamber				3.2 Valves				3.3 Inlet pipe				3.4 Outlet pipe				3.5 Overflow pipe				3.6 Drain pipe				3.7 Dechlor. chamber				3.8 Outlet structure			
	X				E				100				E				5				E						2		X			
	3.9 Rip-Rap at outlet				3.10 Equip cabinet box				3.11 Access road				3.12 Embankments				3.13 Access ladder				3.14 Roof vents				3.15 Level transducer				3.16 RTU Antenna			
	X				X				20				E				5				E				N				X			

REMEDIAL WORK ACTIVITY LIST

Item	Location	Activity description	Qty	Unit	U	Make safe	Comments	Rep Photo	Mon freq
2.1	IS	Seal & repair crack	155	m	1	Yes	Water was observed to be pouring out of joint between panels	45 - 47	
1.1		Spalled concrete - repair	0.003	m3	3		At top of wall caused by load from roof slab	55	
1.2		Power wash / clean	110	m2	R		50% of roof area	58	
2.2		Panel joint - repair	0.2	m3	3		Concrete filler section has fallen out from between precast concrete roof panels	59, 60	
1.3		Honeycombed concrete - repair	0.01	m3	M			43	2yrs
1.9		Bolts/nuts – re-galvanize	9	No	R		Apply Galvacon	60	
1.10		Wire brush & Power tool– paint	2	m2	R			57	
2.2		Seal & repair cracks	135	m	3			58, 142, 143	
3.11		Road surface - regrade	1	km	R		General maintenance required on road		
3.3		Wire brush & Power tool– paint	5	m2	R		10” dia. pipe	62	
3.7		Mounting bolts at injection water filler - replace	2	No	R			61	
3.7		Power wash / clean	20	m2	R		Algae growth on roof of dechlorination chamber	51	
2.3	IS	Seal & repair crack	50	m	1		New seal needed along circumference of tank at joint between wall and floor	148-153	
1.12	AS	Strengthen reservoir at base in horiz dir	1	LS	2		Provide ring beam at base of reservoir	48	
3.5	IS	Wire brush & Power tool– paint	1	m2	R		Corroded overflow pipe bracket supports	147	
3.13	IS	Wire brush & Power tool– paint	0.5	m2	R		Corroded bolts at attachment to wall	146	

Rating “R”		*Structural integrity and safety of user*	*Functionality-secondary to Structural Integrity Does it perform as originally designed?*	*Maintenance priority and urgency of repair*	*Urgency“U”*	
					Monitor	*M*
E		*No defects*	*New condition – no defects*	*Not applicable*	*Routine*	*R*
4	*G*	*Min relevancy*	*Acceptable, functioning as intended but maintenance required*	*Not required before next principle inspection*	*5yrs or >*	*4*
3	*F*		*Functioning as intended. Minor to more extensive rehab required to upgrade to new*	*. Preventative maintenance required within specified period*	*< 3 yrs*	*3*
2	*P*		*Unacceptable, not functioning as intended Minor to Major rehabilitation required*	*Work required within specified time period*	*< 2 yrs*	*2*
1	*V*	*Max relevancy*	*Immediate action. Collapse imminent*	*Danger to users – immediate repair required*	*ASAP*	*1*

N – Not accessible; X – Not applicable, % - percentage of element representing rating “R”

NP – North Wall Panel; NP1 – panel 1 on north face of reservoir; SP1-6; Panels 1 to 6 on south face of reservoir; RPi – Roof panel “i”; FPi – Floor panel ”i”; WS – West Side; AS – All Sides; IS – Inside of tank; R – Roof; F - Floor

43. Honeycombing at wall foundation

44. Anchor blocks for post-tensioned cables. South side of tank adjacent to large vertical leak (Water loss 4 liters per minute)

45. Large leak at wall panel junction

46. Upper half of tank at leak seam

47. Close up of large leak

48. General view of anchor block adjacent to large leak

49. Eastern side of tank showing east side anchor blocks and further leaks

50. Leak at panel junction showing possible corrosion staining

51. General view of anchor blocks. Note algae growth on chlorination building roof

52. Note efflorescence at SE anchor block

53. "Closing in" section of concrete between two wall panels at North side of tanks

54. Horizontal and vertical cracks adjacent to north west anchor blocks

55. Spalling at top of wall – NW side

56. General view of concrete key locating roof concrete slab onto walls – NW side

57. Roof hatch and vent

58. Note concrete precast panels making up the roof structure

59. Concrete filler section has fallen out from between two precast concrete roof panels

60. Joint between precast concrete roof panels at access hatch

61.   Mounting bolts corroded

62. General view of inlet pipe in chlorination chamber

63. General view of chlorination building

142. Underside of roof from inside of tank

143. Note water leaking through roof panel joints

144. 250 Φ bellmouth inlet drain

145. 200 pvc overflow pipe

146. Corroded bolt at access ladder support inside of tank

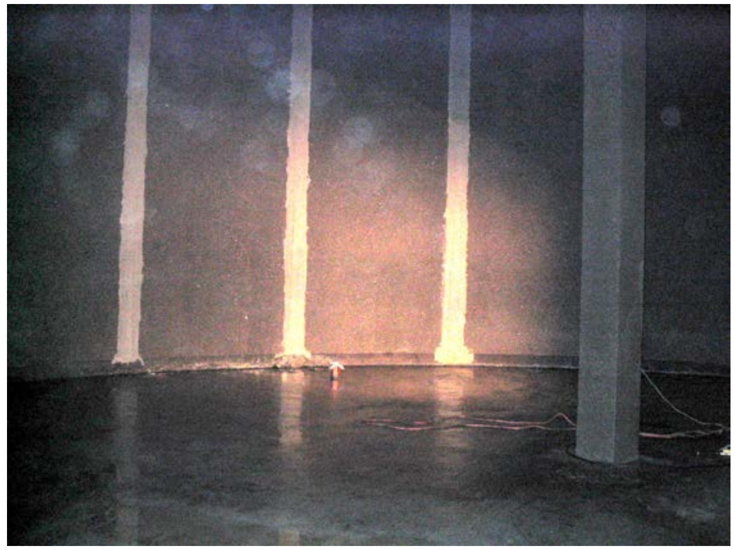
147. Access ladder and overflow pipe. Note corroded overflow pipe bracket supports

148. Rubberized type of coating material used along joint between the wall and base slab

149. Evidence of failure (note air or water bubbles visible on the surface of the material) in the sealing material along joint between wall and base slab.

150. The rubberized material was easily pulled away from the wall and revealed vertical joints between wall panels. Water was seen to be leaking through this joint from the outside of the tank.


152. Evidence of general failure of sealing material along edge of wall and bottom slab and along the vertical joints in wall panels.


153. General view of inside of tank showing vertical and horizontal joints in tank wall

VILLAGE OF LIONS BAY	WATER RESERVOIR FIELD INSPECTION SHEET	Highway Tank

Current inspection				Inspector	Firm	Date (dmy)
Principle	✔	Monitoring		Eric de Fleuriot & Garth Begley	Earth Tech	9 Sep 2004 24 Nov 2004
Last Principle inspection						
Last Monitoring inspection						

Reservoir type: Concrete circular tank constructed above ground Purpose: Drinking water Design volume: 21700 Gals (82143 litres) Dimensions: 19.25'dia x 12' high (5.87m x 3.66m)	Built in: ≈1960 Air temperature: 16 °C Top of water level: 10' (3.05m) Date last cleaned: No records

1. Tank	1.1 Walls				1.2 Roof				1.3 Wall Fdn				1.4 Floor				1.5 Column				1.6 Column foundation				1.7 Wall stability				1.8 Drain sump			
	R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)			
Panels	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
1		5				5			N				N				X				X				E							
Panels	1.9 Guardrail				1.10 Access hatch				1.11				1.12 Miscellaneous				**2. Joint bet. panels**				2.1 Walls				2.2 Roof				2.3 Floor			
1	X				N								95	5							X				X				X			

3. Auxiliary items	3.1 Check valve chamber				3.2 Valves				3.3 Inlet pipe				3.4 Outlet pipe				3.5 Overflow pipe				3.6 Drain pipe				3.7 Dechlor. chamber				3.8 Outlet structure			
	E				E				5				5				5				5				X				X			
	3.9 Rip-Rap at outlet				3.10 Equip cabinet box				3.11 Access road				3.12 Embankments				3.13 Access ladder				3.14 Roof vents				3.15 Level transducer				3.16 RTU Antenna			
	X				X				E				E						100		N				X				X			

REMEDIAL WORK ACTIVITY LIST

Item	Location	Activity description	Qty	Unit	U	Make safe	Comments	Rep Photo	Mon freq
3.4	WS	Debris remove	0.001	m3	R				
1.1	AS	Seal repair cracks	35	m	3		Vertical – 25m; Horizontal – 11m	37-39	3 yrs
1.12	AS	Power wash & clean external surface of reservoir	100	m2	R		Surface should be regularly cleaned of algae and moss	37-39	
1.12	WS	Shakes – replace	20	No	2		Roof structure on top of reservoir consists of a timber structure and shakes	34, 36	
3.13	IS	Interior ladder - replace	1	No	2		Ladder corroded, so should be replaced	137,139	
1.2	R	Seal repair cracks	15	m	M		Efflorescence can be seen on underside of roof slab thus showing the location of cracks	139,140	3 yrs
3.4	IS	Wire brush & Power tool - paint	0.5	m2	2		Corrosion evident on outlet pipe	138	
3.3	IS	Wire brush & Power tool - paint	0.5	m2	2		Corrosion evident on inlet pipe	138	
3.5	IS	Wire brush & Power tool - paint	0.25	m2	2		Corrosion evident on overflow pipe	136	
3.6	IS	Wire brush & Power tool - paint	2	m2	2		Corrosion evident on drain pipe	141	

Rating "R"		*Structural integrity and safety of user*	*Functionality-secondary to Structural Integrity Does it perform as originally designed?*	*Maintenance priority and urgency of repair*	*Urgency"U"*	
					Monitor	*M*
E		*No defects*	*New condition – no defects*	*Not applicable*	*Routine*	*R*
4	*G*	*Min relevancy*	*Acceptable, functioning as intended but maintenance required*	*Not required before next principle inspection*	*5yrs or >*	*4*
3	*F*		*Functioning as intended. Minor to more extensive rehab required to upgrade to new*	*. Preventative maintenance required within specified period*	*< 3 yrs*	*3*
2	*P*		*Unacceptable, not functioning as intended Minor to Major rehabilitation required*	*Work required within specified time period*	*< 2 yrs*	*2*
1	*V*	*Max relevancy*	*Immediate action. Collapse imminent*	*Danger to users – immediate repair required*	*ASAP*	*1*

N – Not accessible; X – Not applicable, % - percentage of element representing rating "R"
NP – North Wall Panel; NP1 – panel 1 on north face of reservoir; SP1-6; Panels 1 to 6 on south face of reservoir; RPi – Roof panel "i"; FPi – Floor panel "i"; WS – West Side; AS – All Sides; IS – Inside of tank; R – Roof; F - Floor

32. Valve chamber

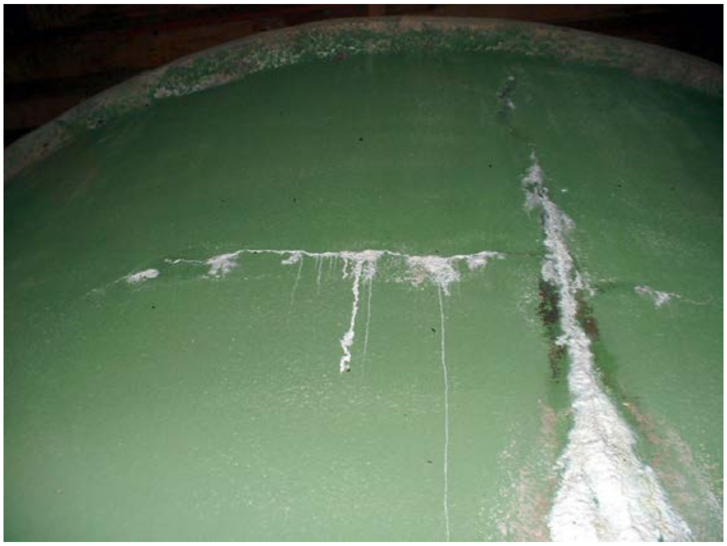
33. Open latch at valve chamber

34. Rotten shakes

35. General view of roof structure

36. Lattice wall

37. Efflorescence and corrosion stains at vertical crack



38. Horizontal and vertical cracks on tank western side

39. Efflorescence and corrosion staining at vertical crack

40. Fill station sensing line

41. General view of roof structure

42. General view of roof structure

136. Overflow pipe slightly corroded


137. Corroded interior ladder


138. Inlet pipe


139. Underside of roof slab and interior ladder. Note cracks


140. Underside of roof slab. Note cracks


141. Drain

VILLAGE OF LIONS BAY	WATER RESERVOIR FIELD INSPECTION SHEET	Phase IV Tank

Current inspection				Inspector	Firm	Date (dmy)
Principle	✔	Monitoring		Eric de Fleuriot & Garth Begley	Earth Tech	9 Sep 2004
Last Principle inspection						
Last Monitoring inspection						

Reservoir type: Circular concrete tank constructed above ground Purpose: Design volume: 22000 Gals (75708 litres) Dimensions: 21.25'dia x 10' high (6.48m x 3.048m)	Built in: ≈1960 Air temperature: 16 °C Top of water level: ? Date last cleaned: No records

1. Tank	1.1 Walls				1.2 Roof				1.3 Wall Fdn				1.4 Floor				1.5 Column				1.6 Column foundation				1.7 Wall stability				1.8 Drain sump			
	R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)				R(%)			
Panels	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
1		90	10		100				N				N				X				X				E				X			
Panels	1.9 Guardrail				1.10 Access hatch				1.11				1.12 Miscellaneous				**2. Joint bet. panels**				2.1 Walls				2.2 Roof				2.3 Floor			
1	X				100										100							X				X				X			

3. Auxiliary items	3.1 Check valve chamber				3.2 Valves				3.3 Inlet pipe				3.4 Outlet pipe				3.5 Overflow pipe				3.6 Drain pipe				3.7 Dechlor. chamber				3.8 Outlet structure			
	100						5		E				N				N				N				X				X			
	3.9 Rip-Rap at outlet				3.10 Equip cabinet box				3.11 Access road				3.12 Embankments				3.13 Access ladder				3.14 Roof vents				3.15 Level transducer				3.16 RTU Antenna			
	X				X				E				E				X				X				E				X			

REMEDIAL WORK ACTIVITY LIST

Item	Location	Activity description	Qty	Unit	U	Make safe	Comments	Rep Photo	Mon freq
3.2		Altitude valve - rebuild	1	No	R			76	
3.1		Walls - paint	6	m2	2			80	
3.1		Door - adjust	1	No	R			80	
1.12		Hydro poles – replace	2	No	R			71	
1.10		Hatch – replace	1	No	2			78	
1.1		Cracks – seal / repair	4	m	3		Seal from inside with a protective and waterproofing slurry seal with glass fiber reinforcement from the inside of tank if possible (SikaTop Seal 107 or similar approved)	72	
1.1		Honeycombed concrete – repair	0.05	m3	M		Outer surface of wall has shallow honeycombing which is not affecting the tanks integrity	73, 75	2yrs
1.2		Debris / vegetation – remove and power wash	3	m3	R			77, 79	
1.1		Algae / vegetation – remove and power wash	60	m2	R		Power wash the outer face of the tank	74	
1.12		Power wash the inside of the tanks	1	LS	R				

Rating "R"		*Structural integrity and safety of user*	*Functionality-secondary to Structural Integrity Does it perform as originally designed?*	*Maintenance priority and urgency of repair*	*Urgency "U"*	
					Monitor	*M*
E		*No defects*	*New condition – no defects*	*Not applicable*	*Routine*	*R*
4	*G*	*Min relevancy*	*Acceptable, functioning as intended but maintenance required*	*Not required before next principle inspection*	*5yrs or >*	*4*
3	*F*		*Functioning as intended. Minor to more extensive rehab required to upgrade to new*	*. Preventative maintenance required within specified period*	*< 3 yrs*	*3*
2	*P*		*Unacceptable, not functioning as intended Minor to Major rehabilitation required*	*Work required within specified time period*	*< 2 yrs*	*2*
1	*V*	*Max relevancy*	*Immediate action. Collapse imminent*	*Danger to users – immediate repair required*	*ASAP*	*1*

N – Not accessible; X – Not applicable, % - percentage of element representing rating "R"

NP – North Wall Panel; NP1 – panel 1 on north face of reservoir; SP1-6; Panels 1 to 6 on south face of reservoir; RPi – Roof panel "i"; FPi – Floor panel "i"; WS – West Side; AS – All Sides; IS – Inside of tank; R – Roof; F - Floor


71. General view of tank


72. Vertical crack. Evidence of moisture and efflorescence


73. Evidence of honeycombed concrete at horizontal seam


74. Algae growth on wall


75. Honeycombed concrete along horizontal joints


76. Insulated valve sensing line box


77. General photo of roof showing vegetation and algae


78. Roof access hatch


79. Vegetation and algae on roof


80. General view of valve chamber


81. View of fill station valves

VILLAGE OF LIONS BAY	WATER RESERVOIR FIELD INSPECTION SHEET	Phase V Tank

Current inspection				Inspector	Firm	Date (dmy)
Principle	✔	Monitoring		E. de Fleuriot, G. Begley & H. Leung	Earth Tech	9 Sep 2004 18 Nov 2004
Last Principle inspection						
Last Monitoring inspection						

Reservoir type: Circular concrete tank constructed above ground
Purpose:
Design volume: 25000 Gals (94635 litres)
Dimensions: 21.25'dia x 12' high (6.48m x 3.658m)

Built in: ≈1960
Air temperature: 16 °C
Top of water level: ?
Date last cleaned: No records

1. Tank	1.1 Walls				1.2 Roof				1.3 Wall Fdn				1.4 Floor				1.5 Column				1.6 Column foundation				1.7 Wall stability				1.8 Drain sump			
	R(%)				***R(%)***				***R(%)***				***R(%)***				***R(%)***				***R(%)***				***R(%)***				***R(%)***			
Panels	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**
1		99	1		90	10			N				N				X				X				E				X			
Panels	1.9 Guardrail				1.10 Access hatch				1.11				1.12 Miscellaneous				**2. Joint bet. panels**				2.1 Walls				2.2 Roof				2.3 Floor			
1	X				E								100								X				X				X			

3. Auxiliary items	3.1 Check valve chamber				3.2 Valves				3.3 Inlet pipe				3.4 Outlet pipe				3.5 Overflow pipe				3.6 Drain pipe				3.7 Dechlor. chamber				3.8 Outlet structure			
	20				5					20				20				50			N				X				X			
	3.9 Rip-Rap at outlet				3.10 Equip cabinet box				3.11 Access road				3.12 Embankments				3.13 Access ladder				3.14 Roof vents				3.15 Level transducer				3.16 RTU Antenna			
	X				X				E				E				100				X				E				X			

REMEDIAL WORK ACTIVITY LIST

Item	Location	Activity description	Qty	Unit	U	Make safe	Comments	Rep Photo	Mon freq
3.1		Debris – remove	1	m3	R		Debris accumulation on roof	89	
1.1		Hole in wall – seal	1	No	1		Plug hole with SikaTop 122 or sim approved	84, 164	
1.1		Algae / vegetation – remove and power wash	20	m2	R		Algae on outside of tank wall	84, 85	
1.1		Protective and water proofing slurry seal – apply to walls on inside of tank	75	m2	4		Many cracks are observed on the outer face of the tank wall. It is best to seal from the inside (SikaTop Seal 107 or similar approved)	83, 92	
1.2		Water ponding - repair	10	m2	3		Level off with self leveling mortar	87	
1.2		Algae / Vegetation – remove and power wash	0.2	m3	R			87	
1.2		Crack - seal	20	m	M			86	3yrs
3.2		Wire brush & Power tool - paint	1	m2	R		Local touching up required to valves	90, 91	
3.3		Wire brush & Power tool - paint	1	m2	R		Corroded Inlet pipe in valve chamber	90, 91	
3.5	IS	Wire brush & Power tool - paint	2	m2	2		Corroded overflow pipe	170,172	
1.1		Power wash / clean	75	m2	R		General cleaning up of walls required	82, 83, 92	
2.1		Cementitious Coating –remove and replace	75	m2	3		Cementitious coating used for water proofing require to be replaced	165, 166	
3.3	IS	Pipe bracket & Anchorage – install with stainless steel	2	No	2		Overflow pipe anchorage inside the reservoir were taken out for concrete surface repair and have not been reinstated.	167,168	
3.13	IS	Ladder Rung – replace with stainless steel	10	No	M		Ladder rung has rusted resulting in minor section loss.	169	1yr
3.4	IS	Wire brush & Power tool - paint	0.5	m	2		Corroded outlet pipe - minor section loss	171	
1.12		Electrical box - new	1	No	1		Electrical box inside valve chamber non-existent. Wires are exposed	91	
3.1		General maintenance required	1	No	R			89 - 91	

Rating "R"		*Structural integrity and safety of user*	*Functionality-secondary to Structural Integrity Does it perform as originally designed?*	*Maintenance priority and urgency of repair*	*Urgency"U"*	
					Monitor	*M*
E		*No defects*	*New condition – no defects*	*Not applicable*	*Routine*	*R*
4	*G*	*Min relevancy*	*Acceptable, functioning as intended but maintenance required*	*Not required before next principle inspection*	*5yrs or >*	*4*
3	*F*		*Functioning as intended. Minor to more extensive rehab required to upgrade to new*	*. Preventative maintenance required within specified period*	*< 3 yrs*	*3*
2	*P*		*Unacceptable, not functioning as intended Minor to Major rehabilitation required*	*Work required within specified time period*	*< 2 yrs*	*2*
1	*V*	*Max relevancy*	*Immediate action. Collapse imminent*	*Danger to users – immediate repair required*	*ASAP*	*1*

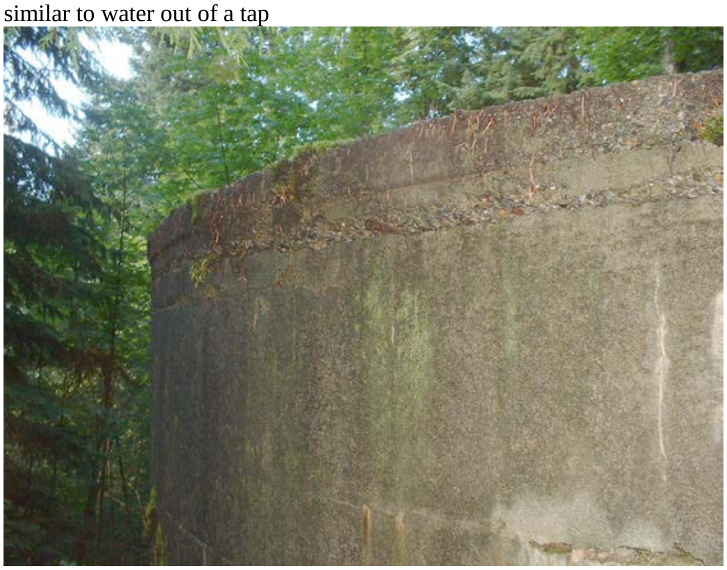
N – Not accessible; X – Not applicable, % - percentage of element representing rating "R"
NP – North Wall Panel; NP1 – panel 1 on north face of reservoir; SP1-6; Panels 1 to 6 on south face of reservoir; RPi – Roof panel "i"; FPi – Floor panel "i"; WS – West Side; AS – All Sides; IS – Inside of tank; R – Roof; F - Floor

82. General view of tank

83. Vertical and transverse cracks

84. Hole at bottom of wall where water was observed to pouring out similar to water out of a tap

85. Algae growth on tank wall



86. Horizontal crack at roof level on wall

87. Water pooling on roof


88. View of hatch on roof


89. Debris on valve chamber roof


90. View of inlet pipe


91. View of electrical box inside valve chamber


92. General view of cracking on wall


164. Cracked and delaminated concrete at east side of reservoir interior wall.

165. Cementitious coating material peeled off at top of interior wall.

166. Spalling cementitious coating on interior wall.

167. Missing anchorage at top of overflow pipe

168. Missing anchorage at top of overflow pipe

169. Corroded ladder rung

170. Corroded overflow pipe at mid height


171. Corroded Outlet pipe on reservoir floor


172. Corroded overflow pipe at bottom.


173. Joint between reservoir interior wall and floor in good condition