April 28, 2014

FACTUAL GEOTECHNICAL REPORT FOR

Colliery Dams Remediation Project, Nanaimo, BC

Submitted to:
Colliery Dams Technical Committee
Nanaimo City Hall
455 Wallace Street
Nanaimo, BC
V9R 5J6

REPORT

Report **Number:** 1314470516-004-R-Rev0-7000

Distribution:

4 copies - Colliery Dams Technical Committee

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by the City of Nanaimo to be part of the Colliery Dam Technical Committee. The Colliery Dam Technical Committee's mandate is to identify an environmentally minimally invasive, cost- and time-effective remediation solution for the Colliery Dam system that meets safety standards, satisfies Dam Safety Section requirements and the respective objectives of the City of Nanaimo, Snuneymuxw First Nation, and the Colliery Dam Park Preservation Society. The following factual report provides a summary of the field work carried out to date to collect additional data to aid in the development of option(s) for remediating the existing dams.

Geophysical, geotechnical, environmental, structural and hydrogeological data was collected in the field January 15 to April 3, 2014. This report also contains relevant geotechnical information collected by EBA Engineering Consults Ltd. (EBA) in 2009 and Golder in 1978, as well as relevant information from the 1980 as-built reports prepared by Willis Cunliffe and Tait Ltd. (Willis Cunliffe and Tait) as outlined in Sections 3 of this report. This report is a data report and as such contains descriptions of the investigation methods, testing results, and factual data collected. Interpretations of the stratigraphy between test locations and the engineering properties of the various strata are not addressed in this report. The impacts of contamination are also not addressed in this report and will be outlined in a subsequent design report. All elevations are relative to Geodetic Datum, unless otherwise indicated.

This report should be read in conjunction with the "*Information and Limitations of This Report*" which is included following the text of this report. The reader's attention is specifically drawn to this information, as it is essential that it is followed for the proper use and interpretation of this report.

2.0 SITE LOCATION AND DESCRIPTION

The Middle and Lower Chase Dams are situated to the southeast of the City of Nanaimo on the Chase River and are furthest dams downstream of a series of four dams on the Chase River system, see Figure 1. The dams are currently located within a municipal park (Colliery Dam Park). The dams can be accessed by way of Nanaimo Lakes Road to the north, see Figure 2.

It is our understanding that the dams were constructed in the early 20th century to provide coal washing water during the coal mining era of Nanaimo. Middle and Lower Chase Dams are 13 and 23.5 m high and 50 and 77 m long, respectively. The dams appear to have been engineered structures when constructed nearly a hundred years ago, but no records of their design and construction are available.

It is our understanding that both dams generally comprised of a central concrete core wall buttressed by variable rock fill slopes constructed upstream and downstream of the concrete wall. The upstream slopes are underwater and survey attempts to determine the condition and configuration of the fill on either dam have been unsuccessful due to heavy siltation. It is our understanding based on historical maps that a railway track was constructed over the Lower Dam in 1918. Cinders and slag fill appeared to have been added to the downstream shell to permit crossing at orientation not parallel to concrete wall.

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3.0 HISTORIC GEOTECHNICAL AND STRUCTURAL INFORMATION

A full review of all the historic information available on the two dams will be provided in a subsequent design report. Historic geotechnical and structural information collected on the two dams is presented herein.

3.1 Geotechnical Investigation of Lower and Middle Dam in 1978

In 1978 Golder was retained by Willis Cunliffe and Tate to carry out geotechnical investigations at each of the dams as part of a geotechnical investigation of five dams within the municipal boundaries of the City of Nanaimo (Golder 1978). The geotechnical investigation comprised of putting down three boreholes and four test pits at the Middle Dam and four boreholes and four test pits at the Lower Dam. Difficult drilling through coarse earth fill did not allow for sampling or density measurements in all boreholes. The borehole and test pit records for these holes can be found in Appendix A, Annex A. The locations of the boreholes and test pits are shown on Figure 3 and 6.

3.2 EBA Testing Pitting Investigation of Lower and Middle Dam in 2009

EBA were retained by the City of Nanaimo to conduct a seismic hazard assessment for the Middle and Lower Dams (EBA 2010). As part of this assessment EBA put down three test pits on the downstream side of the Middle Dam and five test pits on the downstream side of the Lower Dam. The test pit records for these holes can be found in Appendix A, Annex B. The locations of the test pits are shown on Figure 3 and 6.

3.3 Willis Cunliffe and Tait 1980 As-Built Report

Willis Cunliffe and Tate were retained by the City of Nanaimo to rehabilitate the Middle and Lower Dams in August of 1980. As-built reports prepared by Willis Cunliffe and Tate outline the extent of the rehabilitation on both dams (Willis Cunliffe and Tate, 1980). The As-built report can be found in Appendix A, Annex C. Relevant geotechnical and structural rehabilitation carried out in 1980 has been shown on Figure 4, 5 and 7.

4.0 FIELD WORK SUMMARY

The field work that was carried out by Golder on the dams between January 15 and April 3, 2014 is outlined below in Table 1.

Table 1: Summary of Site Investigations

Investigation	Investigation Method	Location	Date
Geophysical	Surface Ground Penetrating Radar (GPR)	Middle and Lower Dam	January 15 to 17, 2014
	Multichannel Analysis of Surface Waves (MSAW) combined with Seismic Refraction	Lower Dam	January 15 to 17, 2014
	Optical and acoustic televiewers	Lower Dam	March 25 and 26, 2014
	Downhole GPR	Lower Dam	March 25 and 26, 2014

Investigation	Investigation Method	Location	Date
	Downhole Seismic	Lower Dam	March 21, 2014
Geotechnical	Sonic Drilling	Lower Dam	February 11 to 14, 2014
	Test Pitting	Lower Dam	April 1 to 2, 2014
Environmental	Sonic Drilling	Lower Dam	February 11 to 14, 2014
Structural	Diamond Drilling	Lower Dam	February 11 to 14, 2014
Hydrogeology	Packer Testing	Lower Dam	March 24 and 25, 2014

5.0 GEOPHYSICAL INVESTIGATIONS

Golder carried out a surface geophysical investigation consisting of GPR and MSAW combined with Seismic Refraction on the Middle and Lower Dam January 15 to 17, 2014. Details on the methodology and the results of this investigation can be found in Appendix B, Annex A.

Optical and acoustic televiewers and downhole GPR were put down in coreholes, CH14-02 and CH14-03, located in the Lower Dam concrete wall on March 25 and 26, 2014. Details on the methodology and the results of this corehole geophysics field work can be found in Appendix B, Annex B.

On March 21, 2014, ConeTec investigations Ltd. carried out downhole seismic testing in an installation within one of the sonic holes, SH14-05, details on the sonic drilling and the installation can be found in section 6.0 below. Details on the methodology and the results of the down hole seismic field work can be found in Appendix B, Annex C.

6.0 GEOTECHNICAL INVESTIGATION OF LOWER DAM

Golder carried out a Geotechnical investigation of the Lower Dam in two phases. Phase one consisted of sonic drilling on the dam crest and phase two consisted of test pitting on the downstream face, near the existing spillway and on the dam crest. The geotechnical investigation field work was carried out under the full-time inspection of a member of Golder's geotechnical staff, who identified borehole and test pit locations in the field, logged the subsurface conditions encountered, and collected samples for detailed examination and laboratory testing.

Field identification and classification of soils was carried out in accordance with Golder's soil classification system. A summary of the key aspects of the classification system is presented in Appendix C, Annex A. Surveying of the borehole and test pit locations was not carried out. The locations shown on Figure 6 are based on GPS coordinates taken at the time of the investigation.

6.1 Sonic Drilling

A total of three boreholes (SH14-04 to SH14-06) were advanced using a track-mounted ATV drill rig (Sonic Drilling) supplied and operated by Mud Bay Drilling Co. Ltd., (Mud Bay) of Surrey, BC.

Sonic drilling utilizes a dual-cased single tube core barrel system that employs high frequency mechanical vibration to obtain continuous core samples of the soils. The drilling technique involves vibrating the entire drill string at a frequency rate between 50 and 150 cycles per second, adjusted during operation to suit the ground conditions encountered. The technique employs low speed rotational motion, coupled with downward pressure, to advance the drill string. Borehole advancement is achieved through the process of fracturing, shearing, and displacement depending on the type and consistency of the material encountered.

The soil enters the core barrel providing 102 or 122 mm diameter continuous core samples. Upon completion of each drill run, the outer steel casing was advanced to the end of the run, the core barrel and drill rods were removed, and the continuous sonic core sample was vibrated out of the core barrel directly into a plastic sample bag before being transferred into wooden core boxes.

The sonic cores recovered from each borehole were logged in the field, and taken to Golder's sample storage facility at #300–3811 North Fraser Way, Burnaby, BC where the cores were further examined and photographed. Core photographs can be found in Appendix C, Annex B.

Sonic vibration from the drilling method does cause some disturbance of the soil structure, and can destroy secondary structure features within the soil strata of the continuous core samples that are retrieved. In addition, heating of the core barrel during sonic drilling may reduce the *in-situ* moisture content of the continuous core sample obtained. It should be noted that the sonic drilling method tended to "pulverize boulder and cobble sized particles" while advancing through the soil strata, as well as tending to "pulverize" the upper weathered bedrock.

Various diameters of steel casing were installed in the sonic boreholes to stabilize the borehole during drilling. Typically, 152 mm diameter steel casings were advanced following drilling of each run, and over-ride casings of 178 mm and 203 mm diameter were locally used as required by drilling conditions. Both the core barrel and casing shoes have water jets to allow for cooling and lubrication of the bit, and to flush cuttings out of the hole. Advancement of the drill string was typically carried out without addition of fluid, to prevent additional disturbance and washing of the soils. Advancement of the casing was carried out behind the drill string with the assistance of drill fluids. Water based drilling fluid was used for sonic drilling throughout this investigation.

Following completion of SH14-04 a standpipe piezometer was installed the details of which are outlined below in section 9.1. A 76 mm PVC pipe with the annulus grouted was installed in SH14-05 upon completion to facilitate down hole geophysics testing. SH14-06 was backfilled with a 2 m bentonite seal followed by pea gravel and bentonite chips in alternating lifts in accordance with the BC Groundwater Protection Act (BCGPA), and then capped with 0.3 m of concrete at surface. Soil conditions as well installation details for each of the sonic holes are presented on the Record of Testholes in Appendix C, Annex A.

6.2 Test Pitting

A total of eleven test pits were put down at selected accessible areas within the site and excavated by hand using a shovel and spade to depths between 0.3 and 1.5 m below the existing ground surface. The test pits were terminated at the maximum reach of the equipment or at the maximum depth allowable to maintain hole stability. Test pits were backfilled upon completion. A record of the soil conditions encountered in the test pits can be found in the Record of Testholes, Appendix C, Annex A.

6.3 Laboratory Testing

Laboratory classification tests were performed on selected soil samples obtained from the investigation. The samples were selected from the continuous cores retrieved from the drilling. The classification tests included sieve distribution analyses and a determination of specific gravity. Classification testing was carried out by ALS Laboratories.

Sample preparation was carried out in general conformance with SSIR-51 METHOD 3.2.1; sieve gradation. It is important to recognize that the sampling methods in the field limit the maximum particle size that can be recovered from the boreholes. As such, the laboratory gradation test results shown reflect these maximum sizes, and may not be representative of boulder, cobble, or coarse gravel content.

The classification test results are summarized on the Record of Testholes in Appendix C, Annex A. Detailed results for each of the grain size distribution analysis testing and specific gravity determinations are presented in Appendix C, Annex C.

7.0 ENVIRONMENTAL INVESTIGATION OF LOWER DAM

Suspect slag, ash and cinder fill was encountered in the sonic holes during Phase one of the geotechnical investigation on the Lower Dam. The cinders and slag fill was encountered below surficial fill and extended 3.6 to 5.4 m below ground surface. Samples of the soil containing visible cinders and slag fill were collected from varying depth intervals for environmental evaluation and testing. The results of an initial geo-environmental assessment on the suspected cinders and slag fill are outlined in Appendix D.

8.0 STRUCTURAL INVESTIGATION OF LOWER DAM

Golder carried out a structural investigation of the Lower Dam concrete wall on February 11 to 14, 2014. The investigation consisted of diamond drilling into the concrete wall. The structural investigation field work was carried out under the full-time inspection of a member of Golder’s geotechnical staff, who identified corehole locations in the field and carried out in-situ measurements. A structural engineer, a representative from Herold Engineering, was onsite in order to assess the condition of the core and rebar.

Surveying of the corehole locations was not carried out. The locations shown on Figure 6 are based on GPS coordinates taken at the time of the investigation.

8.1 Diamond Drilling

Concrete and bedrock coring was carried out on the Lower Dam using a diamond drilling rig supplied and operated by Cabo Drilling Corp. (Cabo) of Surrey, BC. A PQ sampler was used with an external of diameter of 122.6 mm and an internal diameter of 85 mm. PQ coring was carried out at two locations and the holes were put down to bedrock. Water is injected into the drill pipe to wash out the rock cuttings produced by the bit and also to reduce the heat produced due to friction which causes less wear and tear of the bits.

The full width of the concrete wall was exposed 0.6 to 0.7 m below ground surface at each of the core hole locations. The holes were then collared in the center of the wall and surveyed during drilling. Provisions were in place through our Risk Management Plan (RMP) for grouting the coreholes in the event that the drilling deviated or if poor quality concrete was encountered, to such a degree that the stability of the borehole could not be maintained. The holes did not deviate more than 2% during drilling and poor quality concrete was not encountered. In addition corehole instability was not encountered or observed during or after drilling. A copy of the RMP can be found in Appendix E, Annex D; the RMP was never implemented during drilling.

The concrete and bedrock core was collected in core boxes and transferred to the Golder's sample storage facility where the cores were further examined and photographed. Core photographs can be found in Appendix E, Annex B.

The core holes were capped upon completion and left open to facilitate in-situ testing. The Record of Corehole Sheets is presented in Appendix E, Annex A.

8.2 Laboratory Testing

Samples of the concrete and rock core were taken from the core boxes for further testing, see the record of corehole sheets in Appendix E, Annex A for sample locations and depths.

8.2.1 Concrete Testing

A total of five Unconfined Compressive Strength (UCS), two direct tensile strengths, two modulus of elasticity and two poisons ratios were carried out on samples of the concrete taken from the core. These tests were carried out to characterize the Lower Dam concrete wall properties. Table 2 below summarizes the preliminary laboratory tests carried out.

Table 2: Preliminary test program for concrete cores

Concrete Properties	Test Method	CH14-02	CH14-03
Unconfined Compressive Strength	CSA A23.2-9C/14C	3 specimens	2 specimens
Direct Tensile Strength of Concrete Pour Joint	CSA A23.2-6B Procedure B	1 specimen	1 specimen
Modulus of Elasticity and Poisson's Ratio	ASTM C 469	1 specimen	1 specimen

It is standard practice for the testing of concrete cores that diameter of concrete cores is at least three times the size of the maximum coarse aggregates. This is to reduce size effects from the coarse aggregates. Although the concrete specimens used for our testing were selected to avoid the presence of large coarse aggregates in the concrete, the aggregate sizes in these specimens were still generally larger than one-third of the core diameter. Therefore, test results obtained from these tests should be considered as approximate values only.

As the dam concrete is normally exposed to water from weather and reservoir, all the concrete specimens selected for testing were soaked in water (per CSA A23.2-14C) for 48 hrs. prior to testing.

Detailed results for each of the tests are presented in Appendix E, Annex C.

8.2.2 Rock Testing

One selected rock core sample from borehole CH14-03 was submitted to the Golder laboratory in Burnaby for moisture content and unconfined compressive strength (UCS) testing. Sample preparation was carried out in general conformance with ASTM D4543-04, the moisture content test was carried out in general conformance with ASTM D2216-92 and the unconfined compressive strength (UCS) test was performed in general conformance with ASTM D2938-95. Results of the laboratory rock testing are presented in Appendix E, Annex C.

9.0 HYDROGEOLOGY INVESTIGATION OF LOWER DAM

The ground water condition within the rockfill of the lower dam was investigated with a standpipe piezometer installed in one of the sonic holes. The in-situ hydraulic conductivity of the concrete wall was investigated by in-situ testing in the coreholes put down in the concrete wall.

9.1 Piezometer Installation

Following completion of SH14-04 a single standpipe piezometer was installed. The standpipe piezometer consisted 51 mm diameter PVC pipe having machine slotted (#10 slot) tip sections. The length of the slotted sections was 3.1 m. The bored void below the target depth of the single piezometer was filled with bentonite chips to comply with the BCGPA.

A layer of filter sand for bedding was placed just below the base of each piezometer. The standpipe piezometer was then lowered to the target zone, and silica filter sand was placed as a filter pack around the slotted piezometer screen section. The filter sand however, was lost to the surrounding in-situ rockfill therefore pea gravel was used as a filter pack for the remainder of the slotted piezometer screen section. The pea gravel was extended some 0.5 m above the top of the screened section, and an upper bentonite plug was placed to the top of the rockfill to isolate the screen section. Following installation of the bentonite seal, the bored void between the piezometer and hole was backfilled with bentonite chips and pea gravel in alternating lifts in accordance with the BCGPA, and then capped with a flush mounted well cover.

Details of the piezometer installations are shown on the Record of Testholes in Appendix C, Annex A.

9.1.1 Water Level Monitoring

Groundwater level measurements were taken following completion of drilling and during the test pitting investigation. The measurements were collected using a water level meter. Groundwater monitoring results for the piezometer is presented in Table 3. The piezometer was found to be dry on both occasions.

Table 3: Water Level Monitoring in Lower Dam Downstream Fills

Borehole No.	Elevation at Ground Surface	Elevation at Top of Pipe	Screen Top	Screen Bottom	Groundwater Elevation	Groundwater Elevation
	m geodetic	m geodetic	m geodetic	m geodetic	m geodetic	m geodetic
DATE					**February 14, 2014**	**April 1, 2014**
SH14-04	73.500	73.45	64.0	61.0	DRY	DRY

9.2 In-situ Hydraulic Conductivity Testing

In-situ hydraulic conductivity tests were carried out in the form of falling head tests within the coreholes. Details on the in-situ hydraulic conductivity testing and the results associated with the testing are presented in Appendix F.

10.0 CLOSURE

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

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

Anne Crowley
Geotechnical Group

Bruce Downing, P.Eng.
Principal

AC/BRD/sn

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IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

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

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

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

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

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

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

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

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

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

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

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

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

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

REFERENCES

ASTM D 4543-04, Standard Practices for Preparing Rock Core as Cylindrical Test Specimens and Verifying Conformance to Dimensional and Shape Tolerances, , American Society for Testing and Materials.

ASTM D 2938-95, Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens, American Society for Testing and Materials.

ASTM D 2216-92, Laboratory Determination of Water (Moisture) Content of Soil and Rock, American Society for Testing and Materials.

ASTM C 469, Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression, American Society for Testing and Materials.

CSA A23.2-9C/14C, Compressive Strength of Cylindrical Concrete Specimens, Canadian Standards Association

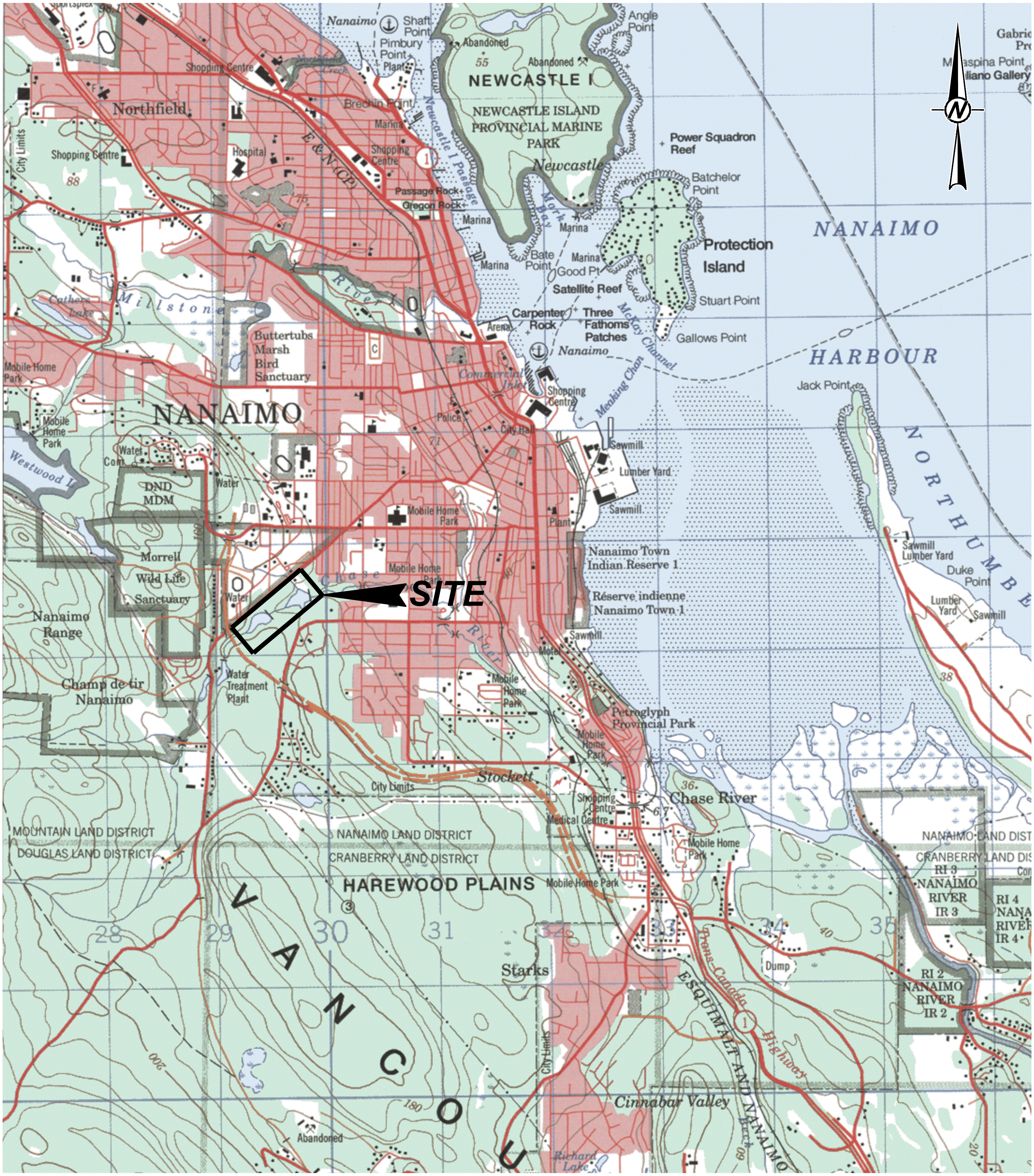
CSA A23.2-6B Procedure B, Method of Test for the Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus, Canadian Standards Association

SSIR-51 (Soil Survey Investigations Report No. 51), Soil Survey Field and Laboratory Methods Manual, National Soil Survey Center, Method 3.2.1

EBA Engineering Consultants Ltd., 2010, Seismic Hazard Assessment Middle and Lower Chase Dams file reference N13101249, April 14, 2010.

Golder Associates Ltd., 1978, Report to Willis Cunliffe & Tait Limited on Site Investigation Nanaimo Dams Nanaimo, British Columbia, file reference V78040, May 1978.

Willis Cunliffe & Tait Limited, 1980, Repairs As-builts: Removal of Middle and Lower Chase River Dam Tender No. 1445.



A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.
REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

KEY PLAN

0 5 10 15

SCALE A METRES

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-01
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	
CHECK	A.C.	2014-04-25		1
REVIEW	B.D.	2014-04-25		

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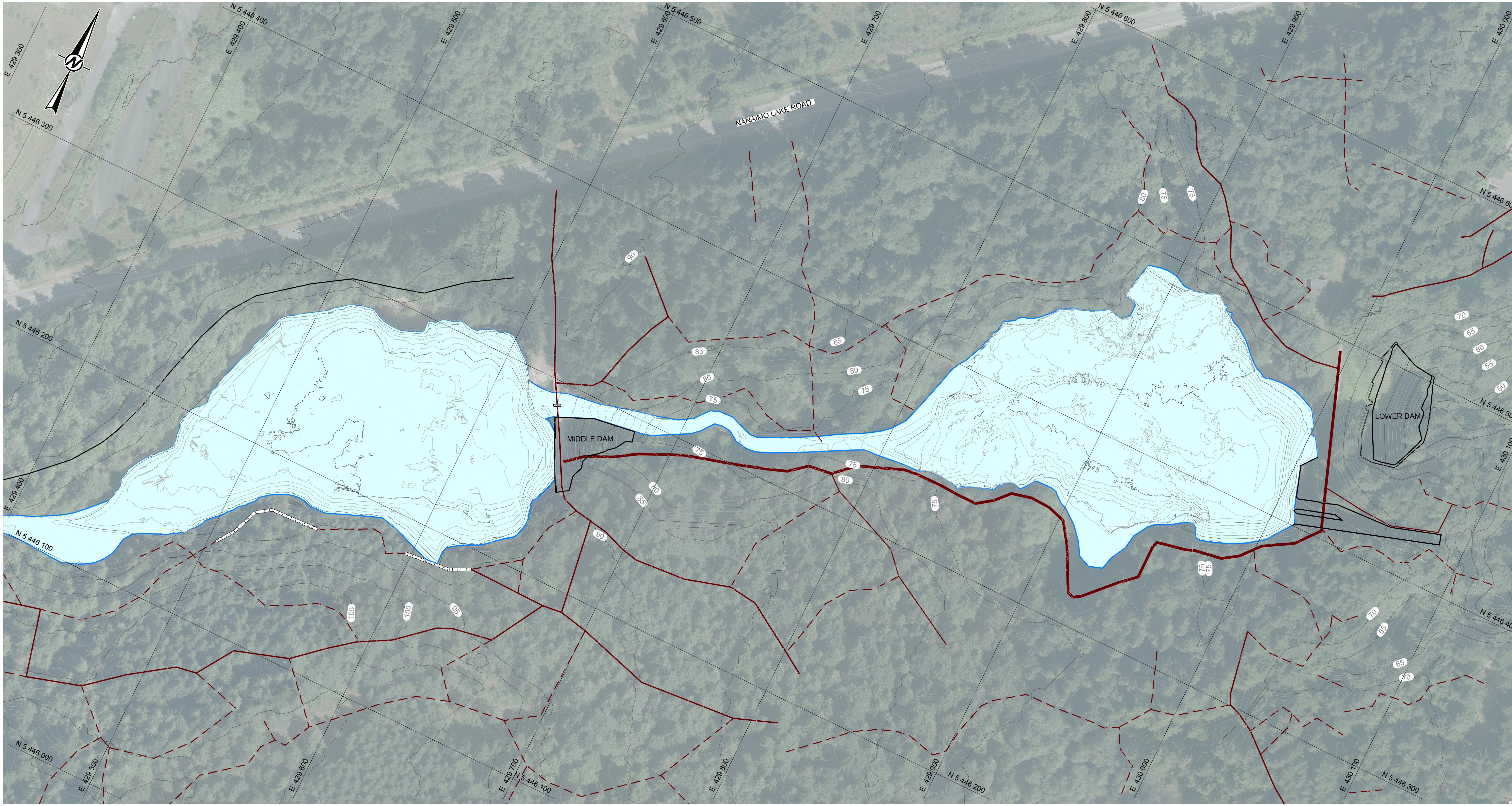


LEGEND

	NORMAL OPERATING LEVEL OF RESERVOIR
	MAJOR TRAILS
	MINOR TRAILS
	MAIN PAVED PATHWAYS

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS. (EBA 2010)
5. AERIAL PHOTO FROM CITY OF NANAIMO WEBSITE, IMAGE FILES: 552D.tif and 652B.tif.

0 8 16 24

SCALE

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT

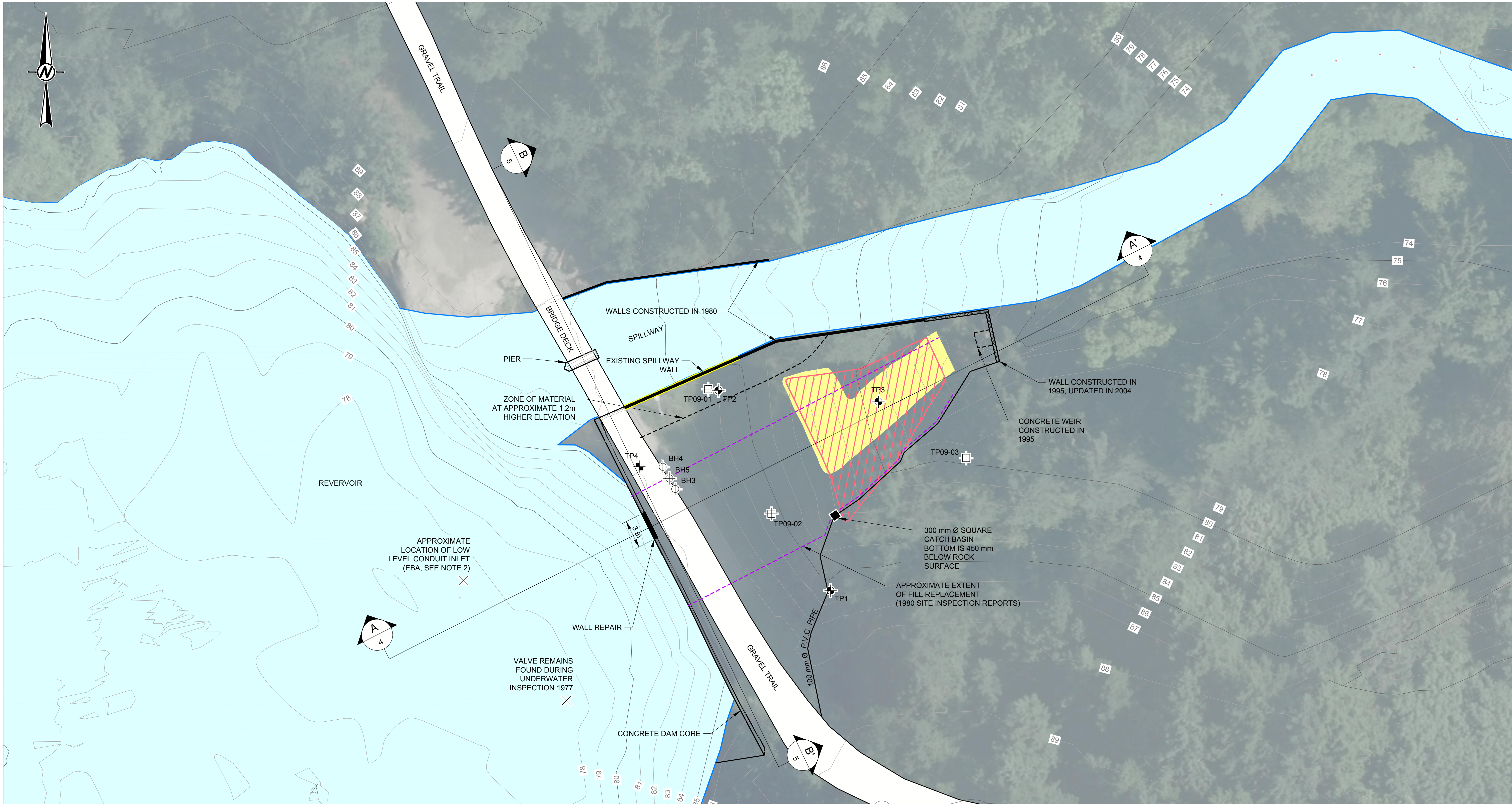
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

SITE LOCATION PLAN

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-02
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	2
CHECK	A.C.	2014-04-25		
REVIEW	B.D.	2014-04-25		



LEGEND

- BOUNDARY OF SHOT ROCK BUTTRESS (AS-BUILT 1980)
- DRAINAGE BLANKET ZONE (AVERAGE DEPTH 1.5m), AS-BUILT 1980
- NORMAL OPERATING LEVEL OF RESERVOIR
- 1978 BOREHOLE (GOLDER)
- 1978 TEST PIT PUT DOWN BY HAND (GOLDER)
- 1978 TEST PIT PUT DOWN BY EXCAVATION (GOLDER)
- 2009 TEST PIT (EBA)

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS. (EBA 2010)
5. AERIAL PHOTO FROM CITY OF NANAIMO WEBSITE, IMAGE FILES: 552D.tif and 652B.tif.

0 8 16 24
SCALE

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE
LOCATION PLAN
MIDDLE DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-03
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	
CHECK	A.C.	2014-04-25		3
REVIEW	B.D.	2014-04-25		

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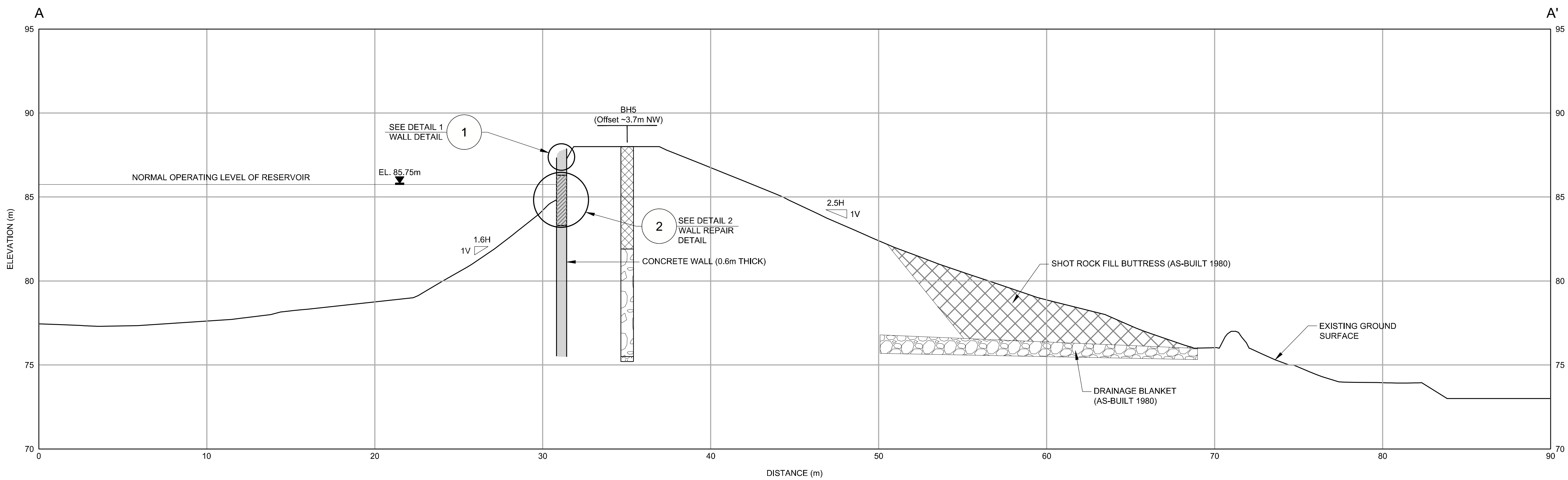
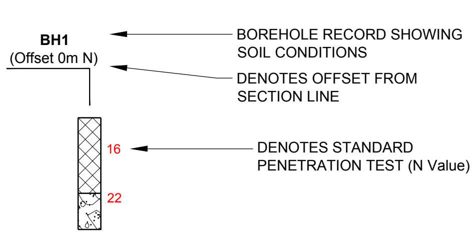


SCALE A A 3 CROSS-SECTION A-A'

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND

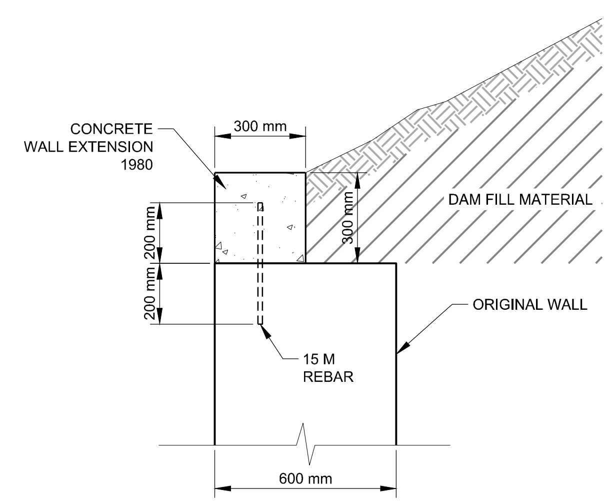


NOTE

1. THE INFERRED STRATIGRAPHY BOUNDARY IS NOT SHOWN ON THIS FIGURE.

REFERENCES

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



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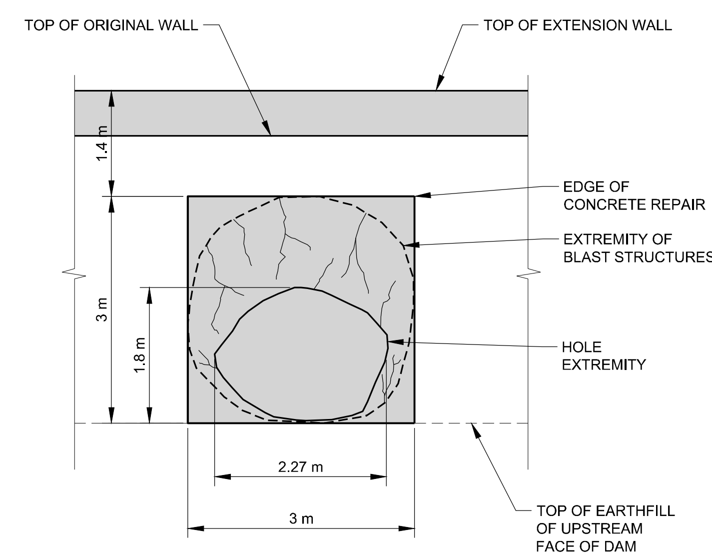
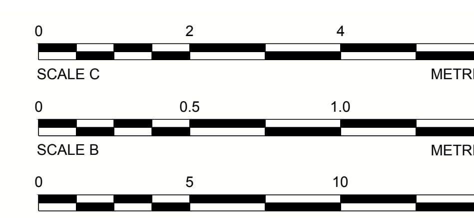


SCALE C 2 WALL REPAIR DETAIL



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A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT

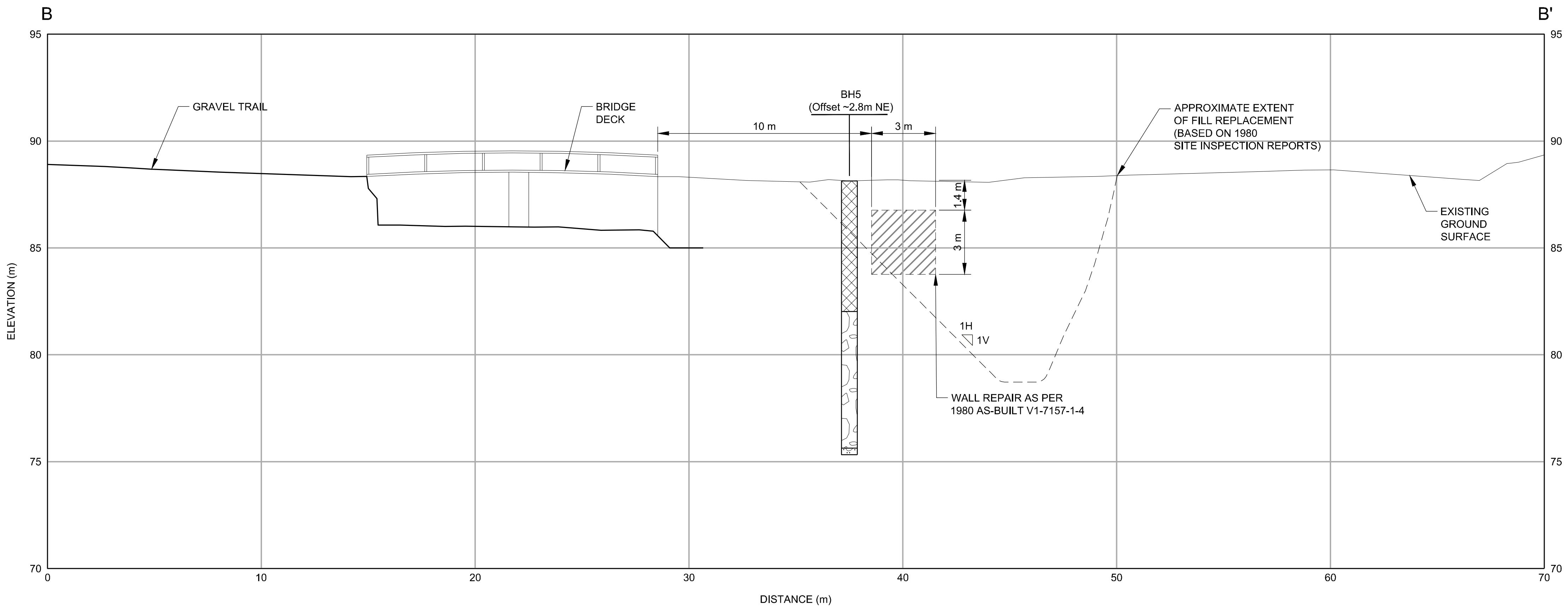
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

CROSS-SECTION A-A' MIDDLE DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-04
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	
CHECK	A.C.	2014-04-25		4
REVIEW	B.D.	2014-04-25		

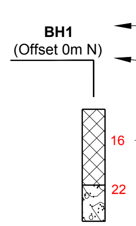


SCALE A B 3 CROSS-SECTION B-B'

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND



- BOREHOLE RECORD SHOWING SOIL CONDITIONS
- DENOTES OFFSET FROM SECTION LINE
- DENOTES STANDARD PENETRATION TEST (N Value)

NOTE

1. THE INFERRED STRATIGRAPHY BOUNDARY IS NOT SHOWN ON THIS FIGURE.

REFERENCES

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

0 5 10 15
SCALE A METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE
CROSS-SECTION B-B' MIDDLE DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-05
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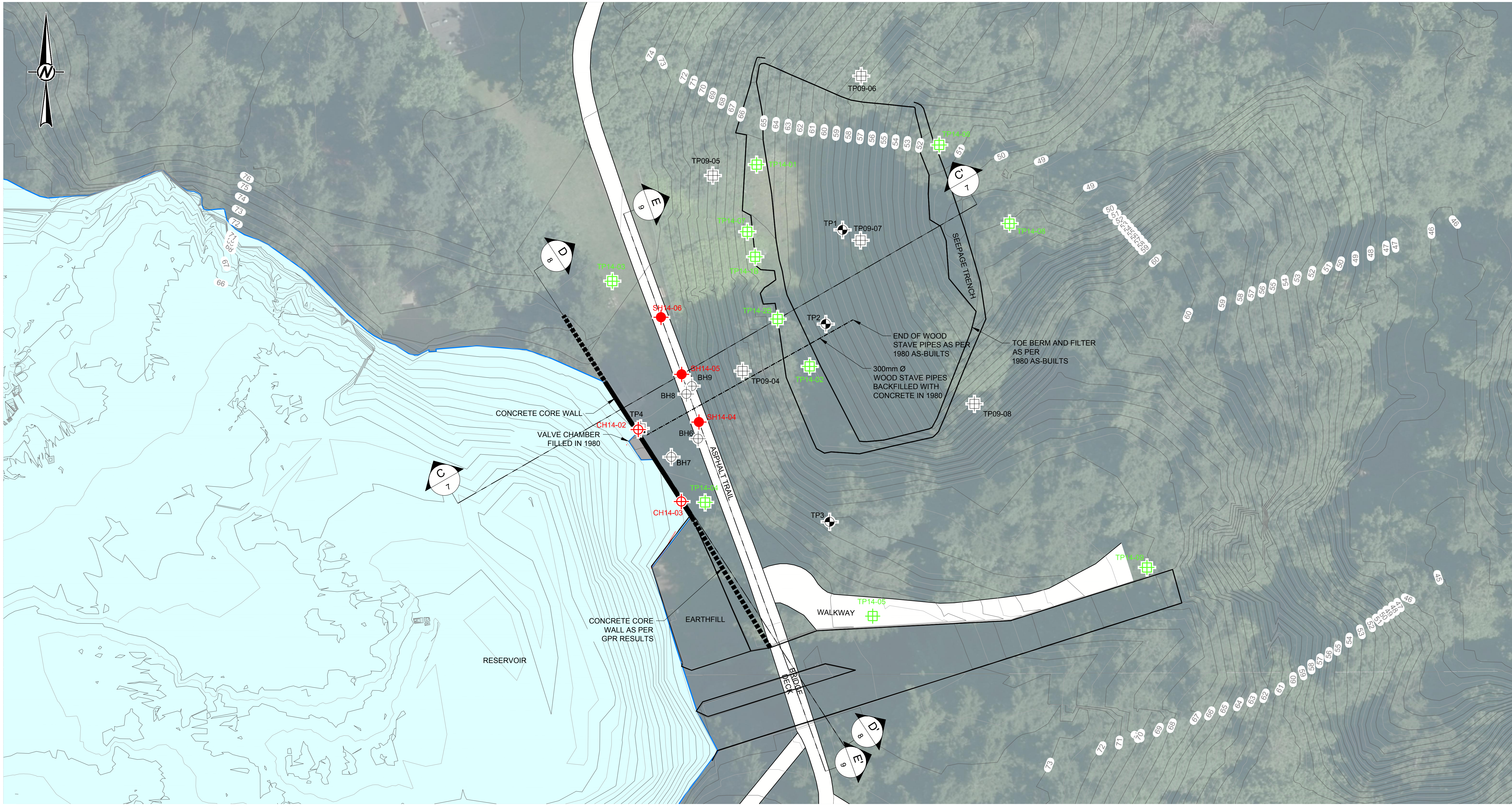
REVIEW	B.D.	2014-04-25		



LEGEND

NORMAL OPERATING LEVEL OF RESERVOIR	OUTLINE OF WALL, 1.2m IN THICKNESS, AT 0.6m BELOW GROUND SURFACE
1978 BOREHOLE (GOLDER)	2014 SONIC HOLE (GOLDER)
1978 TEST PIT PUT DOWN BY EXCAVATOR (GOLDER)	2014 COREHOLE (GOLDER)
1978 TEST PIT PUT DOWN BY HAND (GOLDER)	2014 TEST PIT PUT DOWN BY HAND (GOLDER)
2009 TEST PIT (EBA)	

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park lower dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS. (EBA 2010)
5. AERIAL PHOTO FROM CITY OF NANAIMO WEBSITE, IMAGE FILES: 552D.tif and 652B.tif.

0 12 24 36
SCALE METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
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PROJECT
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE
LOCATION PLAN
LOWER DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-06
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	6
CHECK	A.C.	2014-04-25		
REVIEW	B.D.	2014-04-25		

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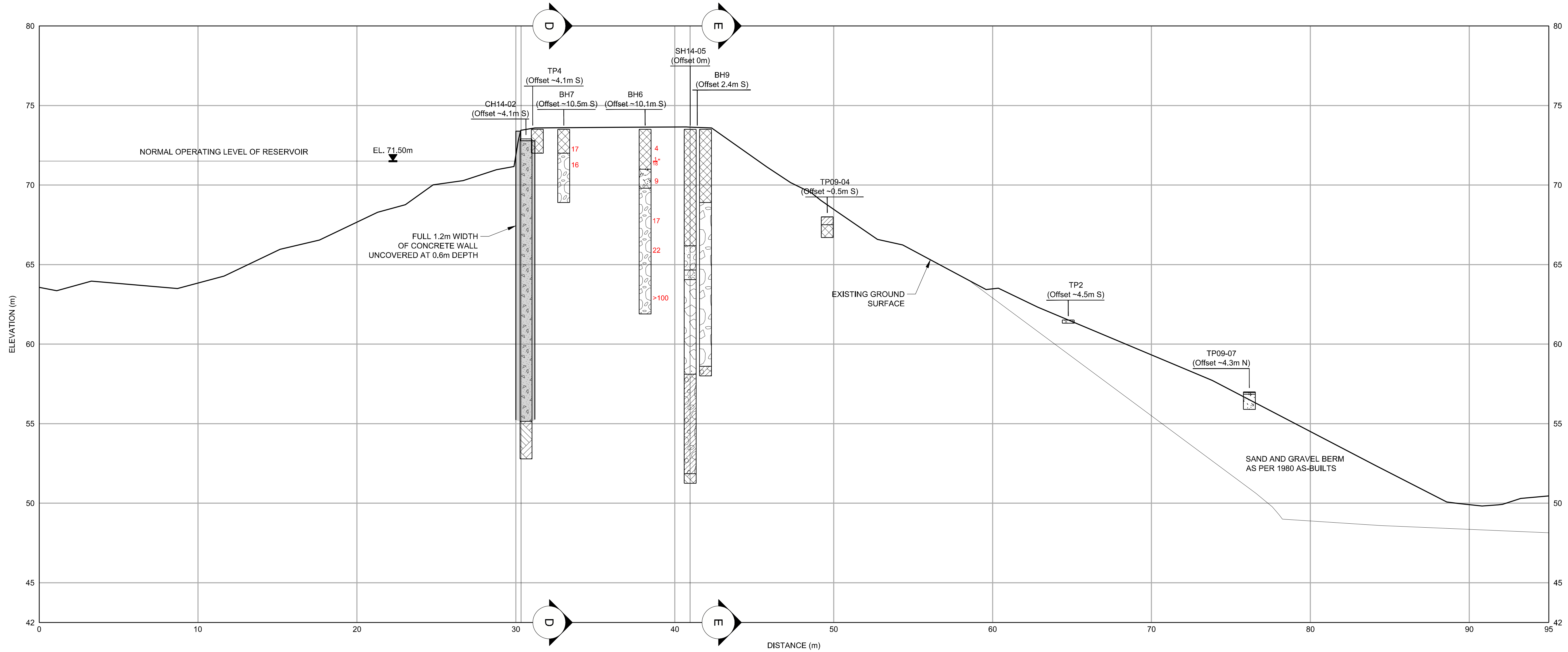
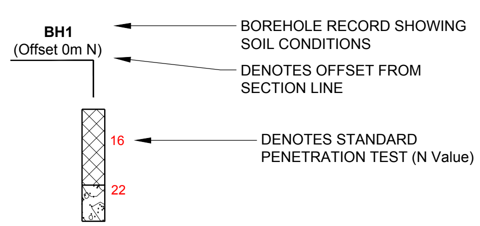


SCALE A C 6 CROSS-SECTION C-C'

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND



NOTE

1. THE INFERRED STRATIGRAPHY BOUNDARY IS NOT SHOWN ON THIS FIGURE.

REFERENCES

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

0 5 10 15

SCALE A METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

CROSS-SECTION C-C'
LOWER DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-07
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
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CHECK	A.C.	2014-04-25		7
REVIEW	B.D.	2014-04-25		

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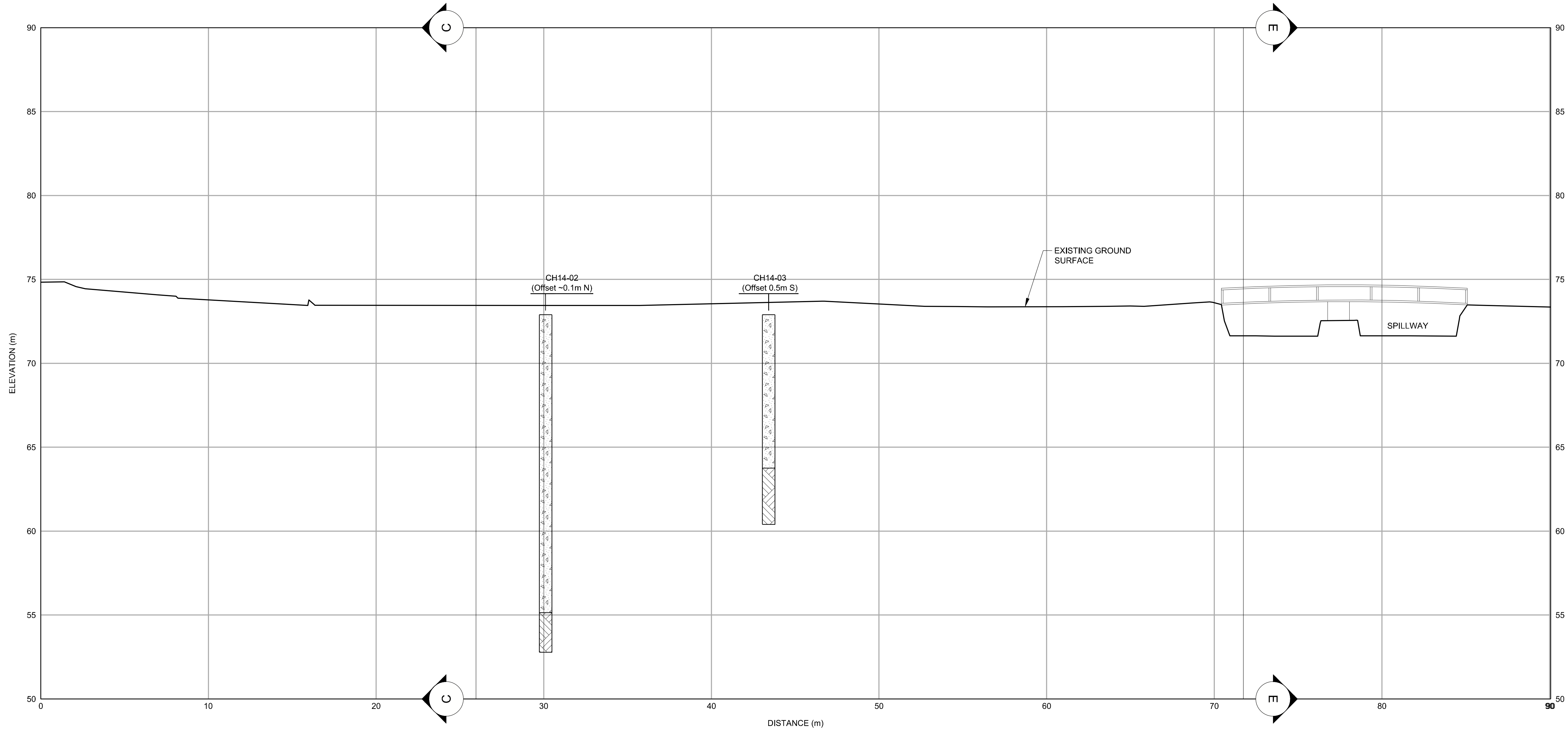

SCALE A D 6 CROSS-SECTION D-D'

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND

BH1 (Offset 0m N)

- BOREHOLE RECORD SHOWING SOIL CONDITIONS
- DENOTES OFFSET FROM SECTION LINE
- 16, 22 — DENOTES STANDARD PENETRATION TEST (N Value)

NOTE

1. THE INFERRED STRATIGRAPHY BOUNDARY IS NOT SHOWN ON THIS FIGURE.

REFERENCES

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

0 5 10 15
SCALE A METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT
CITY OF NANAIMO
PROJECT NAME
NANAIMO, B.C.

TITLE
CROSS-SECTION D-D'
LOWER DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-08
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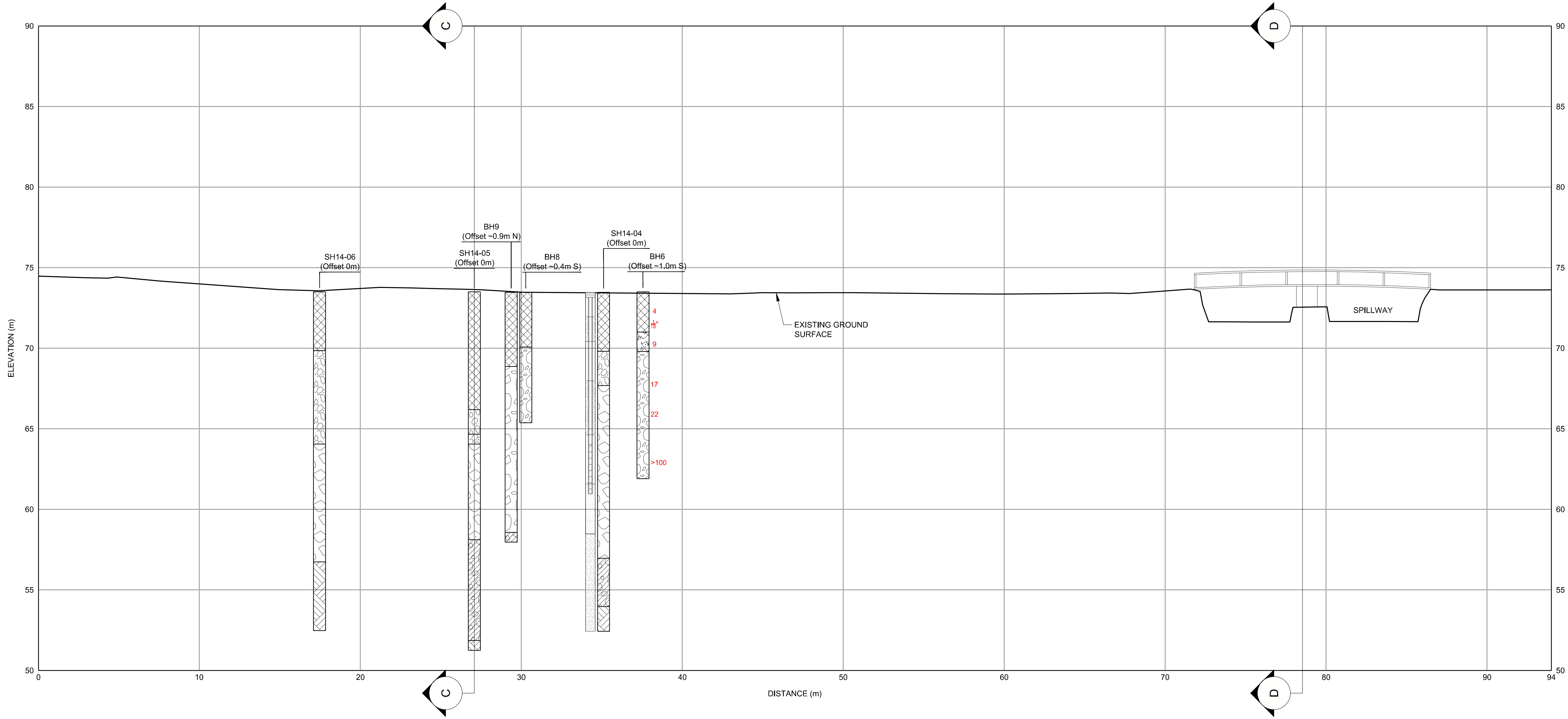
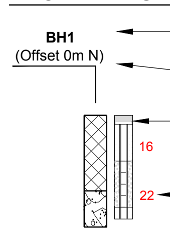


SCALE A E 6 CROSS-SECTION E-E'

LITHOLOGY GRAPHIC LEGEND

- CINDERS AND SLAG FILL
- RANDOM VARIABLE FILL
- ROCKFILL
- CONCRETE
- FINE GRAINED FILL
- BEDROCK

PROFILE LEGEND



- BOREHOLE RECORD SHOWING SOIL CONDITIONS
- DENOTES OFFSET FROM SECTION LINE
- DENOTES PIEZOMETER INSTALLATION
- DENOTES STANDARD PENETRATION TEST (N Value)

NOTE

1. THE INFERRED STRATIGRAPHY BOUNDARY IS NOT SHOWN ON THIS FIGURE.

REFERENCES

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

0 5 10 15
SCALE A METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-25	ISSUED WITH FACTUAL REPORT	A.C.	M.R.	A.C.	B.D.

PROJECT
CITY OF NANAIMO
PROJECT NAME
NANAIMO, B.C.

TITLE
CROSS-SECTION E-E'
LOWER DAM

Golder Associates

PROJECT No.	13-1447-0516/7300		FILE No.	1314470516_7300-09
DESIGN	A.C.	2014-04-11	SCALE	AS SHOWN
CADD	M.R.	2014-04-14	FIGURE	
CHECK	A.C.	2014-04-25		9
REVIEW	B.D.	2014-04-25		

APPENDIX A

Appendix A-Historic Investigations

Annex A Golder 1978 Investigation Lower and Middle Dam

Project No. V78040

RECORD OF BOREHOLE 3

MIDDLE CHASE RIVER DAM

LOCATION (See Figure 3) BORING DATE March 16, 1978

BOREHOLE TYPE Rotory BOREHOLE DIAMETER 114 mm

SAMPLER HAMMER WEIGHT 63.6 kg. DROP 762mm DATUM WCT Dwg. VI 6325-1-1

SOIL PROFILE ELEV. / DEPTH	SOIL PROFILE DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.8	Ground Surface							- drill with air, no sampling
0.0	Loose to compact brown SAND & GRAVEL some silt. (FILL)							- lost air circulation at 4.6m
94.1 / 6.7	ROCKFILL							- hole open to 7.6m no water encountered
91.7 / 9.1	End of Borehole							

VERTICAL SCALE 1 cm to 1 m

Golder Associates

DRAWN B.D.
CHECKED G.

Project No. V78040

RECORD OF BOREHOLE 4
MIDDLE CHASE RIVER DAM

LOCATION (See Figure 3) BORING DATE March 17, 1978

BOREHOLE TYPE Rotary BOREHOLE DIAMETER 114mm

SAMPLER HAMMER WEIGHT 63.6kg. DROP 762 mm DATUM WCT Dwg. VI 6325-1-1

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_p — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.8	Ground Surface							drilling with air
0.0	Loose to compact SAND GRAVEL, COBBLES, BOULDERS (FILL)		1	DO	31			
			2	"	13			
			3	"	>100			
90.1 / 10.7	End of Borehole							rods stuck in hole

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN R.D.
CHECKED G.T.

Project No. V78042

RECORD OF BOREHOLE 5
MIDDLE CHASE RIVER DAM

LOCATION (See Figure 3)
BORING DATE March 28-29, 1978

BOREHOLE TYPE Air Track
BOREHOLE DIAMETER 50 mm

SAMPLER HAMMER WEIGHT - LB. DROP - IN.
DATUM WCT Dwg. VI 6325-1-1

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.8	Ground Surface							
0.0	Loose to compact sand & gravel (FILL)							
94.7 / 6.1	ROCKFILL							- lost air circ. at 6.1m no return
88.3 / 12.5	TILL - LIKE MATERIAL							- rods stuck in hole
12.8	End of Borehole							

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN R.Q.
CHECKED G.L.

RECORD OF BOREHOLE 6
LOWER CHASE RIVER DAM

Project No. 1780412

LOCATION (See Figure 2) BORING DATE March 14, 1978

BOREHOLE TYPE Rotary BOREHOLE DIAMETER 114mm

SAMPLER HAMMER WEIGHT 63.6kg. DROP 762mm DATUM W,C,T, Dwg. VI 6325-1-1

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0	Very loose cinders, slag, etc. (FILL)		1	D.O.	4			
			2	"	1/18"			
97.8 / 2.5	Loose to compact SANDS GRAVELS, COBBLES (FILL)		3	"	9	Lost		
96.6 / 3.7	Loose gravels cobbles & boulders (ROCKFILL)							Lost mud circulation
			4	"	17			
			5	"	22	Lost		
			6	"	>100	Lost		Hole cased to 10.3 lost mud circ at 10.3m, no return 10.3m - 11.6.m
88.7 / 11.6	End of Borehole							Stopped because possibility of jamming rods in hole, also casing damaged from driving into rockfill.

VERTICAL SCALE 1 :100

Golder Associates

DRAWN R.D.
CHECKED G.

Project No. V78042

RECORD OF BOREHOLE 7
LOWER CHASE RIVER DAM

LOCATION (See Figure 2) | BORING DATE March 15, 1978

BOREHOLE TYPE Rotary | BOREHOLE DIAMETER 114 mm

SAMPLER HAMMER WEIGHT 63.6 kg. DROP 762 mm | DATUM WCT Dwg. VI 6325-1-1

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0	Loose, rust brown fine to coarse SAND, some gravel trace silt & cinders (FILL)							
98.8			1	DO	17			
1.5	Very coarse gravels with cobbles & boulders (ROCKFILL)		2	"	16	lost		- Lost mud circ. at 1.5m - drill with air to 4.6m - no return - stopped because of possibility of jamming rods in hole.
95.7								
4.6	End of Borehole							

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN B.D.
CHECKED [illegible]

Project No. V78042

RECORD OF BOREHOLE 8
LOWER CHASE RIVER DAM

LOCATION (See Figure 2) BORING DATE March 16, 1978

BOREHOLE TYPE Rotary BOREHOLE DIAMETER 114 mm

SAMPLER HAMMER WEIGHT 63.6 kg. DROP 762 mm DATUM W, C, T Dwg. VI 6325-1-1

SOIL PROFILE			SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT						
100.3	Ground Surface							Drill with air
	Loose black SAND GRAVEL, SLAG, CINDERS (FILL)							
96.9 / 3.4	Loose coarse GRAVELS COBBLES & BOULDERS (ROCKFILL)							- hole cased to 6.7 m. No return from 6.7 - 8.1 m - driving shoe for casing damaged
92.2 / 8.1	End of Borehole							

VERTICAL SCALE 1:100

Golder Associates

DRAWN R.D.
CHECKED GL

Project No. V78040

RECORD OF BOREHOLE 9
LOWER CHASE RIVER DAM

LOCATION (See Figure 2) BORING DATE March 28, 1978

BOREHOLE TYPE Air Track BOREHOLE DIAMETER 50 mm

DATUM WCT Dwg. VI 6325-1-1

ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
100.3	Ground Surface							
0.0	Loose cinders, sand, gravels							
95.7 / 4.6	Cobbles & boulders (ROCKFILL)							- lost air circ. at 4.6m - no return
85.4 / 14.9	TILL-LIKE MATERIAL							
84.8 / 15.5	End of Borehole							

VERTICAL SCALE 1 : 100

Golder Associates

DRAWN B.D.
CHECKED

TABLE II
RECORD OF TEST PITS

B. Middle Chase River Dam

Testpit No.	Depth (meters)	Strata Description
1	0 - 0.5	Sandy SILT, some clay, gravel cobbles, many roots. (Fill)
	0.5 - 0.6	Black TOPSOIL & ORGANICS
	0.6	BEDROCK
2	0 - 0.2	TOPSOIL & ORGANICS
	0.2	BEDROCK
3	0 - 0.3	Loose, fine to coarse GRAVEL, trace sand & silt. (Fill)
4	0 - 2.4	Loose to compact, brown SAND & GRAVEL, some clayey silt, cobbles & boulders. (Fill)

TABLE III
RECORD OF TEST PITS

C. Lower Chase River Dam

Testpit No.	Depth (meters)	Strata Description
1	0 - .3	Loose SLAG, CINDERS, COAL (Fill)
	.3 - .6	TOPSOIL & ORGANICS
	.6 - 1.2	Firm, brown sandy, gravelly SILT roots, occ. cobble
2	0 - 1.2	Loose slag, some SAND & GRAVEL (FILL)
3	0 - .9	Loose SLAG, CINDERS & ROOTS (Fill)
	.9 - 1.2	Dense, grey brown, silty gravelly SAND, some cobbles (Till-like).
4	0 - 1.5	Loose CINDERS, SLAG, sand roots. (Fill)
	1.5	ROCKFILL

Annex B EBA 2009 Testing Pit Records

Project: Chase River Dam Seismic Inspections
Project Number: N13101249
Task: Lower and Middle Chase Dam Testpitting
Excavation Method of Testpits: Spade and Pick Axe
Date: March 6, 2009

Middle ChaseDam:

TABLE 1: TESTPIT - TP09-01
START: 12:45PM, END: 1:15PM

Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.05	Veneer of grass/topsoil			
0.05	1.10	SAND (FILL) – gravely, some cobbles to 200 mm, trace silt, dense, angular to rounded gravel and cobbles, moist, greyish brown, trace organics (roots) to 0.30 m. Groundwater not observed Testpit backfilled on completion.	D	0.60-0.70	SA-01

TABLE 2: TESTPIT - TP09-02
START: 1:25PM, END: 2:00PM

Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.05	Veneer of grass/topsoil			
0.05	1.10	SAND (FILL) – gravely, some cobbles to 200 mm, trace silt, dense, angular to subrounded gravel and cobbles, moist, greyish brown, trace organics (roots) to 0.3 m. Groundwater not observed Testpit backfilled on completion.	D	0.80-0.90	SA-01

TABLE 3: TESTPIT - TP09-03
START: 2:10PM, END: 2:30PM

Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.20	SAND (TOPSOIL) – gravely, trace silt, compact, subrounded gravel, damp, blackish brown, organics (roots)			
0.20	0.80	SAND – gravely, trace cobbles to 250 mm, dense, subangular to subrounded gravel and cobbles, reddish brown, trace roots. Groundwater not observed Testpit backfilled on completion.	D	0.70-0.80	SA-01

Lower ChaseDam:

TABLE 4: TESTPIT - TP09-04 START: 11:40AM, END: 12:00PM					
Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.01	Veneer of mowed brush/topsoil			
0.01	0.50	CLAY (FILL) – some silt, trace gravel, firm, low to medium plastic, rounded gravel, moist, brown, organics (roots).			
0.50	1.30	SLAG AND CINDERS (FILL) – some sand, trace coal, loose to compact, subrounded to rounded slag, cinders, sand and coal, damp, grey/brown, trace organics (roots) to 1.0 m. Groundwater not observed Testpit backfilled on completion.	D	0.80-1.00	SA-01

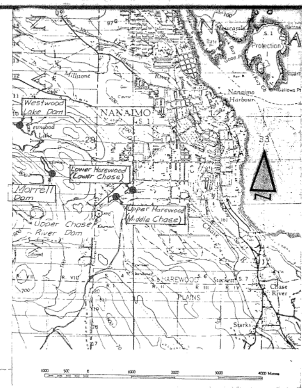
TABLE 5: TESTPIT - TP09-05 START: 11:10AM, END: 11:30AM					
Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.05	Veneer of grass/topsoil			
0.05	1.30	SLAG AND CINDERS (FILL) – some sand, trace coal, loose to compact, subrounded to rounded slag, cinders, sand and coal, damp, grey/brown, trace organics (roots) to 1.0 m. Sloughing to 1.0 m Groundwater not observed Testpit backfilled on completion.	D	0.60-0.80	SA-01

TABLE 6: TESTPIT - TP09-06 START: 10:30AM, END: 11:00AM					
Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.40	SAND (TOPSOIL) – some silt, some gravel, trace clay, dense, subrounded gravel, damp, black and brown, trace organics (roots)			
0.40	0.80	SAND (GLACIAL TILL) – some gravel, some silt, trace clay, dense to very dense, subrounded gravel, damp, light brown. Groundwater not observed Testpit backfilled on completion.	D	0.60-0.70	SA-01

TABLE 7: TESTPIT - TP09-07 START: 9:00AM, END: 9:40AM					
Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.05	Veneer of grass/topsoil			
0.05	0.15	SAND (TOPSOIL) – trace silt, compact, subrounded medium sand, moist, brown and black, organics.			
0.15	1.10	SAND (FILL) – gravely, trace cobbles to 250 mm, dense, rounded to subrounded gravel and cobbles, moist, brown. At 0.9 m, becomes wet Groundwater not observed Testpit backfilled on completion.	D	0.60-0.80	SA-01

TABLE 8: TESTPIT - TP09-08 START: 9:50AM, END: 10:20AM					
Depth (m)		Soil Description	Sample		
From	To		Type	Depth (m)	N/PP
0.00	0.80	COBBLES & CLAY – gravely, some silt, dense, angular cobbles and gravel, wet, brown, trace organics (roots) to 0.5 m The soil encountered is likely weathered bedrock in a clay/silt matrix Groundwater not observed Testpit backfilled on completion.	D	0.60-0.70	SA-01

Annex C Willis Cunliffe and Tait 1980 As-Built Report



Site Plan

KEY PLAN

Note: Contours in feet, geodetic.

INDEX

DWG NO.	SHEET NO.	TITLE
7157-1	1	Site Plan & Key Plan
"	3	Lower Harewood Dam
"	4	Upper Harewood Dam
"	5	Westwood Lake Dam
"	6	Lower Harewood Spillway Details
"	7	Lower Harewood Dam X-Sections of Stability Berm
"	8	" "
7157-1	9	Upper Harewood Dam X-Sections of Reconstructed Dam Surface

6 Indicates sheet number

No.	REVISION DESCRIPTION	DATE	BY
1	As constructed	17/1/84	MD

DESIGN LDP
DRAWN NLJ
CHECKED YAG
APPROVED
DATE July, 1978
SCALE As shown
FIELD BOOK No.

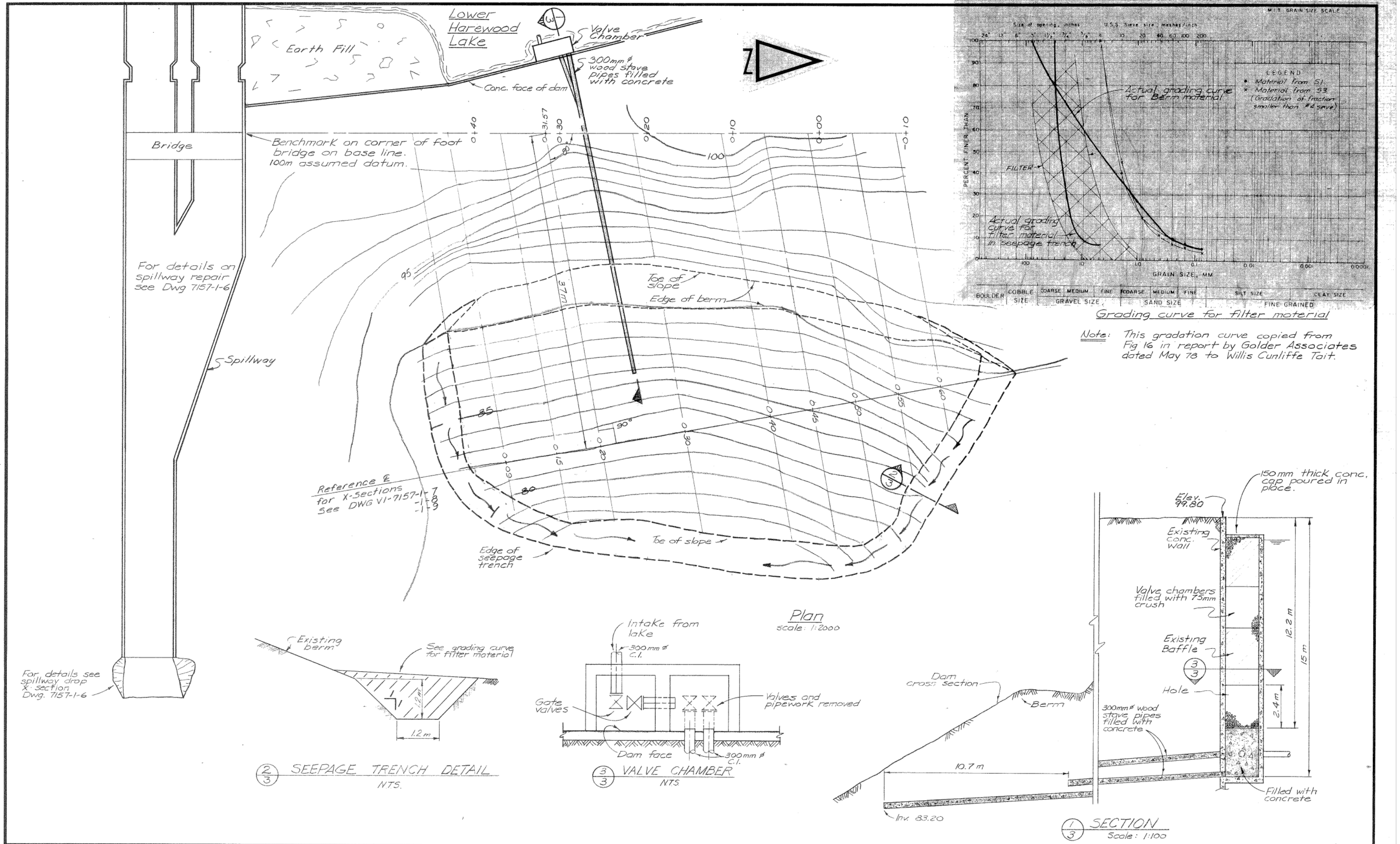
SEAL

WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
SITE PLAN & KEY PLAN

SHEET No. 1 OF 8 REV. 1
DRAWING No. VI 7157-1-1

No 3709



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DESIGN: D.P.
DRAWN: CEB
CHECKED
APPROVED
DATE: Sept. 24/80
SCALE
FIELD BOOK No. Misc. #31

SEAL

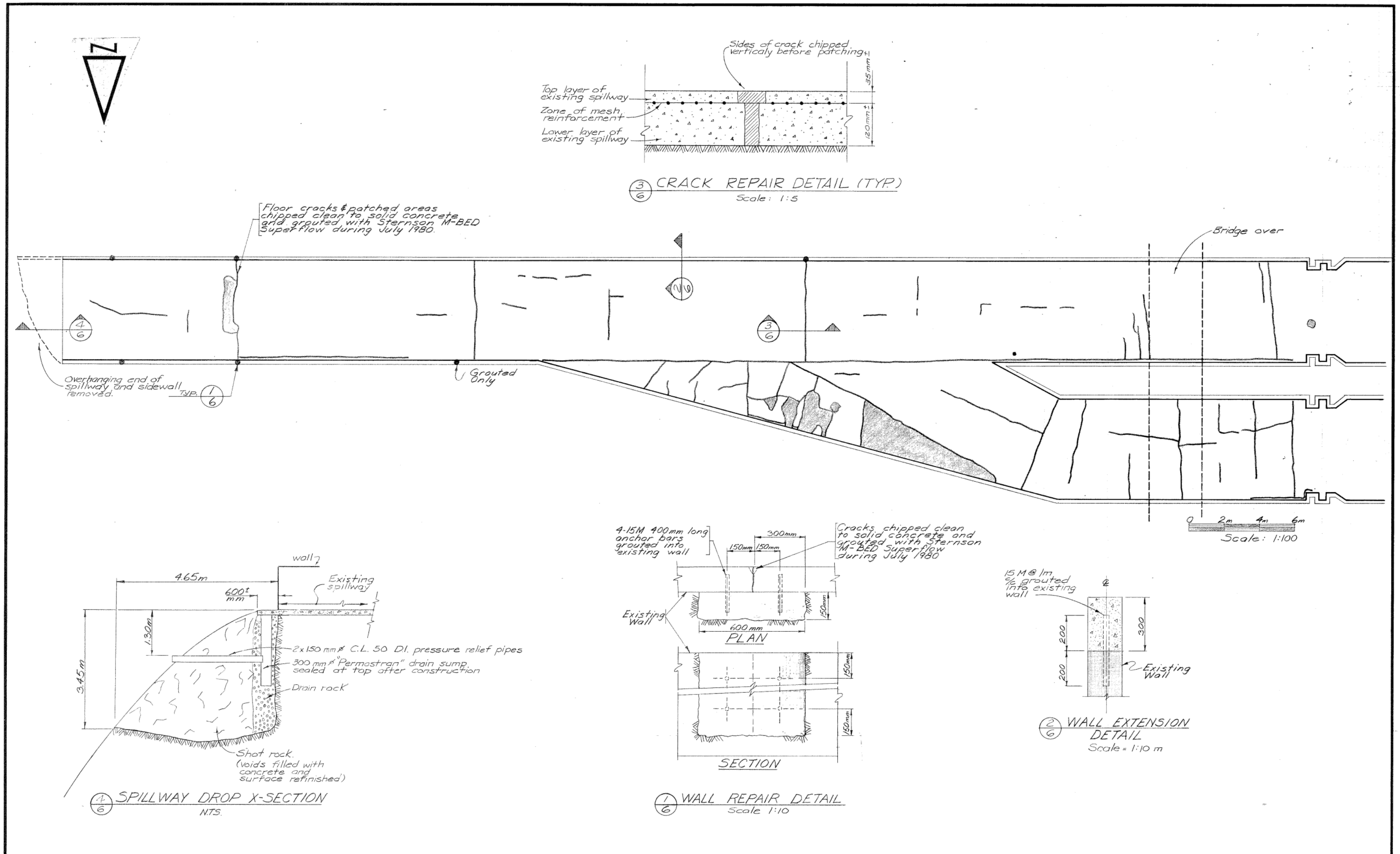
WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
LOWER HAREWOOD DAM

SHEET No. 3 OF 8 REV. 2
DRAWING No. VI-7157-1-3

3709-9-80

№ 3710



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DESIGN DWA.
DRAWN CEB
CHECKED
APPROVED
DATE Sept. 14, /80
FIELD BOOK No. Misc. 31, Non Dams

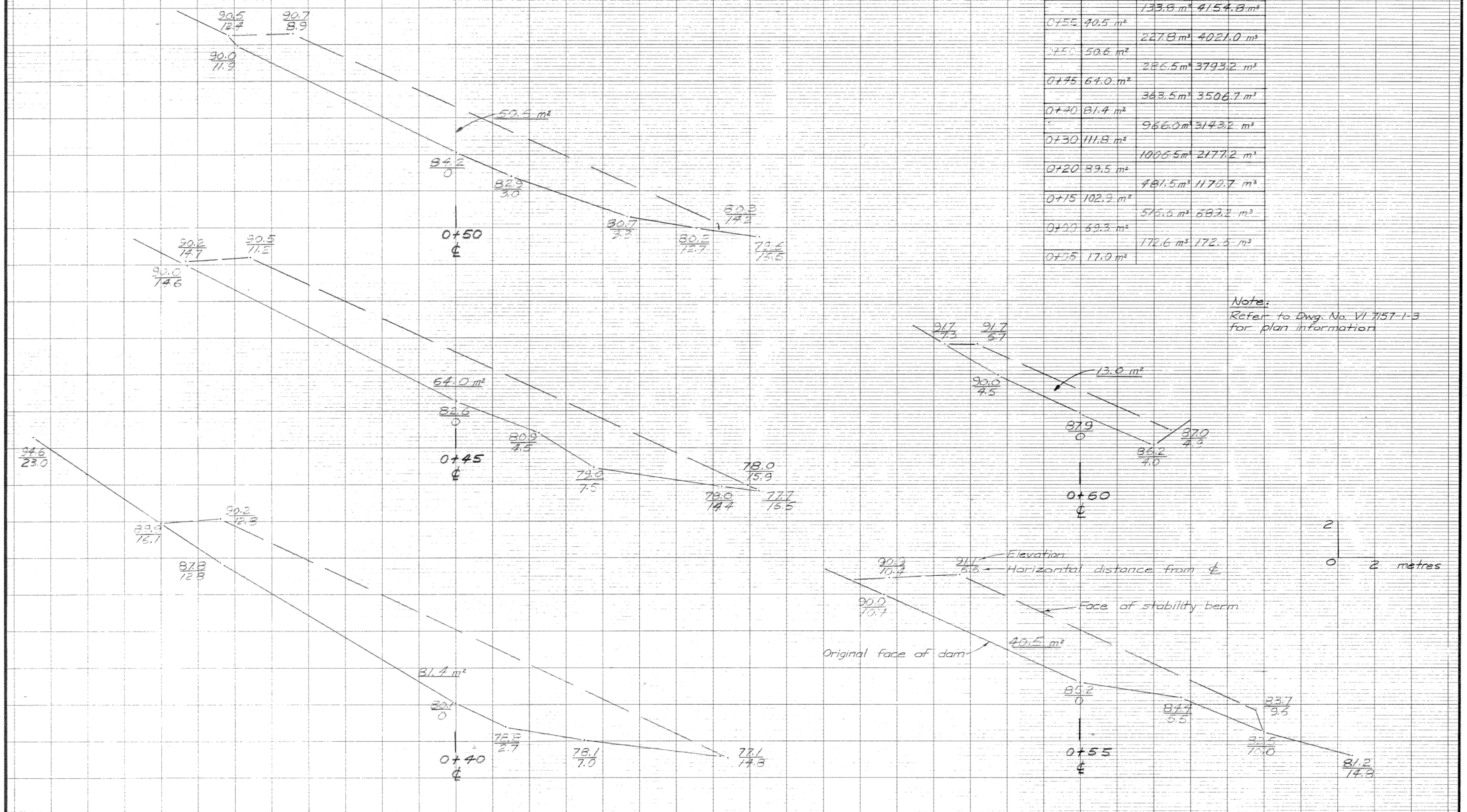
SEAL

WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
LOWER HAREWOOD SPILLWAY DETAILS

SHEET No. 6
OF 8 REV. 1
DRAWING No. VI 7157-1-6

3710-9-80



STA	AREA	VOLUME	Σ VOLUME
0+60	13.0 m²		
		133.8 m³	4154.8 m³
0+55	40.5 m²		
		227.8 m³	4021.0 m³
0+50	50.6 m²		
		286.5 m³	3793.2 m³
0+45	64.0 m²		
		363.5 m³	3506.7 m³
0+40	81.4 m²		
		966.0 m³	3143.2 m³
0+30	111.8 m²		
		1006.5 m³	2177.2 m³
0+20	89.5 m²		
		481.5 m³	1170.7 m³
0+15	102.9 m²		
		516.6 m³	683.2 m³
0+10	69.3 m²		
		172.6 m³	172.5 m³
0+05	17.0 m²		

Note:
Refer to Dwg. No. VI 7157-1-3 for plan information

No.	REVISION DESCRIPTION	DATE	BY

DESIGN
DRAWN A.H.
CHECKED
APPROVED
DATE
FIELD BOOK No. Non Dams Rehab

SEAL

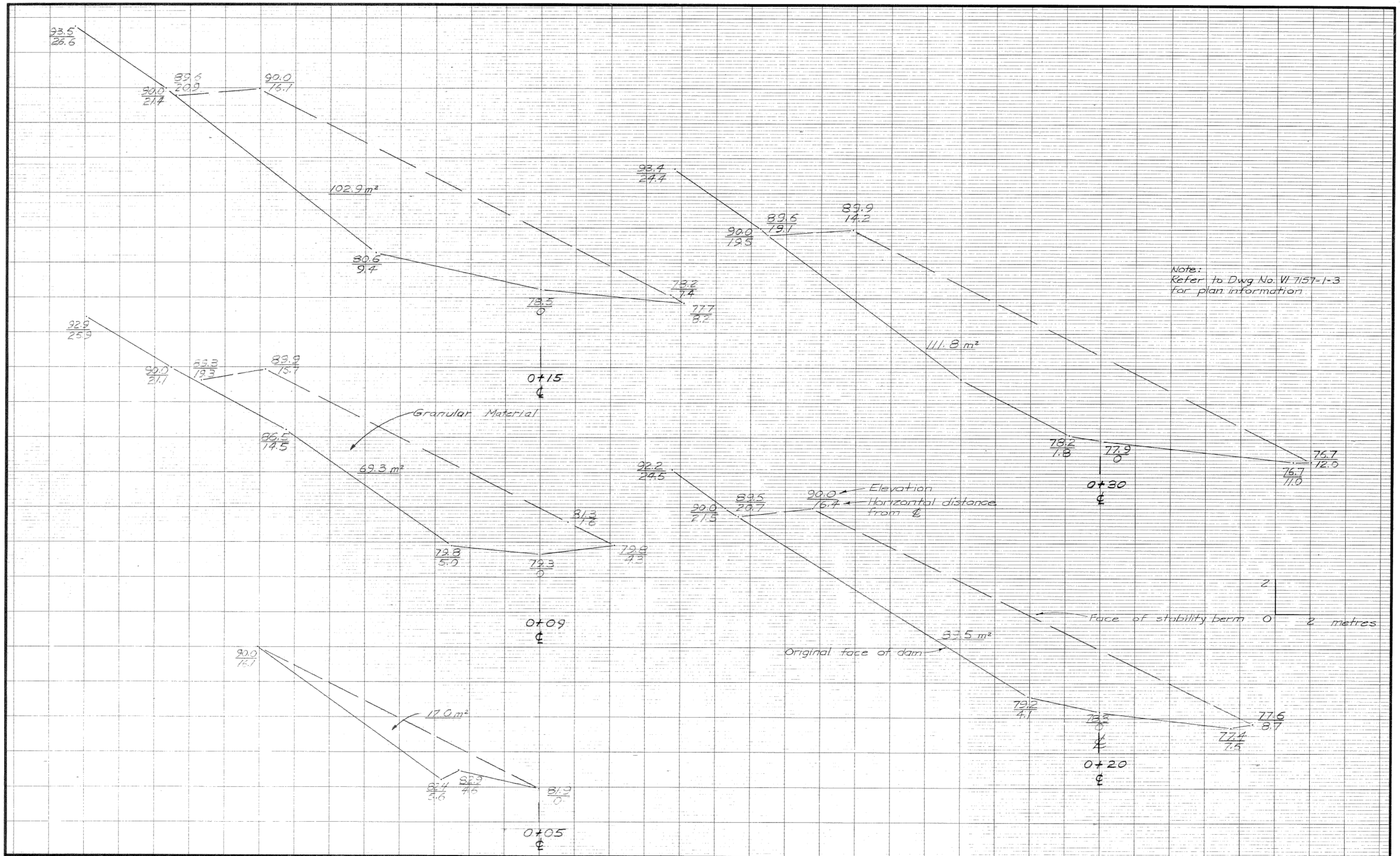
WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
LOWER HAREWOOD DAM
X-SECTIONS OF STABILITY BERM

SHEET No. 7 OF 8
REV.
DRAWING No. VI 7157-1-7

3711-9-80

№ 3711



No.	REVISION DESCRIPTION	DATE	BY

DESIGN
DRAWN A.H.
CHECKED
APPROVED
DATE
FIELD BOOK No. Non Dams Rehab.

SEAL

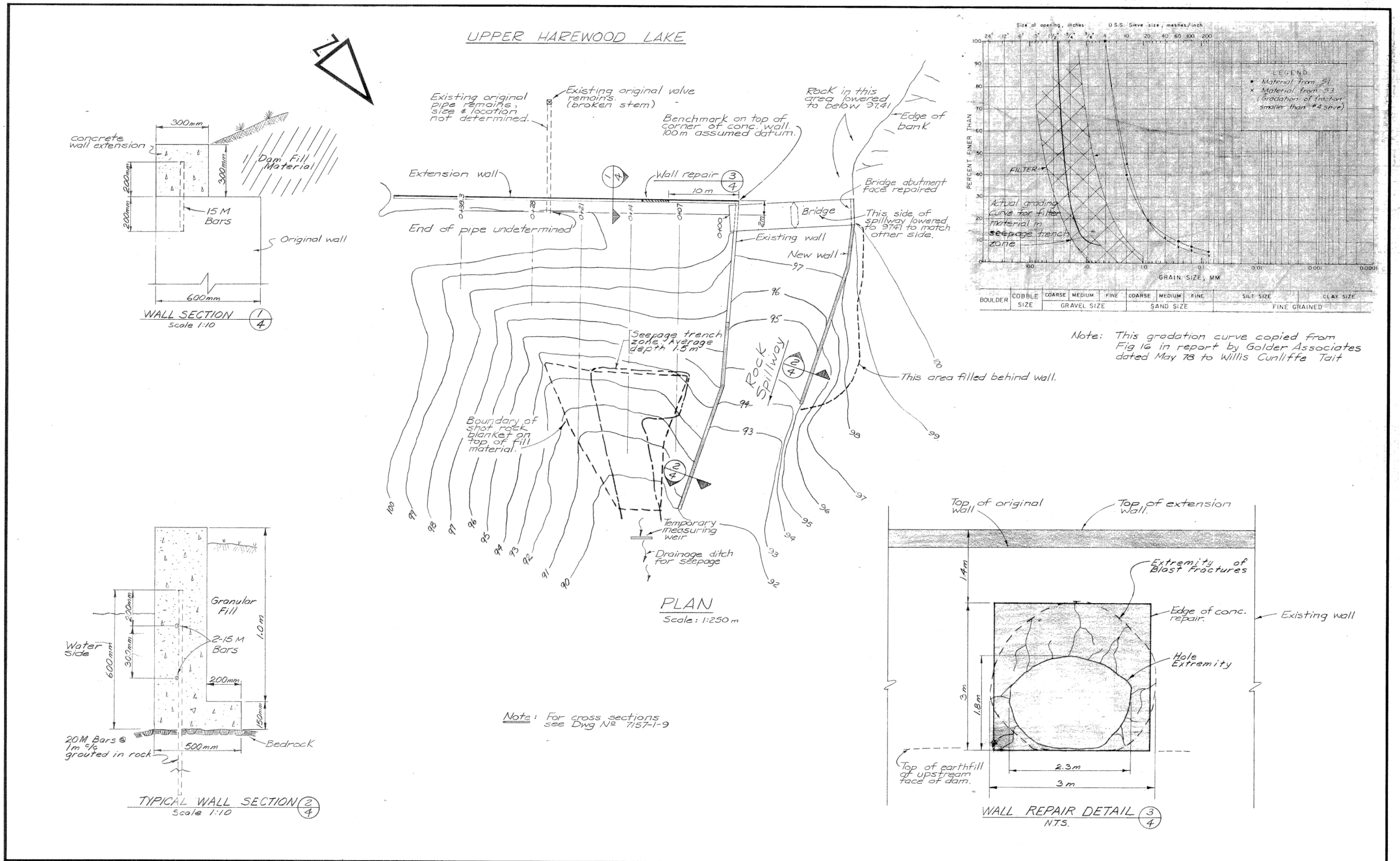
WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION
LOWER HAREWOOD DAM
X-SECTIONS OF STABILITY BERM

SHEET No. 8
OF 8
REV.
DRAWING No. VI 7157-1-8

3712-9-80

№ 3713



No.	REVISION DESCRIPTION	DATE	BY
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DESIGN: DWA
DRAWN: CEB & AH
CHECKED:
APPROVED:
DATE: Sept. 19/80
FIELD BOOK No. Misc. 31, Nan Dams

SEAL

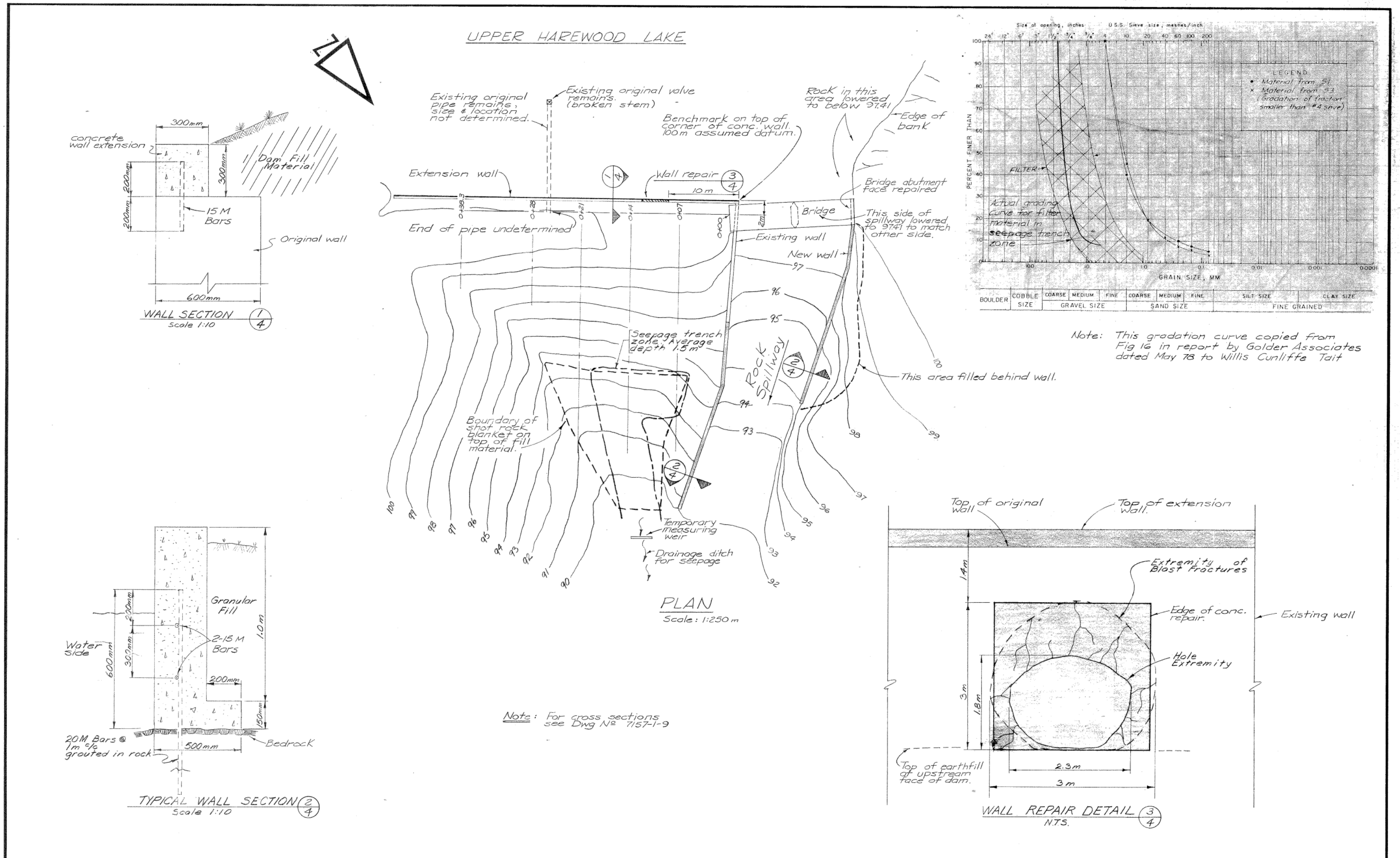
WILLIS CUNLIFFE TAIT
& Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
UPPER HAREWOOD DAM

SHEET No. 4 OF 8 REV. 2
DRAWING No. VI 7157-1-4

3713-9-80

№ 3713



No.	REVISION DESCRIPTION	DATE	BY
2	As Constructed (Redrawn)	Oct 80	CEB

DESIGN: DWA
DRAWN: CEB & AH
CHECKED:
APPROVED:
DATE: Sept. 19/80
FIELD BOOK No. Misc. 31, Nan Dams

SEAL

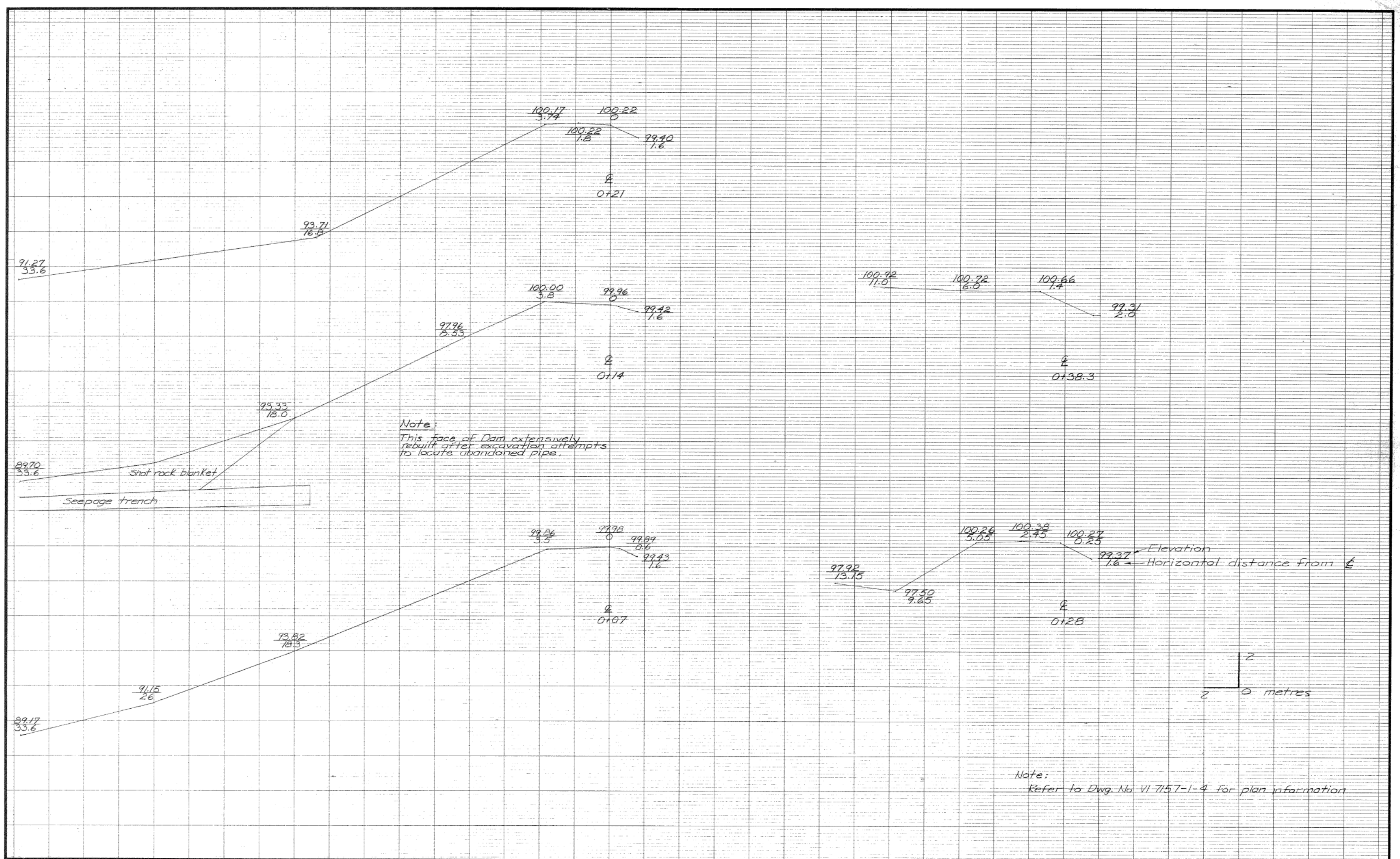
WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO
DAM REHABILITATION PROGRAM
UPPER HAREWOOD DAM

SHEET No. 4 OF 8 REV. 2
DRAWING No. VI 7157-1-4

3713-9-80

No 3714



No.	REVISION DESCRIPTION	DATE	BY

DESIGN
DRAWN CEB
CHECKED
APPROVED
DATE Sept 22, 80
FIELD BOOK No. Non Dams Rehab

SEAL

WILLIS CUNLIFFE TAIT & Company Ltd.

CITY OF NANAIMO

DAM REHABILITATION PROGRAM

UPPER HAREWOOD DAM X-SECTIONS OF RECONSTRUCTED DAM SURFACE

SHEET No. 9 OF 8 REV.

DRAWING No. VI 7157-1-9

3714-9-80

APPENDIX B

Appendix B-Geophysical Investigations

Annex A Surface Investigation of Lower and Middle Dam

TECHNICAL MEMORANDUM

DATE April 30, 2014 **REFERENCE No.** 1314470516-003-TM-Rev1-7000

TO Anne Crowley
Golder Associates Ltd.

CC Jenna Girdner; Bruce Downing; Herb Hawson; Max Maxwell

FROM Robert Luzitano **EMAIL** rluzitano@golder.com

SUMMARY OF SURFACE GEOPHYSICS AT COLLIERY DAMS, NANAIMO, BC

This technical memo provides results from surface geophysical surveys that were carried out at the Lower and Middle Colliery Dams in Nanaimo, BC during middle January 2014. Note that results from a subsequent corehole geophysical investigation carried out at the Lower Dam are reported in a separate technical memo.

1.0 OBJECTIVES

Objectives of the geophysical investigations were directed at gaining some basic information regarding the construction and underlying geometries of the dams and some of the current properties of the materials. Resulting information is to be used in support of a geotechnical assessment of the dams by various engineers. These objectives and corresponding geophysical surveys included:

- Profiling internal layering of Lower and Middle Dams using moderate frequency ground penetrating radar (GPR at 200 MHz, possibly limited to 3-5 m depth);
- Potentially identifying "water table," and other possible variations in water saturation, within Lower and Middle Dams (if conditions allow) from the GPR profiles;
- Potentially profiling underlying bedrock or till interface at both dams, but most importantly beneath the Lower Dam. A second, low frequency/high-powered, GPR system would be used on both dams (where bedrock is shallow), and the deeper-sensing/lower-resolution seismic refraction method would be used only on the Lower Dam;
- Lower Dam—Confirm existence/location of buried concrete core-wall suspected to continue towards the spillway using GPR;
- Lower Dam—Within "The Peninsula," obtain information regarding the upper few metres of fill material, such as the possible existence of rock-fill versus sand-and-gravel fill and its general layering and possibly the existence of shallow bedrock using GPR;
- Lower Dam—Potentially obtain a general (1-D) seismic shear-wave velocity (Vs) versus depth profile of the dam fill using the lowest cost method (MASW—Multi-channel Analysis of Surface Waves) for this initial investigation; should MASW not work, higher-cost downhole seismic could be carried out after proposed boreholes are drilled. MASW would require minimal effort by recording some additional data during the seismic refraction survey without additional set-up;

- Middle Dam—Attempt locating the Low-Level-Outlet (LLO), at least near the toe of down-stream slope, using GPR; and
- Characterizing amount of reinforcement within the concrete core-wall (e.g. existence of rebar and its general spacing and extent) as discernable from the top of the wall along the crest of both dams using higher frequency (400 MHz) GPR.

Note that higher frequency radar signals yield higher resolution, whereas lower frequency yields the possibility of greater depth of penetration. Additionally, where bedrock occurs within the depth-range of radar, GPR would provide a higher resolution profile compared to seismic refraction. Basic principles of the geophysical methods used are discussed in the methodology section below.

These geophysical investigations are part of a more comprehensive geotechnical investigation, and cannot be viewed in isolation from that context.

2.0 SCOPE OF WORK

The scope of work reported here was limited to the surface geophysical investigation which used GPR at both dams and seismic refraction/MASW at the Lower Dam. The various GPR surveys targeted features of different scales and depths requiring the use of two different GPR systems and three different antenna frequencies. Additionally, the GPR surveys reported here were for a larger/deeper scale than that previously carried out on the Lower Dam wall face (for rebar) by Klohn Crippen Berger; in the investigation reported here, GPR surveys were primarily to investigate internal layering and other possible variations within the dams.

The surface geophysical investigation was limited to a total of three days of fieldwork split between the Lower and Middle Dams as follows:

- Lower Dam (2 field days) –
  - GPR (1 field-day) – for internal layering (200 MHz) and possibly the basal interface (high-power 50 MHz, penetration permitting) –
    - 1 - 2 profiles (200 MHz) up the downstream face and possibly some cross-line profiles (cross-line locations determined, in part, by radar features observed on the main profile up the face);
    - 1 GPR profile (50 MHz) up the downstream face to attempt profiling the basal interface;
    - At least 1 GPR profile along top of concrete wall to assess rebar extent as allowed by radar penetration and resolution using one or both of 200 MHz and 400 MHz antennas (depending on access);
    - One or more cross-line profiles on the crest near the spillway to possibly confirm position of buried concrete core-wall and to obtain information regarding peninsula fill material; and,
    - Seismic Refraction/MASW (1 field-day, 2 seismic spreads) – Depending on site access/conditions: one spread down the down-stream face near the middle of the dam; and one spread approximately parallel to the crest positioned at least 15 m away from the concrete wall. Survey to use a 24-channel seismic system with 4.5 Hz geophones spaced 1-2 m along approximately linear spreads. Seismic sources to include: sledge-hammer, passive ambient noise recordings, and possibly an 8-gauge seismic source.

- Middle Dam (1 field day) –
  - **GPR only –** for internal layering (200 MHz) and possibly the basal interface (high-power 50 MHz, penetration permitting) –
    - 1 - 2 profiles (200 MHz) up the downstream face and possibly some cross-line profiles (cross-line locations determined, in part, by radar features observed on the main profile up the face);
    - 1 GPR profile (50 MHz) up the downstream face to attempt profiling the basal interface; and
    - At least 1 profile along top of concrete wall to assess rebar extent as allowed by radar penetration and resolution using one or both of 200 MHz and 400 MHz antennas (depending on access).

3.0 METHODOLOGY

The methods used in this geophysical investigation provided a relatively quick and cost-effective, non-invasive means to achieve the objectives. Preliminary geophysical results were used to assist development and planning of subsequent geotechnical investigations. Basic principles of the geophysical methods of this investigation are discussed in the following sections.

3.1 Ground Penetrating Radar (GPR)

Ground penetrating radar (GPR) operates on the principle that electromagnetic waves (radio pulses), emitted into the ground by a transmitter (Tx) antenna, are partially reflected at subsurface interfaces and can be detected by a receiver (Rx) antenna as illustrated in Figure B-1a. Reflections arise due to contrasts in the dielectric constant of subsurface materials, due primarily to variations in soil moisture content. In particular, there is a strong reflectivity contrast between porous, partially saturated soils and relatively impervious bedrock or most utilities and buried metal such as rebar. Radar range or maximum penetration is controlled by the electrical conductivity of subsurface materials; as conductivity increases, intrinsic attenuation increases, reducing the effective radar sounding range. Conductivity is typically enhanced with increasing moisture content, depending on the concentration of dissolved salts and the fraction of clay minerals present.

The radar systems used here incorporate precise timing electronics to measure the reflection transit-time, from transmitter to receiver, which depends on reflector range and radar signal velocity. A radar profile is acquired by moving the antennas along the ground surface as the radar system records a series of scans at regular intervals. Resulting data are displayed as a series of oscilloscope-like traces having amplitude proportional to reflection strength as illustrated in Figure B-1b. Given an estimate of radar velocity, which can be measured from GPR profiles, corresponding reflector depths may be determined.

GPR data were further processed and interpreted in the office using the ReflexW software by Sandmeier Software in order to determine radar signal velocities and corresponding depth estimates (discussed further in results section below).

3.2 The Seismic Refraction Method

In the seismic refraction method an elastic wave pulse is generated at shallow depth and propagates radially into the subsurface. On encountering boundaries between media having contrasting mechanical properties, including density, elasticity and consequently seismic velocity, the incident wave pulse is partially reflected and partially transmitted into underlying strata (Figure B-2). The so-called ray-path of the incident-transmitted pulse is bent or refracted at the boundary in accordance with Snell's law. In particular, if seismic velocity increases across the boundary, the ray-path is refracted toward the boundary. As the angle of incidence increases, so does the angle of refraction until for some critical incidence angle $i_c = \sin^{-1}(v_n / v_{n+1})$, depending on the relative seismic velocity v_n / v_{n+1}, the refracted wave pulse travels along the boundary and acts as moving source of a secondary wave front which propagates upward into overlying strata. This so-called head wave ultimately reaches the surface where the arrival is detected by a linear array of motion sensitive detectors known as geophones. Since the critically refracted raypath is also the fastest path, this signal is the first to arrive at the geophones. By measuring the elapsed time between initial pulse generation at the shot-point and subsequent arrival of related waves at successively more distant geophones, relatively straight forward graphical analysis and associated calculations yield estimates of layer velocities and thicknesses. More refined interpretations are obtained via elaborate computer-based techniques.

3.2.1 Limitations of Seismic Refraction

As with any geophysical method, seismic profiling involves indirect measurements of subsurface conditions and is subject to the limitations of the particular method. Standard limitation on depth determinations from seismic refraction profiling is accuracy to within approximately 10% of the actual value, subject to the assumptions of the seismic refraction method including:

- Layered subsurface;
- Generally, layer slope variations less than 20 degrees (not ground surface slope);
- Increasing velocity with depth;
- Relatively gradual changes in layer topography;
- Shallowest interface generally deeper than half the geophone spacing; and
- 3-D effects not significant (no large variation in lithology perpendicular to line).

3.3 MASW (Multi-channel Analysis of Surface Waves)

This method was employed for a relatively small effort added to the seismic refraction survey to possibly obtain a general shear-wave velocity (Vs) versus depth profile for the least expense. We note that MASW shotpoints were positioned to minimize adverse interference from the concrete core-wall. However, MASW is intended for sites of simple structure with limited lateral variations, conditions that are largely violated at the Lower Dam site. Due to the relatively complex structure at the site, MASW was not successful and therefore, this method is not discussed further. Subsequently, a Vs-depth curve has been obtained for the upper 9 m of dam fill from a downhole seismic survey in borehole SH14-05 and is reported separately.

4.0 FIELD WORK

The surface geophysical investigation was conducted during January 15-17, 2014 by two geophysicists from Golder's office in Burnaby, BC. Positions of the geophysical profiles are shown on the site plans of the Lower Dam and Middle Dam in Figures B-3 and B-4, respectively. Endpoints of the survey lines were marked in the field by wooden stakes or pinflags, marking paint, and survey flagging for subsequent location. Approximate topographic variation was measured using a hand-held inclinometer along the seismic lines (Figure B-3) and along L-1 on the Middle Dam (Figure B-4).

GPR profiling used two different radar systems: a moderate frequency system (SIR-2 by GSSI) using 200 MHz and 400 MHz antennas; and a low frequency (50 MHz), high-powered (1000 V Tx), system (pulseEKKO-100 by SSI) to maximize the depth of penetration. The SIR-2 with the 200 MHz antenna was used to focus on the internal features of the dam fill, and the 400 MHz antenna was used on the concrete core-walls. Additionally, the high-powered system was run in step mode where the antennas were held stationary while 256 soundings were stacked into a single trace to further enhance the signal against noise, whereas the moderate frequency system was run in continuous mode to maintain high lateral resolution.

Seismic refraction profiling used a 24-channel seismic system (Geode by Geometrics) with twenty-four 4.5 Hz geophones spaced 2 m along the recording spread. A percussion source (12-lb sledge hammer striking a metal base plate) provided sufficient energy with stacking of 6 to 18 successive hits at a given shotpoint. On each of the two lines, a total of 8 or 9 shotpoint locations were recorded, including 5 shotpoints within the geophone spread and 1 to 3 off-end shotpoints positioned up to 40 m off either end of the spread (Figure B-3).

4.1 Lower Dam: Site Conditions and Coverage

The downstream face of the Lower Dam (sloping approximately 27°-36°) includes a toe-berm covering approximately the lower half of the slope; the top of this berm makes a "bench" across the width of the dam face (see Photograph B-1 below). The toe-berm was understood to consist of sand-and-gravel fill which was added in 1980 and was grass covered during the survey. The upper slope was understood to generally consist of slag and cinder fill and was covered by vines (approximately 0.5 m deep) during the survey. These vines prevented the GPR antenna from making direct contact with the ground surface, consequently, somewhat degrading the radar signal penetration into the ground.

Photograph B-1: Lower Dam—looking down geophysical line L-1 from the dam crest. The red box staged on the berm bench is the 200 MHz GPR antenna.

Survey coverage on the Lower Dam (Figure B-3) totalled 10 GPR profiles (including one repeated at low frequency) and 2 seismic profiles consisting of:

- Two 200 MHz GPR profiles down the dam face—**L-1** and **L-2**;
- One 200 MHz GPR cross-profile on the face, along the top of the toe-berm—**L-3** (Photograph B-2);
- One 50 MHz GPR profile down the toe-berm section of **L-1**, starting from the toe of the upper slag slope (Photograph B-3);
- Two seismic refraction profiles on the dam face—**L-1** and **L-3**;
- Seven GPR profiles on the dam crest (all at 200 MHz, except for **L-9** at 400 MHz) consisting of:
  - Extension of **L-1** across the crest;
  - **L-4** along the top of the face;
  - Eastern portion of **L-5** and **L-6** and all of **L-7** acquired primarily to confirm the buried concrete core-wall;
  - Western portion of **L-5** and **L-6** and all of **L-8** acquired to investigate “The Peninsula;” and
  - **L-9** acquired on the top of the exposed additional wall (Photograph B-4).

Profiles L-5 and L-6 are partitioned into east and west by the retaining wall that separates The Peninsula from the dam crest.

Photograph B-2: Lower Dam—looking north along geophysical line L-3.

Photograph B-3: Lower Dam—from the toe-berm bench, looking south with the high powered GPR electronics in the wheelbarrow and the 50 MHz antennas profiling on line L-1.

Photograph B-4: Lower Dam—from The Peninsula looking east, adjacent to the spillway (on the right). The red box on top of the retaining wall is the 400 MHz GPR antenna at the south end of line L-9.

4.2 Middle Dam: Site Conditions and Coverage

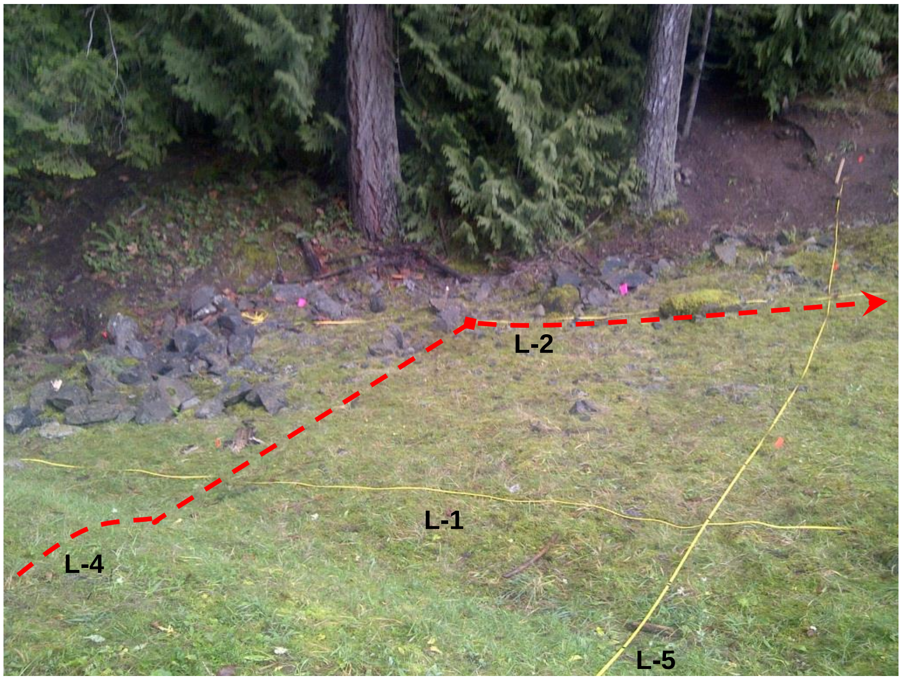
The downstream face of the Middle Dam slopes from approximately 12° at the toe to approximately 25° near the crest. Bedrock outcrop occurs around the toe of the dam and spans the floor of the spillway. The dam face is entirely covered with grass, but with rock fill exposed within approximately the lower half of the slope (Photographs B-5 and B-6).

Survey coverage on the Middle Dam (Figure B-4) totalled 9 GPR profiles (including one repeated at low frequency), including 5 on the dam slope and 3 on the crest. The 9 profiles consisted of:

- Two 200 MHz GPR profiles down the dam face—**L-1** and **L-2** (bedrock outcrop within the bottom 3 m of the 40 m long L-1, see Photographs B-5 and B-6);
- Three 200 MHz GPR cross-profiles within the lower 17 m of the dam face targeting the Lower-Level-Outlet—**L-3**, **L-4**, and **L-5** (Photograph B-7);
- One 50 MHz GPR profile on the dam face—**L-1** (Photograph B-8);
- Two 200 MHz GPR profiles along the dam crest—**L-6** and **L-7**; and
- One 400 MHz GPR profile acquired on the top of the concrete core-wall—**L-8**.

Photograph B-5: Middle Dam—from the crest, looking down the face between lines L-1 and L-2 marked by measuring-tapes. Bedrock outcrop occurs within the red circled area and spans the floor of the spillway.

Photograph B-6: Middle Dam—looking up from concrete weir. Lines L-1 and L-2 are marked by the measuring-tapes. Bedrock outcrop occurs within the red circled area and spans the floor of the spillway. The red box on L-2 is the 200 MHz GPR antenna.



Photograph B-7: Middle Dam—from the spillway on Cross-line L-5 with cross-line L-4 and main-lines L-1 and L-2 marked.

Photograph B-8: Middle Dam—High-powered 50 MHz antennas on line L-1. Bedrock outcrop occurs within the red circled area and spans the floor of the spillway.

5.0 RESULTS AND INTERPRETATION

The following discussion of results is organized by the different areas surveyed and the objective (such as the Lower Dam face and bedrock profiles). Areas of the Lower Dam are presented first, followed by areas of the Middle Dam. However, first some general discussion regarding the data and processing will be provided.

5.1 GPR: General Results and Processing

At both dam sites, GPR data quality was generally good to excellent with depth of penetration ranging between approximately 2 – 4 m through the fill materials for both the 200 MHz and the high-powered 50 MHz antennas. At the Lower Dam, the slag interface mostly blocked the radar signal of both frequencies from penetrating deeper. At the Middle Dam, the 50 MHz antennas provided approximately the same penetration to bedrock as the 200 MHz antennas; both profiling bedrock to approximately 3.5 m depth and to approximately 24 m up the slope from the toe of the dam. On the concrete core-walls of both dams, depth of penetration of the 400 MHz signal ranged between approximately 1 – 3 m from the top of the walls.

GPR data were processed using the Reflex-W reflection processing software by Sandmeier Software. Data processing included:

- **Dewow Filter** (using filter lengths of--17 ns for 50 MHz, 7 ns for 200 MHz, and 3 ns for 400 MHz);
- **Background Removal Filter**;
- **Velocity Analysis** from diffraction hyperbola fitting and trial FK-migrations. Resulting average velocity was used for producing a general depth scale for the radar profiles which are recorded in time (the average velocity is noted on the depth scale);
- **FK-migration** to clarify the image by collapsing diffraction hyperbola and repositioning scattered signal into more correct spatial positions, for a given single average velocity; and
- **Gain** (Energy Decay gain).

Figures of example profiles with interpretations annotated are provided in the discussions below.

5.2 Seismic Refraction: General Results and Processing

The seismic refraction survey on the Lower Dam resulted in mostly clear signal from the underlying bedrock. Seismic processing and modeling was performed using the SeisImager software package by Geometrics.

The interpretation and modeling procedure reported here involved:

1) Picking arrival times of identified first arrivals;
2) Incorporating topography into model; and
3) Seismic modeling using a combination of time-term and tomographic inversion algorithms.

Resulting seismic profiles are discussed below.

5.3 Lower Dam (Slope): Fill Structure from GPR

While some layering within the individual fill materials is faintly visible in the GPR images, this layering does not exhibit the regular planar character typical of construction lifts.

The slag/cinder fill was mostly opaque to the radar signals at both 200 MHz and 50 MHz with maximum penetration of approximately 1 m into the slag. On the vine-covered upper slope, penetration was more limited on L-1 due to a thicker “vine layer” that caused poor antenna coupling with the ground, whereas thinner vines on L-2 allowed for better antenna coupling and up to 1 m penetration. However, within the 1 m penetration depth, no significant features are apparent in the resulting upper slope L-2 profile (figure not included). On the sand-and-gravel toe-berm, the signal penetrated up to approximately 4 m through the berm material and slightly into the underlying slag/cinder fill. The slag fill interface produced a large amplitude reflection at 3 m to 0.5 m depth from 20 m to 30 m distance (upper slope) along Line 1 as apparent in Figure B-5. Further down slope the reflection abruptly becomes weak. This abrupt drop in amplitude could be due to a change in material, including a mix of slag with other fill type or a lack of slag entirely. This amplitude difference could also be enhanced by seepage of rain water along the slag interface from the toe of the upper slope.

Below the sand-and-gravel berm layer, the subsurface reflection radar signal quickly fades to noise from energy scattered through the air from trees and above-ground infrastructure.

Within the sand-and-gravel berm layer, some faint layering can be observed, of which two examples are marked with yellow dashed lines in Figure B-5; however, as noted above, none of the layering appears to be due to construction lifts. Additionally, a number of discrete objects or heterogeneities are observed by their isolated higher amplitude and by their diffraction hyperbolas (in the upper plot of the non-migrated image in Figure B-5); some examples are marked by red crosses. These heterogeneities could include coarser grained deposits, including cobbles, and/or variations in compaction and corresponding moisture retention.

Similar to the profile of L-1, the interpreted profile of L-3 is displayed in Figure B-6 where the interpreted slag fill interface appears to vary in depth between approximately 1.5 to 3 m below the berm crest.

5.4 Lower Dam (Slope): Bedrock Profiles from Seismic Refraction

Resulting seismic refraction profile models for L-1 and L-3 are presented in Figures B-7 and B-8, respectively. The seismic models fit the data well, as illustrated in the travel-time plots (Figures B-9 and B-10) that compare actual and modelled travel-times. The bedrock profile of L-1 is also in reasonable agreement with borehole SH14-06, as shown in Figure B-7.

Comparing the two profiles, the model of L-1 exhibits an extra—third—layer along the base of the overburden (p-wave velocity of 1050 m/s). This extra layer is interpreted to be due to the difference in the sampling of overburden structure by the refracted seismic p-waves along the two different lines; along L-3 (which is perpendicular to the canyon) this layer is probably less extensive and, therefore, undetected. The other two overburden layers have similar velocities between the two profiles and are considered to be essentially the same layers between the profiles. Note, however, that the overburden “seismic layering” is due to differences in stiffness of material which can be due more to compaction, and/or water saturation, than actual changes in fill type.

Bedrock was clearly modeled on both profiles with similar velocities that are indicative of bedrock: below L-1 3675 m/s and below L-3 3886 m/s (Figures B-7 and B-8). These modelled bedrock interfaces could include isolated occurrences of glacial till not resolved by the survey. At the intersection of L-1 and L-3, the somewhat shallower bedrock of L-3 could be due, at least in part, to out-of-profile refraction from the "bedrock hump" observed on L-1 immediately upslope of L-3 (a 3-D effect).

Figure B-11 provides a combined GPR/seismic-bedrock cross-section of L-1. This cross-section clearly illustrates that the slag fill interface interpreted from GPR is a continuation of the upper slope beneath the toe berm.

Note that since these profiles have not been legal-surveyed, elevations were estimated for some key locations from the topographic site plans of this report. Therefore, to distinguish that these elevations are not legal-surveyed elevations, we have added 1000 m to our estimated elevations as shown on the cross-sections of Figures B-7, B-8, and B-11.

5.5 Lower Dam (Crest): L-1 and L-4 GPR Profiles

GPR profiles on the dam crest of L-1 and L-4 (200 MHz) penetrated up to approximately 3 m into the fill material. Although some minor layering and occasional heterogeneities were observed in the field records, none of these features seemed of sufficient interest to warrant additional processing, plotting, and interpretation. The minor layering appears similar to that noted in the toe-berm fill for L-1—regular planar construction lifts are not apparent. Should interest arise in these two profiles, they could be processed and further interpreted in future.

One or more possible buried utilities are observed on L-1 and an obvious utility is observed near the south end of L-4 which also appears to occur on L-5, L-6, and L-7.

5.6 Lower Dam: Buried Core-wall

The 200 MHz GPR profiles of L-5, L-6, and L-7 suggest that the buried concrete core-wall does continue towards the spillway. Signal penetration was up to approximately 2.5 m depth with noticeably wet soil at surface. However, the images are somewhat obscured by interfering heterogeneities in the fill and by diffractions from the edge of the paved trail; the additional processing of migration does not make identification any clearer. Despite this interference, a feature that is consistent with the wall appears at the projected location on each of the profiles. The best image (L-7) is provided as an example in Figure B-12 where the depth to the wall is estimated at approximately 0.8 m.

5.7 Lower Dam: Peninsula

The 200 MHz GPR profiles of L-5, L-6, and L-8 suggest that bedrock may occur within the peninsula at approximately 2 to 3 m depth below grade; however, this interpretation should be confirmed with a testpit or augerhole. As shown in Figure B-13 of L-8, the complex of reflections marked with red dashed lines could all be reflected from an irregular bedrock surface where most of these would be scattered from out-of-profile. Most of these deeper reflections appear to exhibit noticeably larger amplitude and lower frequency compared to the overlying reflections; however, these characteristics could also be caused by a significant increase in water saturation from a diffuse "water-table." The "water-table" interpretation is deemed less likely since the lake water level was only about 1 m below the Peninsula ground surface.

As noted in Figure B-13, the interval between approximately 0.5 – 2 m depth exhibits characteristics suggesting mostly coarse grained fill, but including some layering and possibly isolated “lenses” of finer-grained fill. Above approximately 0.5 m depth, diffraction hyperbola (scattering) is less evident with laminar reflections more dominant, suggesting finer-grained and more layered fill and soil.

5.8 Lower Dam: Newer Core/Retaining Wall

The 400 MHz GPR profile recorded along the top of the core/retaining wall (L-9) is presented in Figure B-14. This wall is actually an additional raise on top of the original core-wall; however, this wall bends at the north end of The Peninsula (at approximately the 30 m position of L-9), apparently leaving the core-wall and forming a retaining wall along the back edge of The Peninsula (see photograph in Figure B-14). North-dipping layers are observed in the wall face, including layers of cobbles; similarly dipping reflections are also observed in the radar image (see photograph at bottom of Figure B-14 and radar reflections marked with yellow dashed lines between L-7 and L-6). Penetration of the radar signal varies between approximately 1 and 2 m below the top of the wall.

Rebar appears to be lacking within this wall, or at least it does not occur in the regular pattern typical of rebar. Typically, rebar produces small distinct diffraction hyperbola that are regularly spaced, often forming an undulating “layer” (for example, see Figure B-17 from the Middle Dam wall). While numerous small diffractions are observed in the L-9 profile, they suggest coarse-grained material rather than rebar.

There is at least one feature that exhibits ringing that is typical of metal (noted in Figure B-14—possibly a pipe or rod, larger than typical rebar). Also, there are a number of features that exhibit multiples that could arise from a water-filled pipe or void (one example noted).

As indicated in Figure B-14 with red line segments, a number of unknown planar structures (of nearly 0.5 m length) occur at irregular intervals and orientations. Occurrence of these structures appears to be limited to within approximately 0.5 m depth from the wall top and only north of the bend where the wall is over-top of the original core-wall.

South of the bend (to approximately the 47-m position), a complex of large amplitude reflections occurs between approximately 0.8 and 1.8 m depth (Figure B-14). This complex of reflections consists of a prominent, mostly continuous, reflection capping more discontinuous reflections and diffraction hyperbolas from scatterers. A possible interpretation is that the capping reflection could be from the bottom of the retaining wall and underlying reflections and diffractions are from coarse-grained fill.

5.9 Middle Dam (Slope): Bedrock and Fill Profiles

The bedrock surface was interpreted beneath the lower half of the slope from both 50 MHz and 200 MHz GPR profiles on L-1. Interpreted GPR profiles of both frequencies are shown in Figure B-15 which illustrates some minor differences in the bedrock profile due to differences in the scale of features reflecting the different frequencies of radar signal. The higher powered 50 MHz signal did not significantly extend the depth of coverage compared to the 200 MHz. A possible explanation may be that, beyond the 21-m position, the bedrock surface may become too steep to produce a sufficient reflection, regardless of frequency. In both profiles, the deepest interpreted bedrock is approximately 3.5 m depth below ground surface.

A number of example overburden layers were interpreted in the higher resolution 200 MHz image of L-1 in Figure B-15. Some of these interfaces are relatively planar, suggesting engineered lifts of fill; however, there appears to be different sections of fill where the interfaces dip in opposite directions (dipping downslope or upslope).

5.10 Middle Dam (Slope): LLO

The Low Level Outlook (LLO) could not be identified within the three GPR profiles (L-3, L-4, and L-5). Resulting radar images were too cluttered and distorted due to the significant variation of the ground surface and heterogeneities within the fill (including rock fill). Reflections from many of these heterogeneities are identical to the reflection expected from the LLO.

5.11 Middle Dam (Crest): GPR Profiles L-6 and L-7

Bedrock was interpreted at either end of both 200 MHz GPR profiles, L-6 and L-7, and other features observed in the two profiles are similar. Profile L-7 is shown in Figure B-16 since it passes through boreholes BH-3 through BH-5. Bedrock outcrops within a few metres of either end of L-7 and occurs within the southern two metres of L-6. Along L-7, the bedrock surface is interpreted to deepen steeply, possibly with a near vertical face approximately 2 m north of BH-4. The three boreholes were drilled to between 9.1 and 12.8 m without encountering bedrock. Within the 2.5 – 4 m depth range of the GPR profiles, the borehole logs indicate sand-and-gravel fill, including some cobbles and boulders, to at least 6 m depth where rock fill was encountered in BH-5 and BH-3.

GPR profiles L-6 and L-7 (Figure B-16) suggest possibly two different fill types separated by an interface that dips northward towards the spillway from within approximately 0.5 m of the ground surface near the 27 m position. North of this boundary, the radar image exhibits a number of large amplitude reflections interpreted as interfaces within the sand-and-gravel fill; south of the boundary, such reflections are much lower amplitude. Additionally, evidence suggests that the material north of the boundary generally has faster radar velocity. Collectively, the evidence suggests that the fill south of the boundary may be of finer grained material than the sand-and-gravel fill encountered in the boreholes to the north.

A number of the fill interfaces interpreted in Figure B-16 are relatively planar, suggesting engineered lifts of fill; however, similar to those noted for L-1 above, there appears to be different sections of fill where the interfaces dip in opposite directions, often suggesting wedge-shaped lifts.

5.12 Middle Dam: Concrete Core-wall

At least two levels of rebar are interpreted in the 400 MHz GPR profile that was acquired along the top of the concrete core-wall with radar penetration depth ranging between approximately 1.5 to 3 m. In Figure B-17 a number of the rebar signatures are marked with red crosses to provide an example of the rebar pattern; such signatures are observed across the length of the profile but are more difficult to pick within the southern third of the profile due to numerous large amplitude reflections that interfere with the rebar signatures. Typical horizontal spacing of the rebar is approximately 0.8 – 1 m with an occasional extra rebar in between. Spacing in the vertical direction (between the two “layers” identified within the upper metre) is estimated to range between approximately 0.2 to 0.6 m; this spacing may continue to greater depths but individual rebar signatures are difficult to identify, especially with the interference from reflections off of interfaces.

Identification of the interfaces marked in Figure B-17 requires coring. Internal concrete reflections can occur from changes in constituent material and/or separate pours. Some of these interfaces may contain elevated levels of moisture to produce the anomalously large amplitude reflections.

6.0 SUMMARY AND CONCLUSIONS

The surface geophysical surveys successfully provided additional information for all but two of the eight objectives: confirming the LLO beneath the toe of the Middle Dam, and obtaining a general Vs curve of the Lower Dam from MASW data piggy-backed on the seismic refraction survey. The LLO of the Middle Dam could not be identified in the GPR profiles due to the degree of clutter and distortion from the heterogeneous fill (including rock fill). Similarly, on the Lower Dam there was too much lateral variation to allow a reliable Vs (shear-wave velocity) profile to be modelled using MASW. However, subsequently, a Vs model has been obtained down to 9 m depth from a downhole seismic survey that is reported separately.

Generally, the radar signal penetrated most of the fill materials to between 2 – 4 m depth below grade, except for the slag/cinder fill at the Lower Dam that yielded a maximum penetration of approximately 1 m. The seismic refraction survey on the Lower Dam profiled the underlying inferred bedrock surface along both seismic profiles. Primary information for each area is highlighted below.

On the Lower Dam, highlights of the information gained from the surface geophysical investigation include:

1) **Fill layering and heterogeneities –** Most GPR profiles exhibit reflections from layering and heterogeneities within the fills; however, none of this apparent layering exhibits the regular planar character typical of construction lifts.

   In particular, the three GPR profiles on the face revealed some internal layering and heterogeneities within the sand-and-gravel toe-berm, and tracked the underlying slag-fill interface to approximately 4 m depth, possibly to within a few metres above the toe of the dam. GPR profiles suggest a possible material change of the slag-fill approximately 10 m down the slope from the toe-berm crest.

2) **Variations in water saturation –** GPR profiles on the face and crest suggest some variations in water saturation probably due to rain water seepage and retention of moisture along heterogeneities.

3) **Bedrock depth** – Along L-1, bedrock depth varies from approximately 2 m below the toe of the dam to approximately 14 m below the upper slope. Along L-3, bedrock depth varies from approximately 6 m near the north side to approximately 12 m near the south side.

4) **Buried original concrete core-wall** – The original concrete core-wall appears to continue towards the spillway at the same orientation as the exposed portion. Top of the buried core-wall is estimated to be at approximately 0.8 – 1 m depth below present ground surface.

5) **"The Peninsula" –** The three GPR profiles exhibit a distinct set of reflections and scattering between approximately 2 and 3 m depth that could be caused by an irregular bedrock surface. More details on interpreted fills are discussed above. This interpretation requires confirmation from a testpit or augerhole to at least 2 – 3 m depth.

6) **Within the additional/newer core-wall –** Rebar appears to be lacking, or at least it does not occur in the regular pattern typical of rebar. While numerous small diffractions are observed, they suggest coarse-grained material rather than rebar. At least 13 unknown planar structures were identified. More details on these and other features are discussed above.

On the Middle Dam, highlights of the information gained from the surface geophysical investigation include:

1) **Fill layering and heterogeneities –** Most of the GPR profiles exhibit clear reflections interpreted to be from layering and heterogeneities within the fills. A number of the interfaces appear to be relatively planar, suggesting engineered lifts of fill; however, there appears to be different sections of fill where the interfaces dip in opposite directions, often suggesting wedge-shaped lifts.

   Additionally, GPR profiles along the crest suggest that two distinct sections of fill may exist, possibly consisting of predominantly different grain sizes. The two sections appear to be separated by an interface that dips northward towards the spillway from within approximately 0.5 m of the ground surface at the 27 m position on L-7.

2) **Variations in water saturation –** GPR profiles on the slope and crest also suggest some variations in water saturation probably due to rain water seepage and retention of moisture along heterogeneities.

3) **Bedrock depth** – Along GPR profile L-1, bedrock outcrop was observed within approximately 3 m up-slope of the wall at the toe of the dam. Up-slope from the outcrop, bedrock was interpreted to approximately 3.5 m depth beneath approximately 24 m up-slope from the wall at the toe of the dam.

   Along the GPR profiles L-6 and L-7 on the dam crest, bedrock was interpreted to range between approximately 0.2 and 2.5 m depth at both the north and south ends of the profiles where outcrop occurs within approximately 3 m of the profile. The bedrock surface appears to deepen steeply, possibly with a near vertical face approximately 2 m north of BH-4.

4) **Low Level Outlet (LLO) –** The LLO could not be identified in the GPR profiles due to the degree of clutter and distortion from the heterogeneous fill (including rock fill).

5) **Core-wall** – Rebar appears to occur at a typical horizontal spacing between approximately 0.8 – 1.0 m, occasionally with an occasional extra rebar located in between. Spacing in the vertical direction is estimated to range between approximately 0.2 to 0.6 m; however, this is based on only the two shallowest "layers" of rebar observed.

   A number of interfaces within the concrete wall were identified, possibly from changes in constituent material and/or separate pours. Some of these interfaces may contain elevated levels of moisture as suggested by anomalously large amplitude reflections. Coring could provide confirmation of these interfaces if appropriate.

7.0 GEOPHYSICS LIMITATIONS

Standard of Care: Golder Associates Ltd. has conducted this investigation in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing in British Columbia, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied, is made.

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

Verification: It is recommended that subsurface conditions interpreted through geophysical survey techniques be verified by physical sampling and/or inspection, in order to confirm and calibrate the data interpretation. Once verification data is available through future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the interpretations, conclusions and recommendations of this report, and to provide amendments, as required.

While a number of probable utilities have been identified in this investigation using GPR, note that utilities have not been mapped exhaustively and that such mapping was beyond the scope of this investigation.

8.0 CLOSURE

This memorandum has been prepared based on the information obtained for the purposes outlined above. Should additional site investigation data become available, Golder Associates should be requested to review this report in light of this information, and provide revised and/or additional recommendations as appropriate.

We trust that this report meets your immediate requirements. Please contact the undersigned should you have any questions or concerns.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

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Senior Geophysicist

Michael (Max) Maxwell, Ph.D., P.Geo., RMC
Principal, Senior Geophysicist

RDL/MGM/sn

Attachments: Figure B-1: Ground Penetrating Radar
Figure B-2: Seismic Refraction Method
Figure B-3: Geophysics Surface Investigation Locations Lower Dam
Figure B-4: Geophysics Surface investigation Locations Middle Dam
Figure B-5: Lower Dam (Face): GPR 200 MHz – L-1 (Lower-Berm)
Figure B-6: Lower Dam (Face): GPR 200 MHz – L-3
Figure B-7: Lower Dam (Face): Seismic Refraction Profile: L-1
Figure B-8: Lower Dam (Face): Seismic Refraction Profile: L-3
Figure B-9: Lower Dam (Face)-L-1: Seismic Refraction TT-Curve/Model Fit
Figure B-10: Lower Dam (Face)-L-3: Seismic Refraction TT-Curve/Model Fit
Figure B-11: Lower Dam (Face)-L-1: Combined Seismic & GPR Interpretation
Figure B-12: Lower Dam (Buried Wall): Example GPR Interpretation L-7
Figure B-13: Lower Dam (Peninsula): Example GPR Interpretation L-8
Figure B-14: Lower Dam: GPR L-9 (400 MHz) on Concrete Wall
Figure B-15: Middle Dam (Slope): GPR L-1 (50 & 200 MHz)
Figure B-16: Middle Dam (Crest): GPR L-7 (200 MHz)
Figure B-17: Middle Dam (Core-wall): GPR L-8 (400 MHz)

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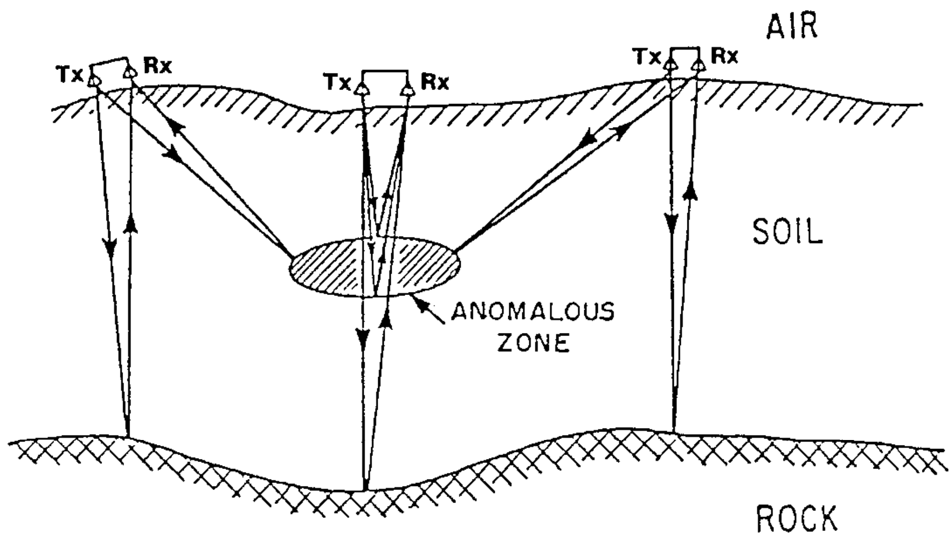


Figure a. Conceptual illustration of the radar being used in the reflection profiling mode on soil over bedrock.

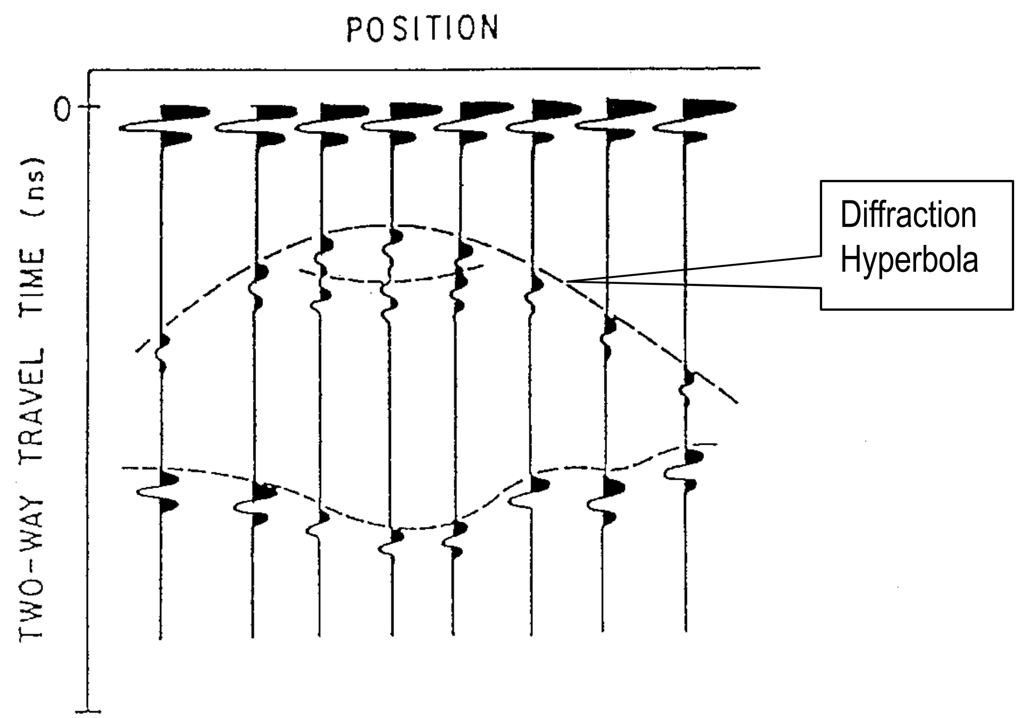
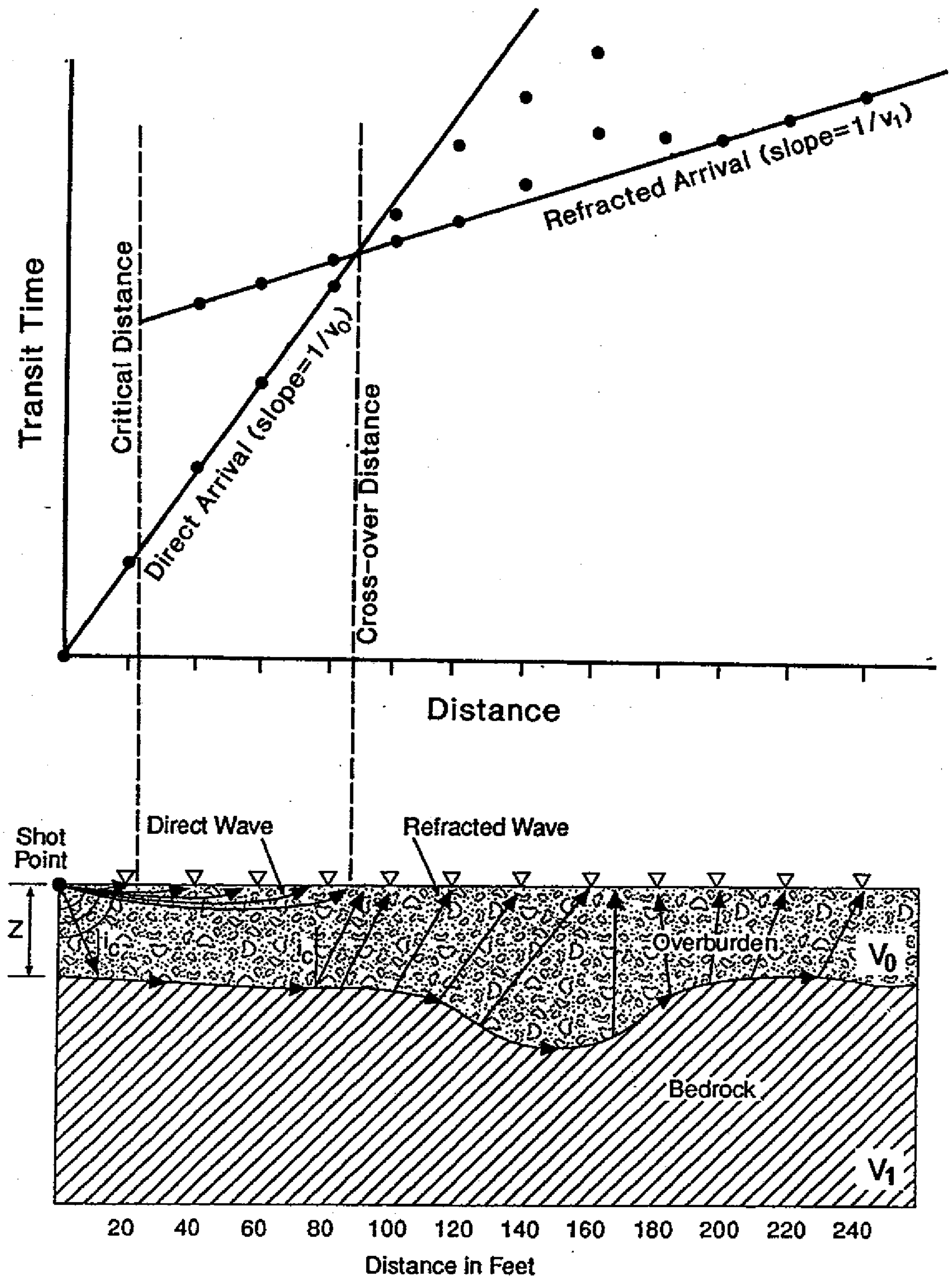


Figure b. Resulting radar record obtained over the idealized situation in Fig. **a.**

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.			
TITLE	**GROUND PENETRATING RADAR**			
Golder Associates	PROJECT No.	13-1447-0516		PHASE No. 7200
	DESIGN	GMC	AUG94	SCALE AS SHOWN REV.
	CADD	----	---	**FIGURE B-1**
	CHECK	RDL	4 APR14	
	REVIEW	MGM	15 APR14	

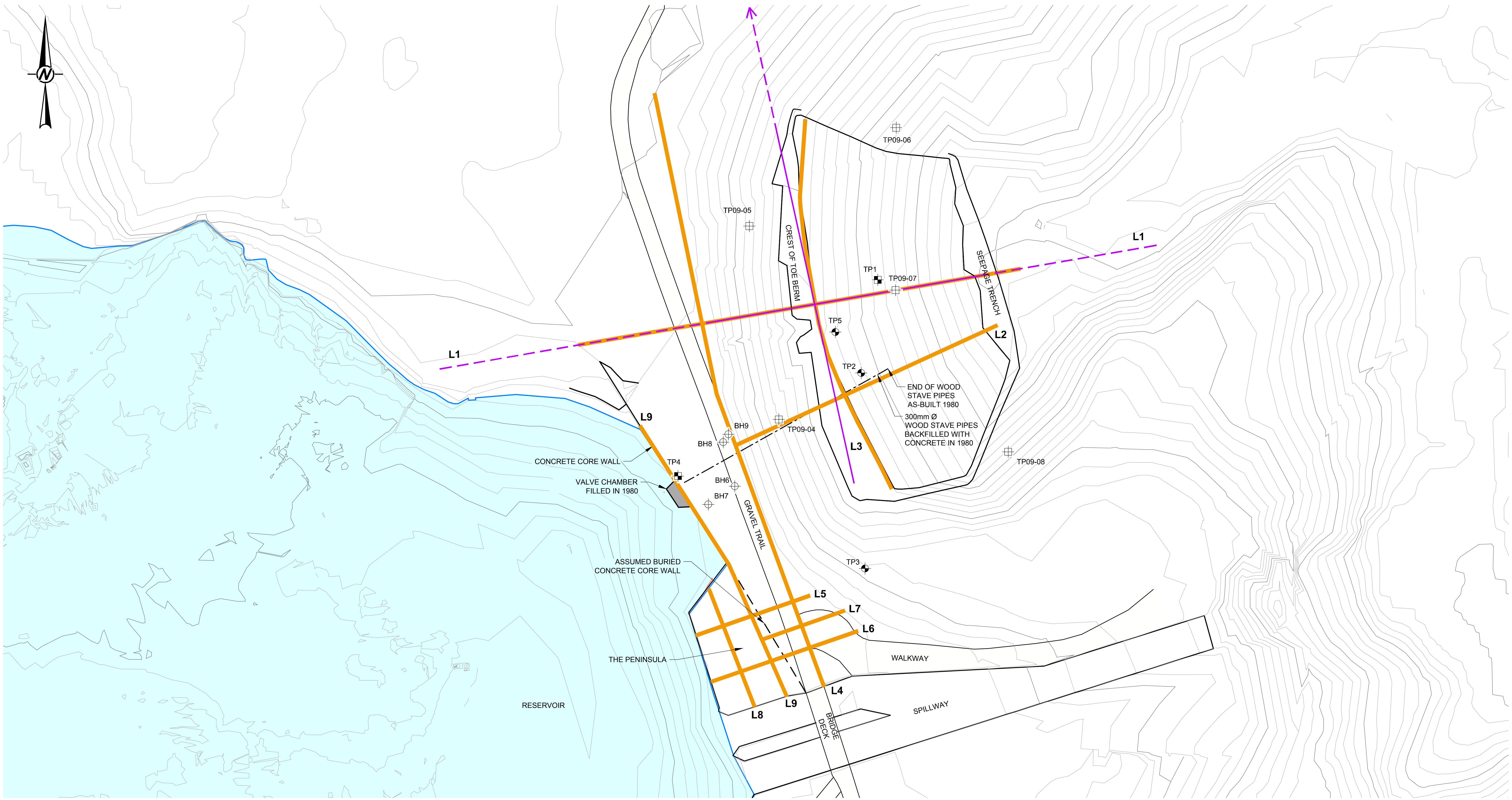
FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig01-02---GPR & SeisRefract.pptx



PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	**SEISMIC REFRACTION METHOD**

Golder Associates				
PROJECT No.	13-1447-0516		PHASE No. 7200	
DESIGN	GMC	AUG94	SCALE AS SHOWN	REV.
CADD	----	---	**FIGURE B-2**	
CHECK	RDL	4 APR14		
REVIEW	MGM	15 APR14		

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig01-02---GPR & SeisRefract.pptx



LEGEND

- GPR LINES
- SEISMIC LINE (DASHED TO OFF-END SHOT POINTS)
- NORMAL OPERATING LEVEL OF RESERVOIR
- 1978 BOREHOLE (GOLDER)
- 1978 TEST PIT PUT DOWN BY HAND (GOLDER)
- 1978 TEST PIT PUT DOWN BY EXCAVATION (GOLDER)
- 2009 TEST PIT (EBA)

NOTE

1. POSITIONS OF GEOPHYSICAL LINES ARE APPROXIMATE AND HAVE NOT BEEN LOCATION-SURVEYED AT THIS TIME. (LINES ARE MARKED ON THE GROUND BY WOOD STAKES, PIN FLAGS, AND PAINT FOR SUBSEQUENT LOCATION).

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
3. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, N 13101249, APRIL 14, 2014. (EBA 2010)

0 12 24 36

SCALE

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-30	ISSUED WITH FACTUAL REPORT	R.L.	M.R.	R.L.	M.M.

PROJECT

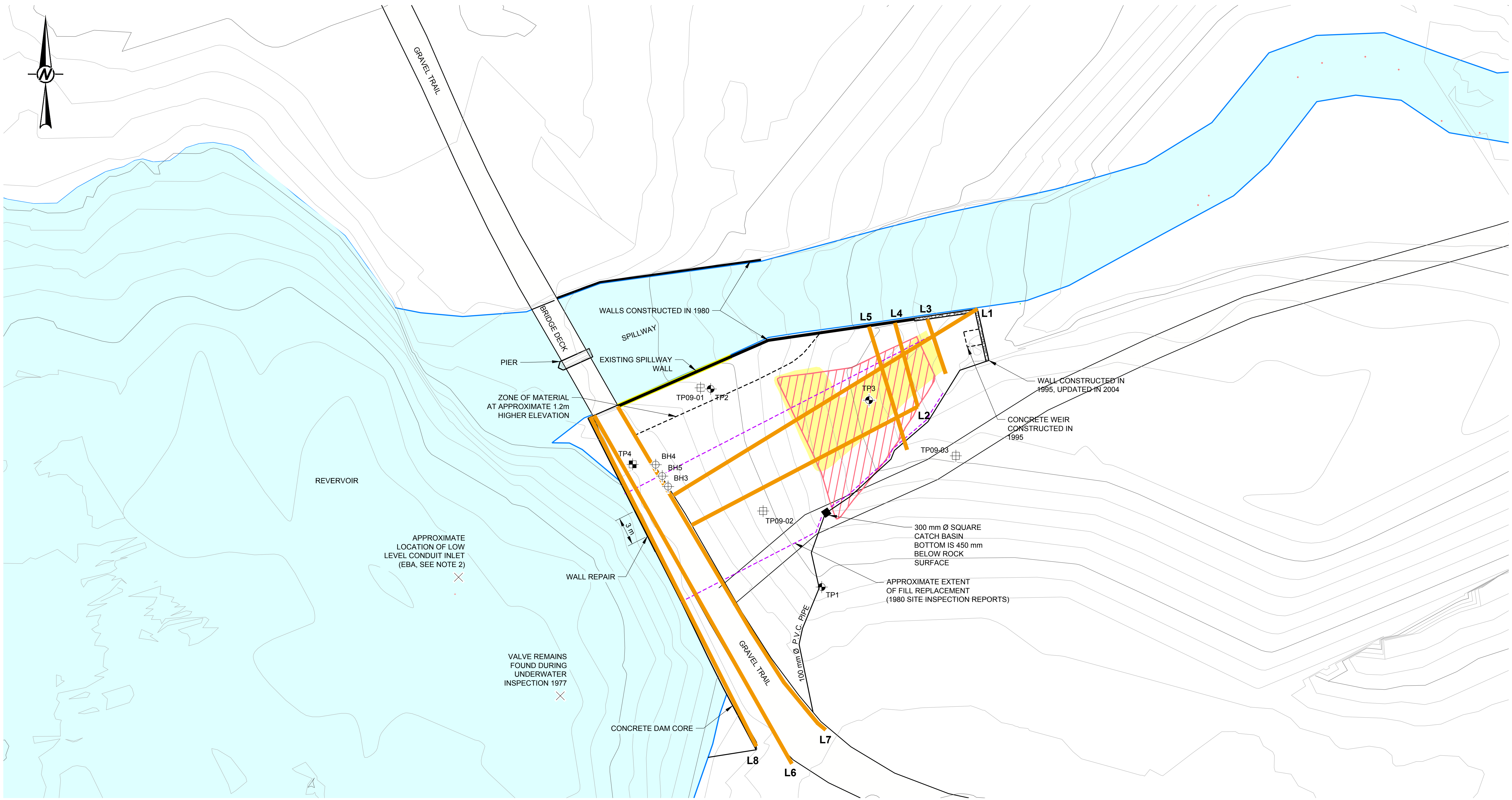
CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

GEOPHYSICS SURFACE INVESTIGATION LOCATIONS LOWER DAM

Golder Associates

PROJECT No.	13-1447-0516/7100	FILE No.	1314470516_2200-01
DESIGN	R.L. 2014-04-09	SCALE	AS SHOWN
CADD	M.R. 2014-04-10	FIGURE	B-3
CHECK	R.L. 2014-04-30		
REVIEW	M.M. 2014-04-30		



M:\Active\Year 2013\1447\13-1447-0516 (Chase Dams - City Of Nanaimo)\DRAFTING\2200\PRODUCTION\Geophysics\1314470516_2200-02.dwg | Layout: Layout1-ANSI_B_FIGURE_LANDSCAPE | Modified: mattrobertson 04/10/2014 3:36 PM | Plotted: mattrobertson 04/30/2014

LEGEND

- GPR LINES
- BOUNDARY OF SHOT ROCK BUTTRESS (AS-BUILT 1980)
- DRAINAGE BLANKET ZONE (AVERAGE DEPTH 1.5m), AS-BUILT 1980
- NORMAL OPERATING LEVEL OF RESERVOIR
- 1978 BOREHOLE (GOLDER)
- 1978 TEST PIT PUT DOWN BY HAND (GOLDER)
- 1978 TEST PIT PUT DOWN BY EXCAVATION (GOLDER)
- 2009 TEST PIT (EBA)

NOTE

1. POSITIONS OF GEOPHYSICAL LINES ARE APPROXIMATE AND HAVE NOT BEEN LOCATION-SURVEYED AT THIS TIME. (LINES ARE MARKED ON THE GROUND BY WOOD STAKES, PIN FLAGS, AND PAINT FOR SUBSEQUENT LOCATIONS)

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
3. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, N 13101249, APRIL 14, 2014. (EBA 2010)

0 8 16 24

SCALE

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-04-30	ISSUED WITH FACTUAL REPORT	R.L.	M.R.	R.L.	M.M.

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

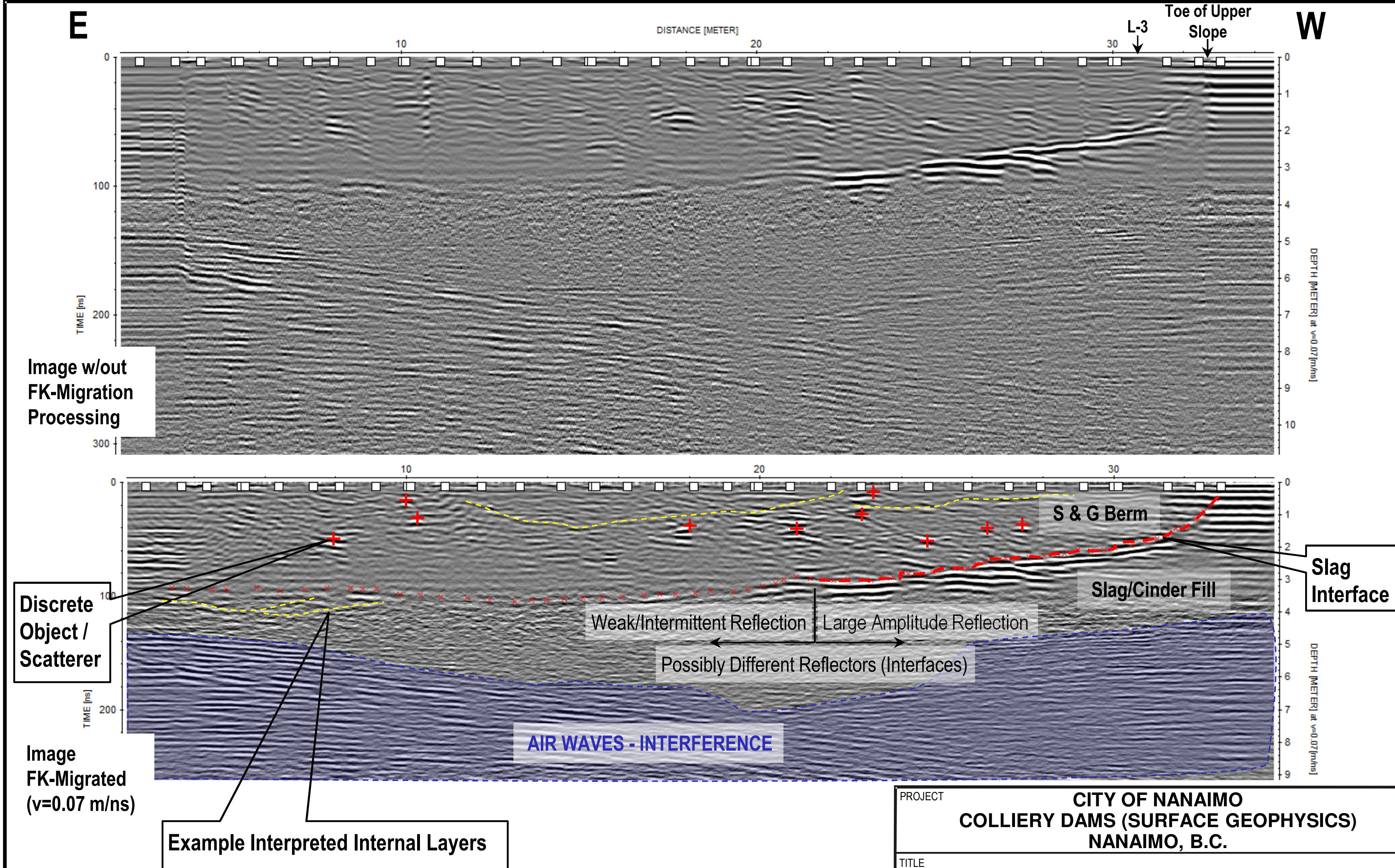
TITLE

GEOPHYSICS
SURFACE INVESTIGATION LOCATIONS
MIDDLE DAM

Golder Associates

PROJECT No.	13-1447-0516/7100		FILE No.	1314470516_2200-02
DESIGN	R.L.	2014-04-09	SCALE	AS SHOWN
CADD	M.R.	2014-04-10	FIGURE	
CHECK	R.L.	2014-04-30		**B-4**
REVIEW	M.M.	2014-04-30		

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



NOTES:

1. Profiles are plotted without topographic adjustment.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes. At this site, elevated moisture content is probably due to retention of rain water at heterogeneities.
3. This figure must be used with the report.

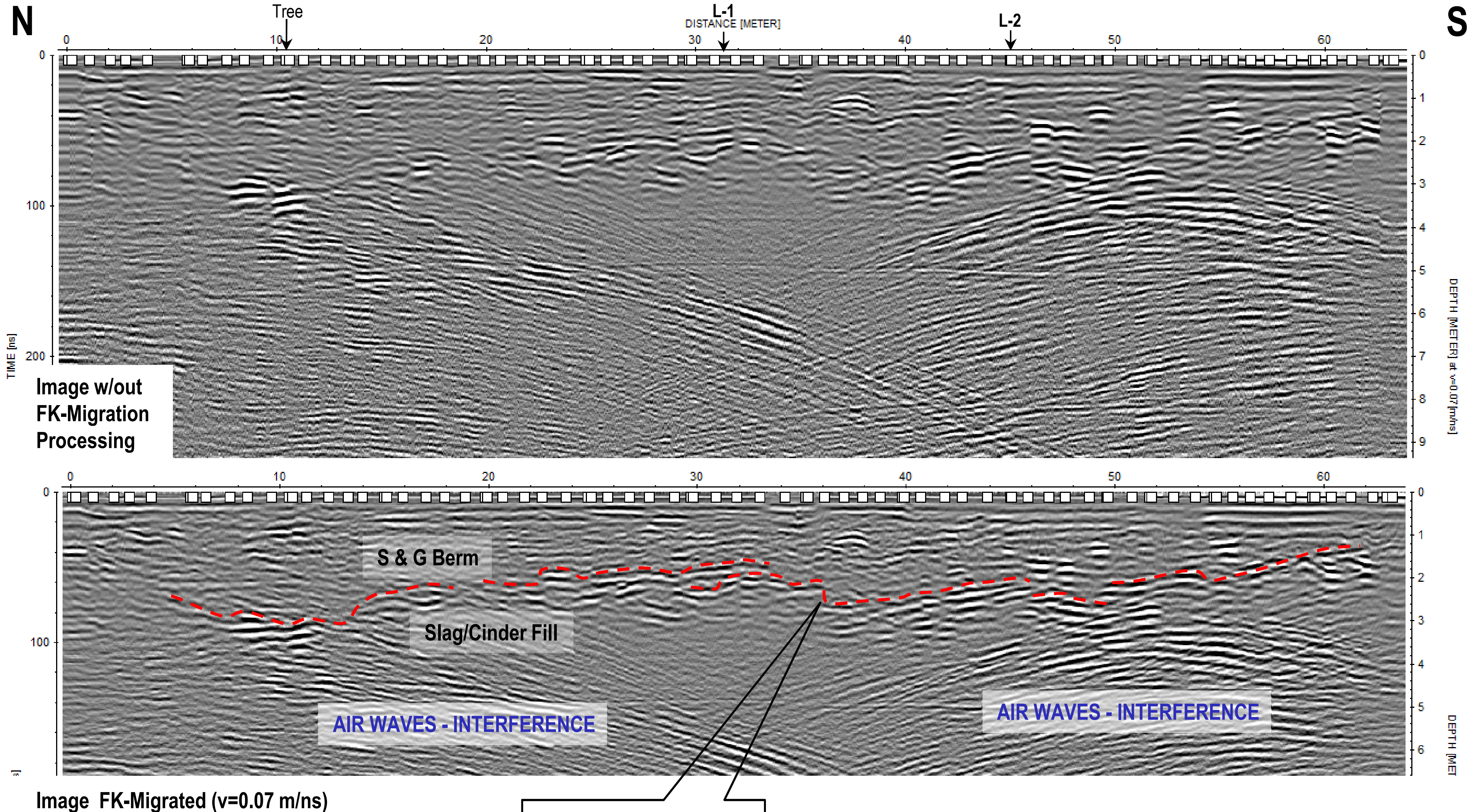
PROJECT
CITY OF NANAIMO
COLLIERY DAMS (SURFACE GEOPHYSICS)
NANAIMO, B.C.

TITLE
LOWER DAM (FACE):
GPR 200 MHz—L-1 (Lower-Berm)

Golder Associates

PROJECT No.	13-1447-0516		PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		**FIGURE B-5**	
CHECK		7APR14		
REVIEW				

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



NOTES:

1. Profiles are plotted without topographic adjustment.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes. At this site, elevated moisture content is probably due to retention of rain water at heterogeneities.
3. This figure must be used with the report.

PROJECT

CITY OF NANAIMO
COLLIERY DAMS (SURFACE GEOPHYSICS)
NANAIMO, B.C.

TITLE

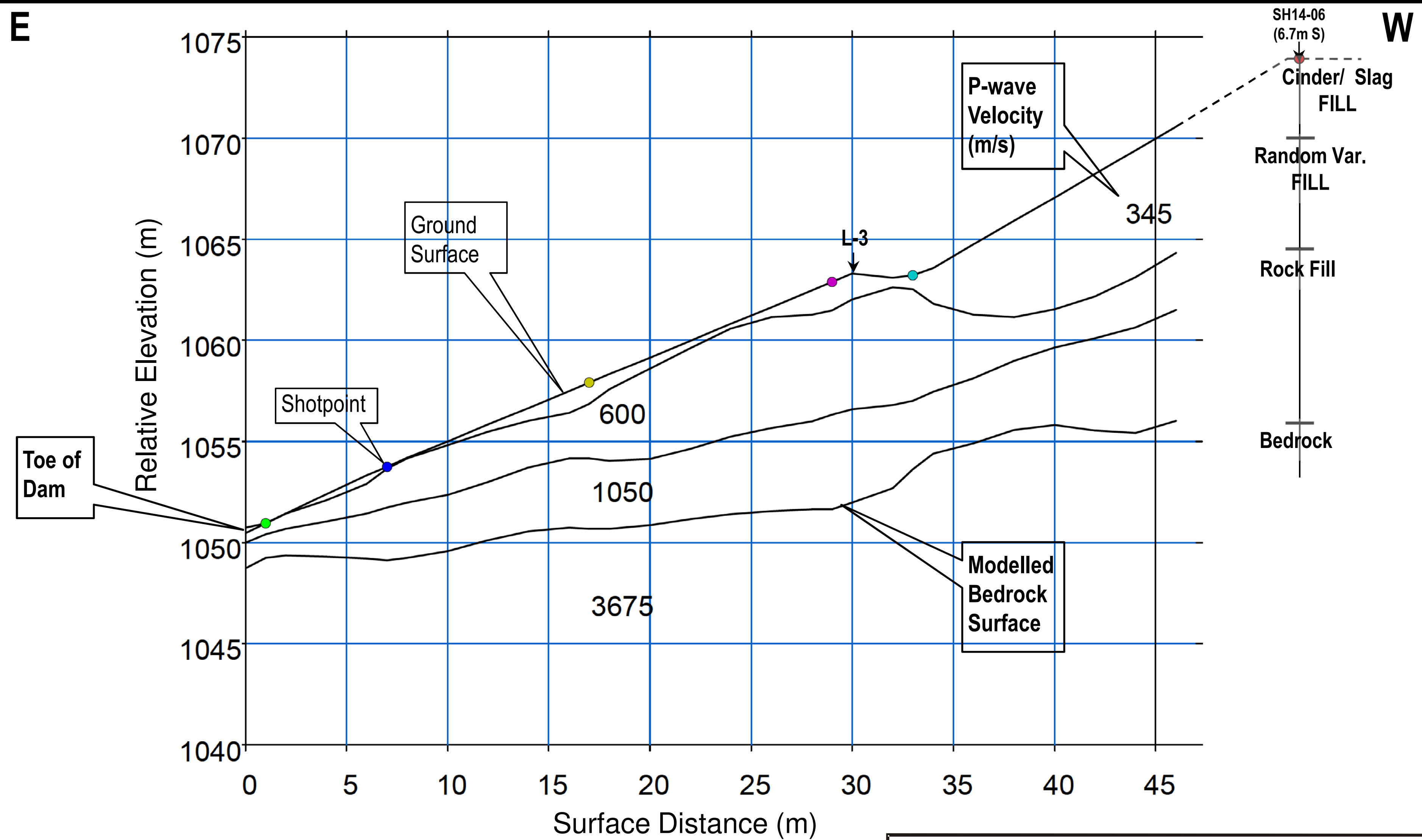
LOWER DAM (FACE):
GPR 200 MHz—L-3

Golder Associates

PROJECT No.	13-1447-0516	PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		
CHECK		7APR14	
REVIEW			

FIGURE B-6

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	**LOWER DAM (FACE): SEISMIC REFRACTION PROFILE: L-1**

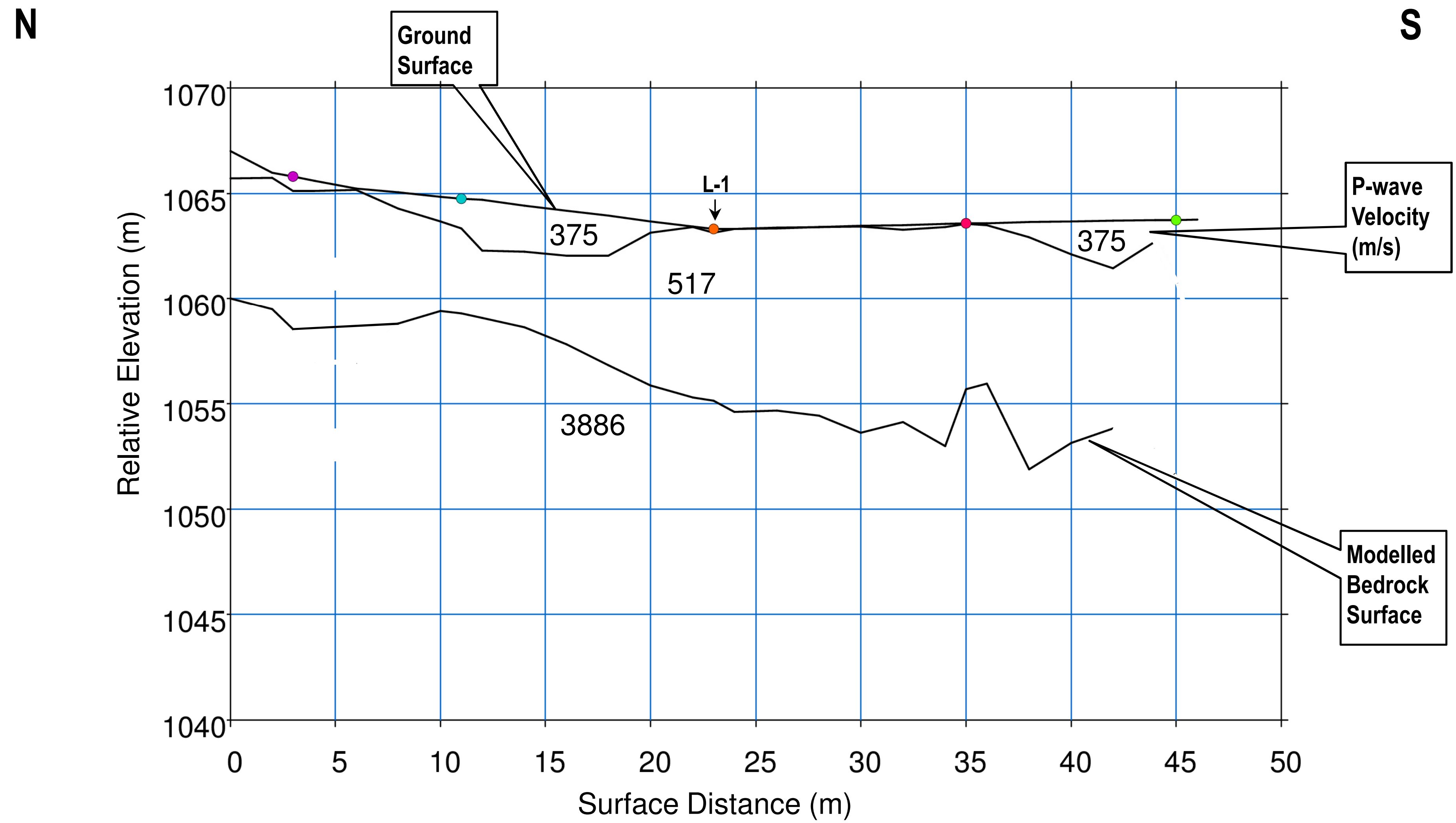
Golder Associates

PROJECT No.	13-1447-0516	PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		**FIGURE B-7**
CHECK		7APR14	
REVIEW			

NOTES:

1. Elevations were estimated from the topographic site plan of this report and 1000 m added.
2. Model misfit (RMS) = 3.58 ms. Reciprocal time mismatch is typically < 1% with a maximum of 1.7% (see Figure B-9).
3. This figure must be used with the report.

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x

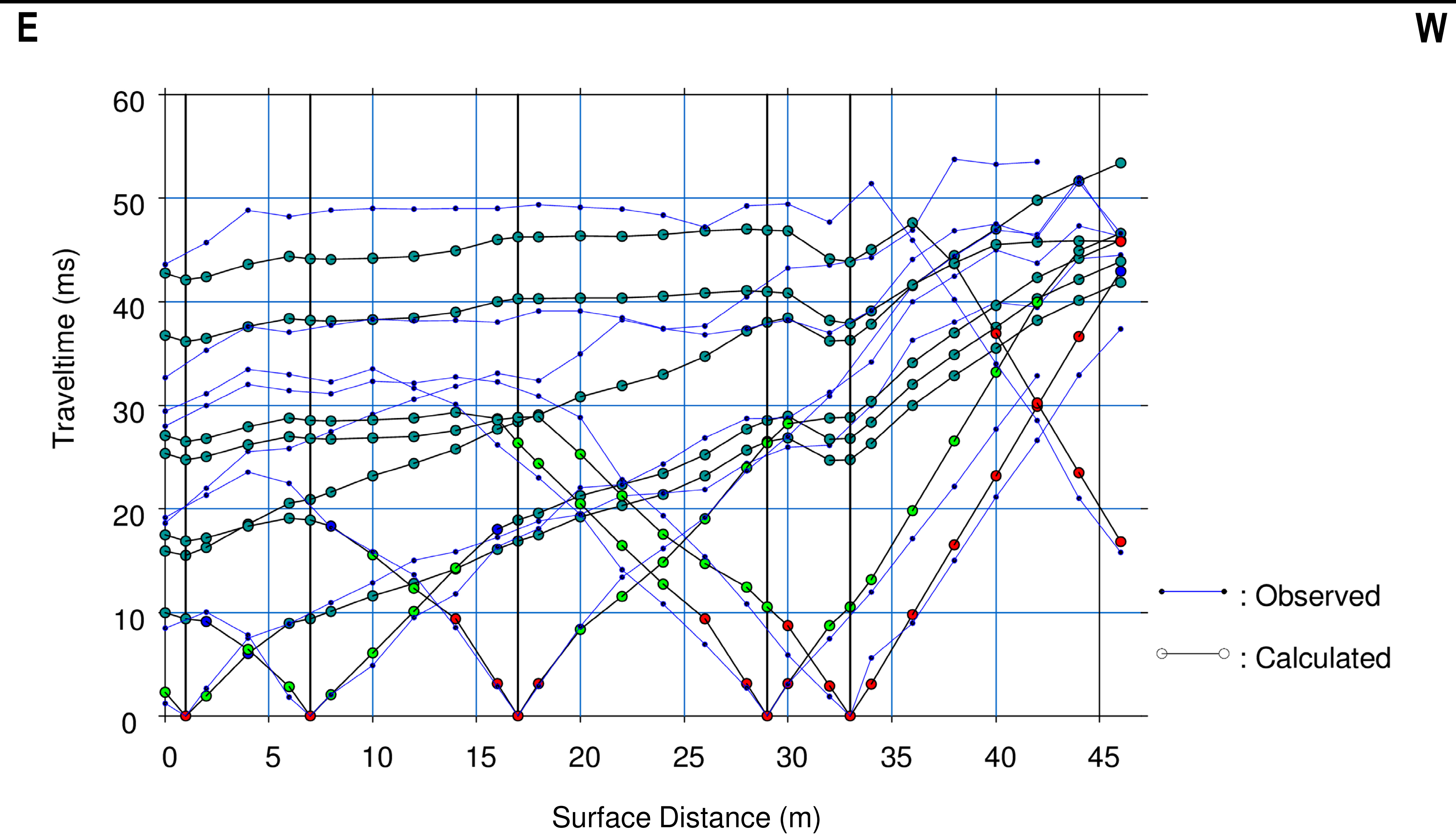


PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.			
TITLE	LOWER DAM (FACE): SEISMIC REFRACTION PROFILE: L-3			
Golder Associates	PROJECT No. 13-1447-0516		PHASE No. 7200	
	DESIGN	RDL 3APR14	SCALE NTS	REV.
	CADD	----	FIGURE B-8	
	CHECK	7APR14		
	REVIEW			

NOTES:

1. Elevations were estimated from the topographic site plan of this report and 1000 m added.
2. Model misfit (RMS) = 1.58 ms. Reciprical time mismatch is typically < 2% with a maximum of 5% (see Figure B-10).
3. This figure must be used with the report.

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



NOTES:

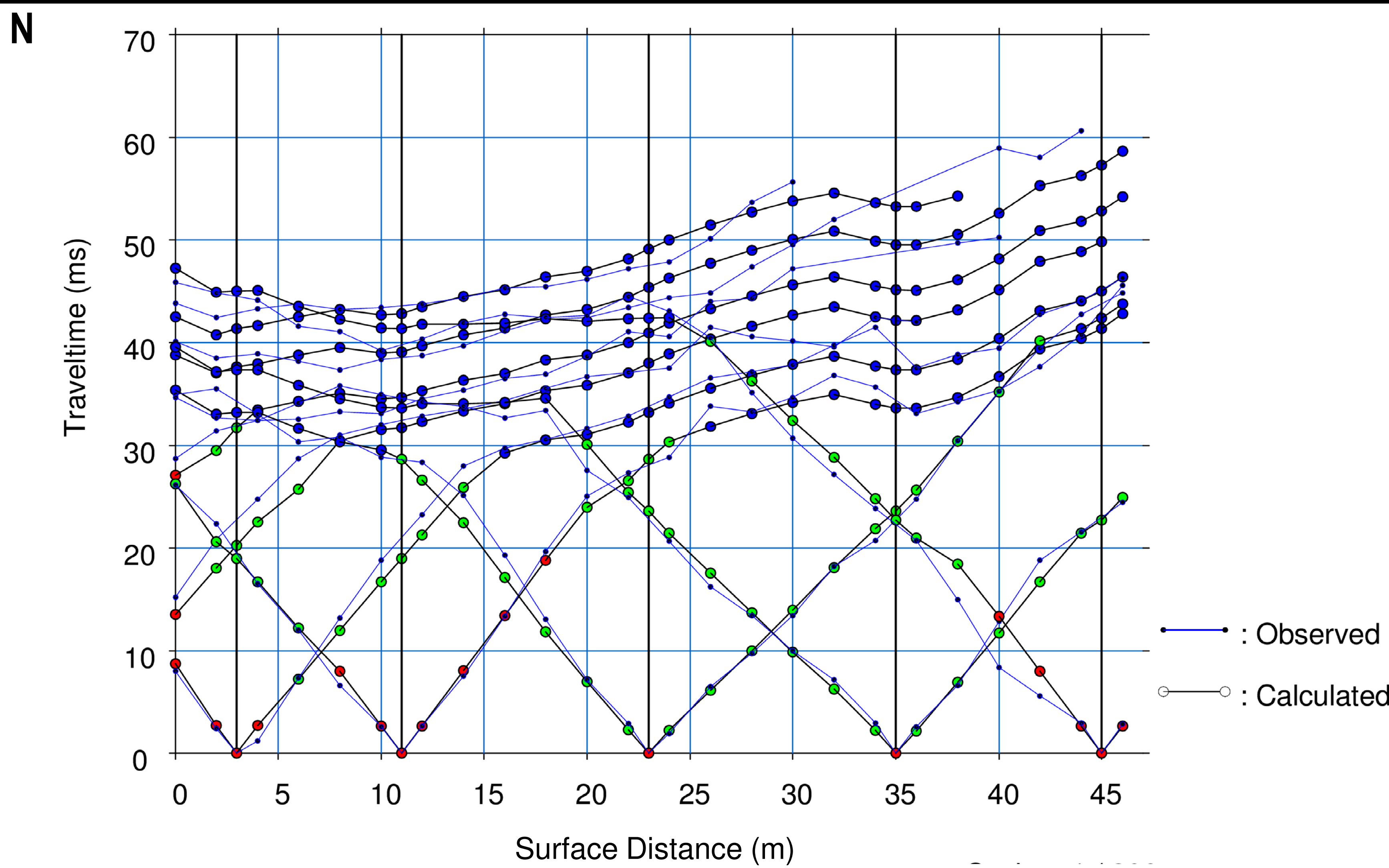
1. Model misfit (RMS) = 3.58 ms. Reciprocal time mismatch is typically < 1% with a maximum of 1.7%.
2. This figure must be used with the report.

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	LOWER DAM (FACE)—L-1: SEISMIC REFRACTION TT-CURVE/MODEL FIT

Golder Associates

PROJECT No.	13-1447-0516		PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		FIGURE B-9	
CHECK		7APR14		
REVIEW				

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



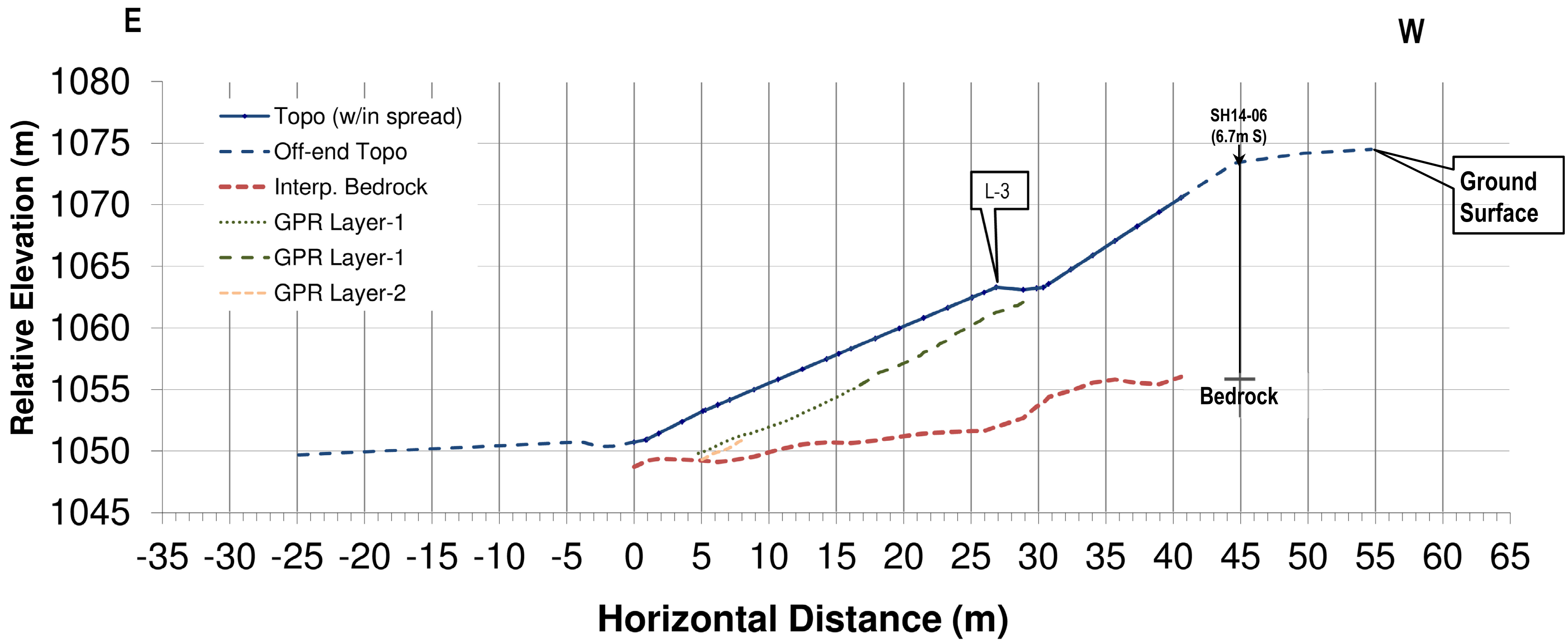
NOTES:

1. Model misfit (RMS) = 1.58 ms. Reciprocal time mismatch is typically < 2% with a maximum of 5%.
2. This figure must be used with the report.

PROJECT	**CITY OF NANAIMO** **COLLIERY DAMS (SURFACE GEOPHYSICS)** **NANAIMO, B.C.**
TITLE	**LOWER DAM (FACE)—L-3:** **SEISMIC REFRACTION TT-CURVE/MODEL FIT**

Golder Associates				
	PROJECT No. 13-1447-0516			PHASE No. 7200
	DESIGN	RDL	3APR14	SCALE NTS REV.
	CADD	----		**FIGURE B-10**
	CHECK		7APR14	
	REVIEW			

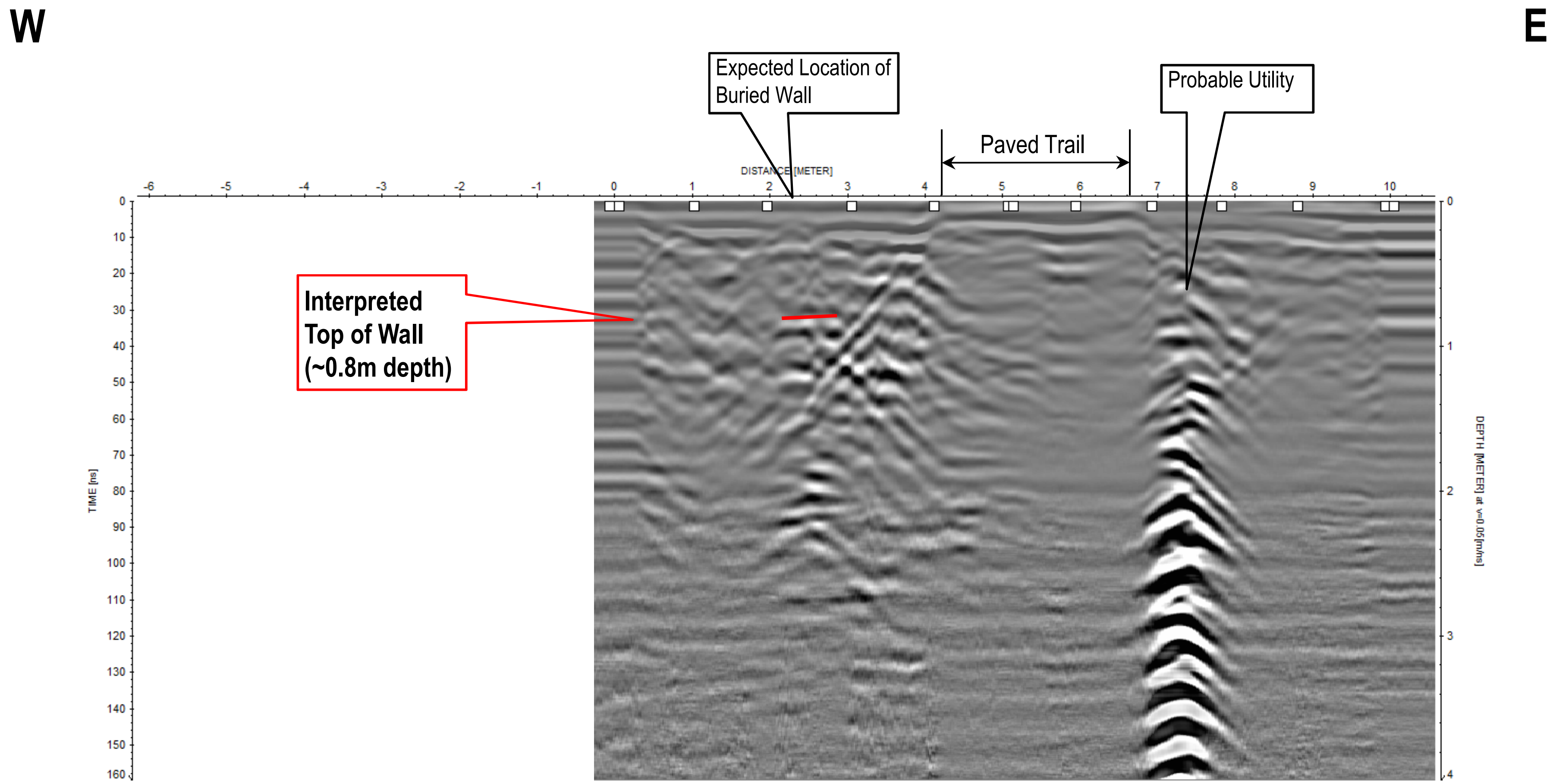
FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



NOTES:
1. Elevations were estimated from the topographic site plan of this report and 1000 m added.
2. This figure must be used with the report.

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.			
TITLE	LOWER DAM (FACE): L-1 COMBINED SEISMIC & GPR INTERPRETATION			
Golder Associates	PROJECT No. 13-1447-0516			PHASE No. 7200
	DESIGN	RDL	3APR14	SCALE NTS REV.
	CADD	----		FIGURE B-11
	CHECK		7APR14	
	REVIEW			

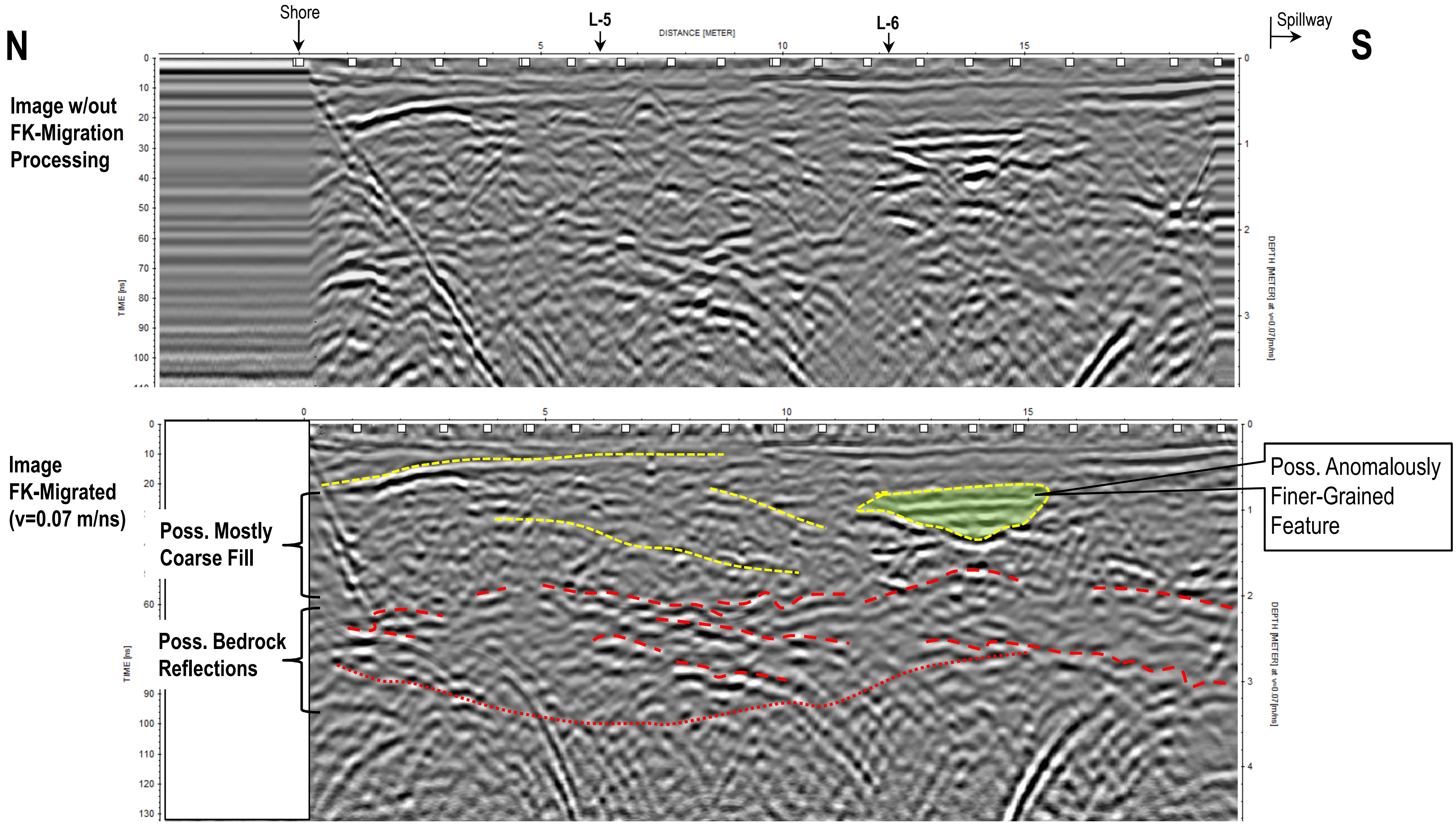
FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig05-13—LwrDam_Geop.ppt x



NOTES:

1. This figure must be used with the report.

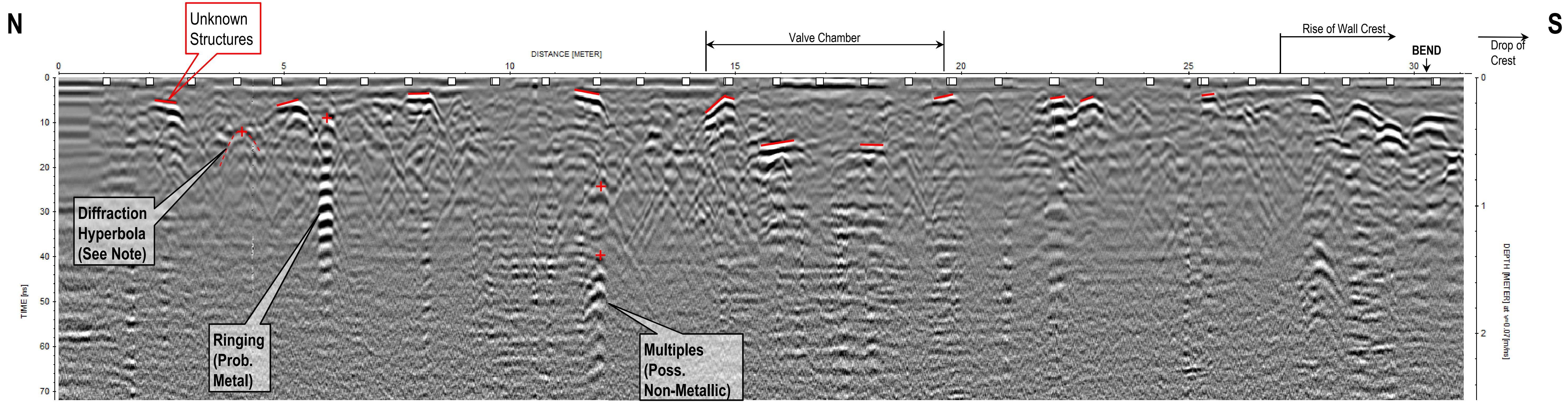
PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.				
TITLE	**LOWER DAM (Buried Wall): Example GPR Interpretation L-7**				
Golder Associates	PROJECT No.	13-1447-0516		PHASE No. 7200	
	DESIGN	RDL	3APR14	SCALE NTS	REV.
	CADD	----		**FIGURE B-12**	
	CHECK		7APR14		
	REVIEW				



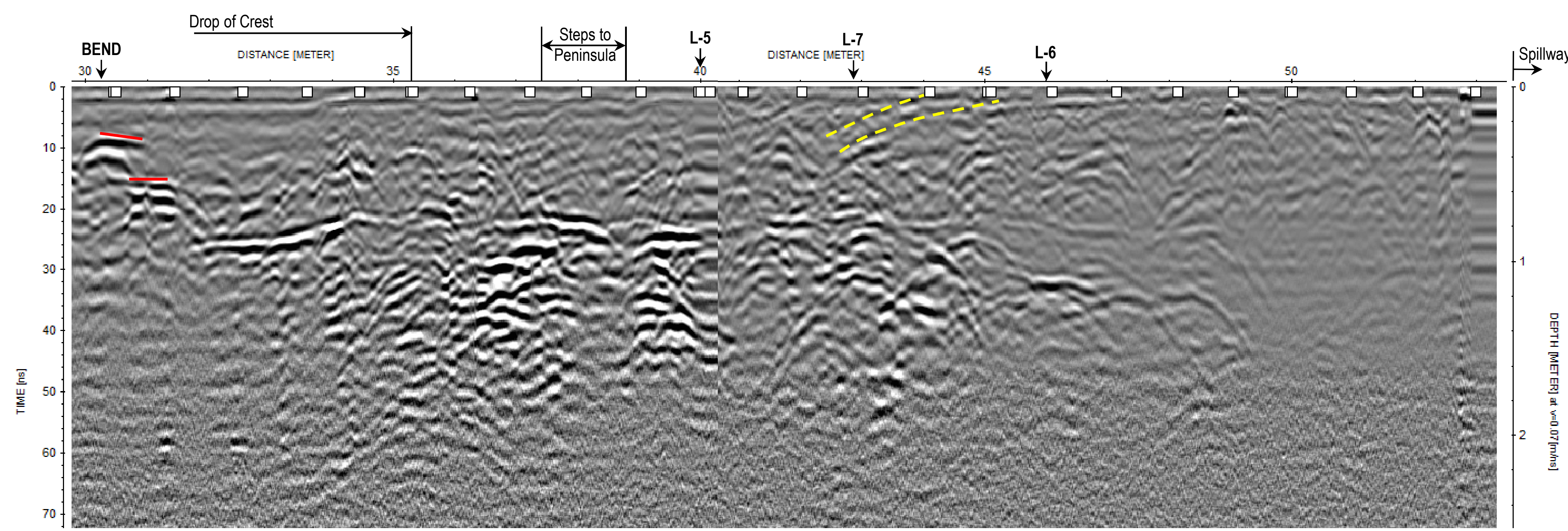
NOTES:

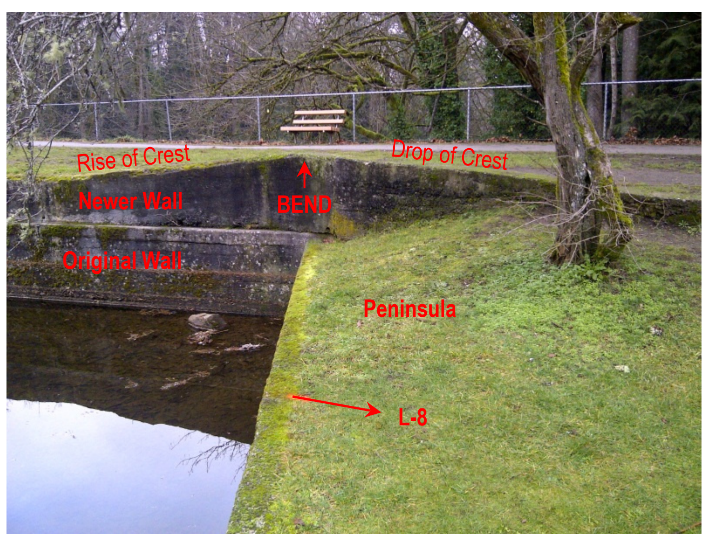
1. Interpretation requires calibration with borehole or testpit.
2. This figure must be used with the report.

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.			
TITLE	**LOWER DAM (Peninsula): Example GPR Interpretation L-8**			
Golder Associates	PROJECT No. 13-1447-0516		PHASE No. 7200	
	DESIGN	RDL	3APR14	SCALE NTS	REV.
	CADD	----		**FIGURE B-13**
	CHECK		7APR14	
	REVIEW			



Continued





NOTES:

1. The numerous diffraction hyperbolas do not exhibit the pattern or character of rebar, but suggest scattering from possibly coarse material (such as cobbles) or other discrete objects. Rebar may exist at a more random pattern.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes.
3. This figure must be used with the report.

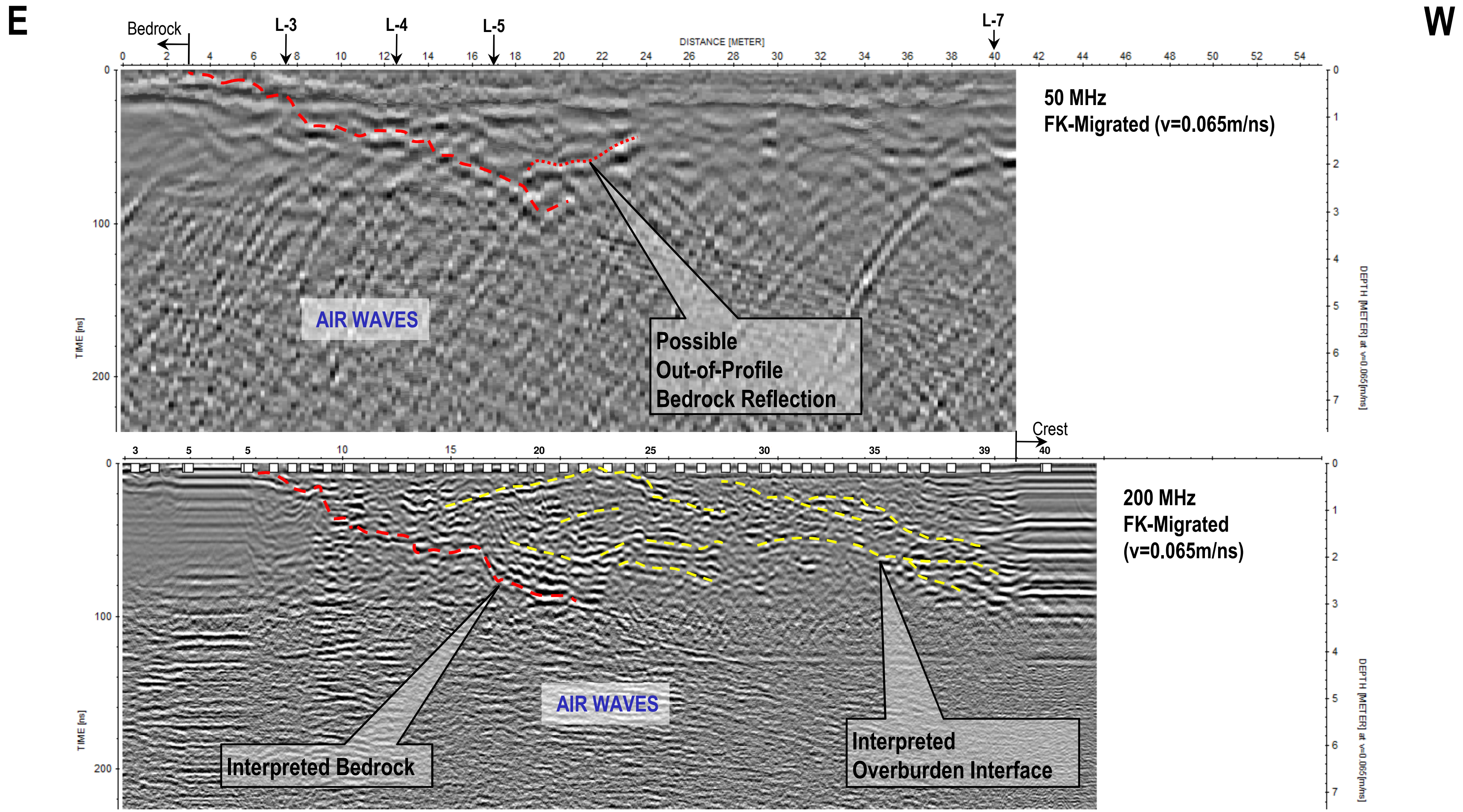
PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	LOWER DAM: GPR L-9 (400 MHz) on Concrete Wall

Golder Associates

PROJECT No.	13-1447-0516		PHASE No.	7200
DESIGN	RDL	7APR14	SCALE NTS	REV.
CADD	--	n/a	FIGURE B-14	
CHECK	--	8APR14		
REVIEW				

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig14—LwrDam_GPR-L9wall.ppt x

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig15-17—MidDam_Geop.ppt x

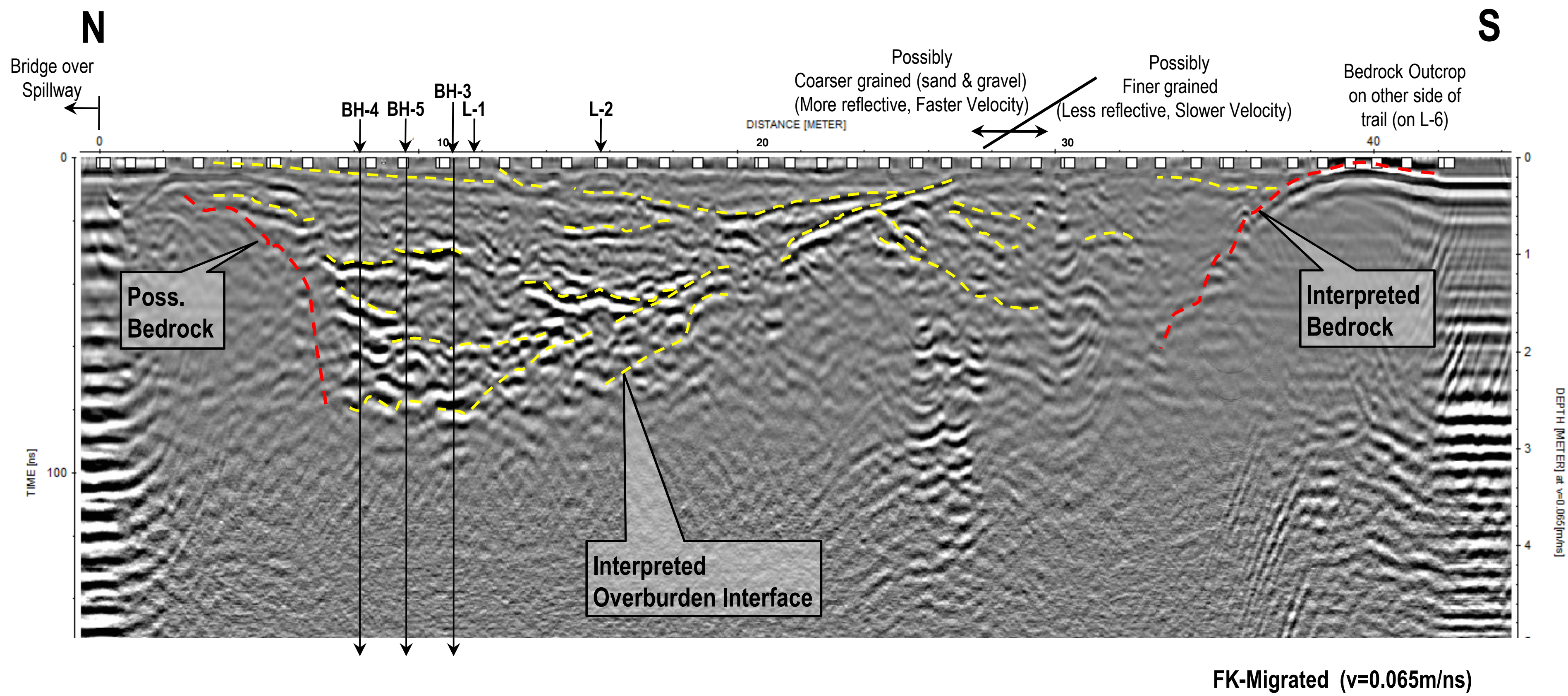


PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	MIDDLE DAM (SLOPE): GPR L-1 (50 & 200 MHz)

PROJECT No.	13-1447-0516	PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		FIGURE B-15
CHECK		7APR14	
REVIEW			

Golder Associates

NOTES:
1. Profiles are plotted without topographic adjustment.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes. On this profile, elevated moisture content could be due to retention of rain water at heterogeneities, or seepage from the spillway.
3. This figure must be used with the report.



NOTES:

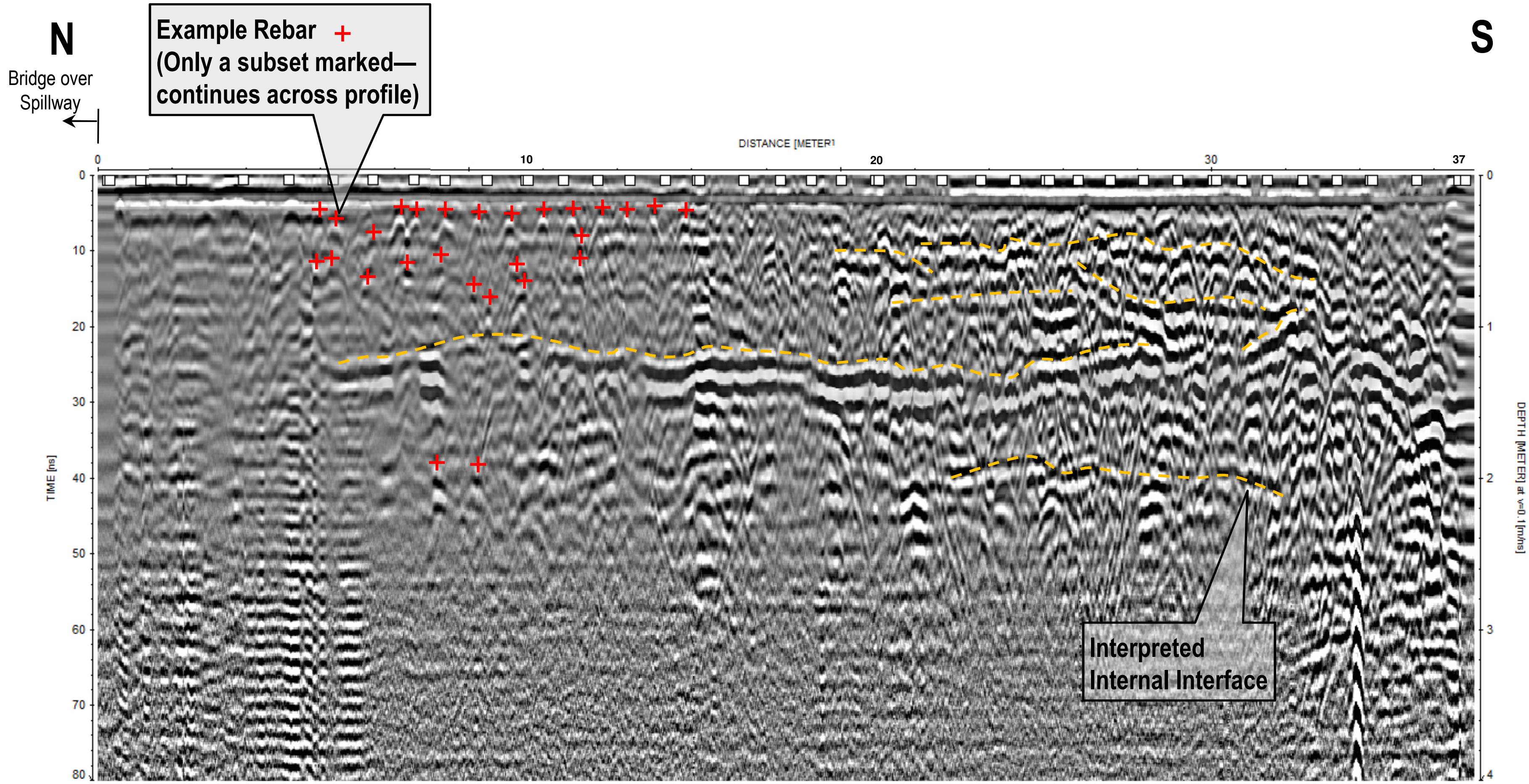
1. Profiles are plotted without topographic adjustment.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes. On this profile, elevated moisture content is probably due to retention of rain water at heterogeneities.
3. This figure must be used with the report.

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	MIDDLE DAM (CREST): GPR L-7 (200 MHz)

Golder Associates

PROJECT No.	13-1447-0516		PHASE No. 7200	
DESIGN	RDL	3APR14	SCALE NTS	REV.
CADD	----		FIGURE B-16	
CHECK		7APR14		
REVIEW				

FILE: O:\Active_2014\1419\13-1447-0516-7000-7200--Nanaimo Dams\07 Deliverables\Final\Surface Geophysics\Figures\Support Files\Fig15-17—MidDam_Geop.ppt x



NOTES:

1. Profiles are plotted without topographic adjustment.
2. Larger amplitude reflections could be caused by higher moisture content and/or material changes. On this profile, elevated moisture content could be due to retention of rain water at heterogeneities, or seepage from the reservoir.
3. This figure must be used with the report.

PROJECT	CITY OF NANAIMO COLLIERY DAMS (SURFACE GEOPHYSICS) NANAIMO, B.C.
TITLE	MIDDLE DAM (CORE-WALL): GPR L-8 (400 MHz)

Golder Associates	PROJECT No. 13-1447-0516		PHASE No. 7200	
	DESIGN	RDL	3APR14	SCALE NTS	REV.
	CADD	----		FIGURE B-17
	CHECK		7APR14	
	REVIEW			

Annex B Summary of Corehole Geophysics of Lower Dam

TECHNICAL MEMORANDUM

DATE	April 16, 2014	**REFERENCE No.**	1314470516-003-TM-Rev0-7000
TO	Jenna Girdner Golder Associates Ltd.		
CC	Max Maxwell		
FROM	Christian Sampaleanu	**EMAIL**	csampaleanu@golder.com

SUMMARY OF COREHOLE GEOPHYSICS AT COLLIERY DAM, NANAIMO, BC

This technical memo provides preliminary results from borehole geophysical surveys that were carried out in the two coreholes that were cored through the concrete wall (top to bottom) of the Lower Colliery Dam.

1.0 OBJECTIVE

Objectives of this survey were to obtain:

- Detailed in-situ imagery of the corehole walls using optical and acoustic televiewers, primarily in support of subsequent packer testing;
- Confirmation of rebar within the concrete wall (existence and possible variation of occurrence) using borehole ground penetrating radar (GPR) with supporting evidence from televiewer magnetometers and images;
- Estimates on variations in wall thickness (from borehole GPR) ; and
- Possible other information that could be inferred from the geophysical data set.

These borehole geophysical results are part of a more comprehensive geotechnical investigation, and cannot be viewed in isolation from that context.

2.0 SCOPE OF WORK

The original scope of work was for geophysical logging in two coreholes, CH14-02 and CH14-03. All boreholes were logged with a combined 3-arm caliper/fluid temperature resistivity probe, and optical and acoustic televiewers. Additionally, GPR profiles were collected in each corehole using a 100 MHz borehole GPR antenna.

3.0 METHODOLOGY

Golder methodology of televiewer logging investigation is typically as a suite of three complimentary logs: caliper, optical televiewer, and acoustic televiewer, all collected using a digital borehole logging system. Borehole GPR data is collected using a separate system. The individual components are discussed below.

3.1 Borehole Logging System

The borehole geophysical logging system used for this work includes a winch, data logger and electronics interface, software, and slimhole probes described below. These were manufactured by Mount Sopris Instruments and Advanced Logic Technology (ALT). The logging system uses a digital controller to provide wireline communications with downhole probes for power and data telemetry. Depth is tracked by using a high-resolution optical encoder mounted on the wire line at the winch. Data were recorded on a laptop computer and displayed in real time, allowing a visual assessment of data quality during the survey.

3.2 Caliper

Borehole diameter caliper measurements are performed by three spring-loaded arms that interact with pot resistors in the probe. Prior to logging operations, the caliper probe is calibrated against rings of known diameter. Changes in borehole diameter (either greater than or smaller than the known bit-size) may be indicative of unstable zones due to large joints, faults and vugs, or soft formations such as shale, coal or mudstone. This information is useful in interpreting televiewer data as well as useful in identifying potential wash-out, cave-in or hole-restriction zones, before sending the televiewers down the hole.

3.3 Borehole Televiewers

The acoustic televiewer (ATV) and optical televiewer (OTV) are designed to obtain images of the borehole wall. The OTV is a high resolution digital camera obtaining detailed colour imagery of the borehole rock and can be used for geological interpretation in addition to geotechnical. The ATV obtains acoustic imagery, using a sound source and a receiver to collect travel time and amplitude data from the borehole walls. Data are collected by a spinning transducer, at a radial sampling of 144 points per rotation and 360 points per rotation for the ATV and OTV respectively. The ATV and OTV logs were collected with a vertical sampling of 1.8 mm and 1.3 mm respectively.

Typically, data recorded by both televiewers are displayed as images that are oriented using data recorded by a three-component fluxgate magnetometer and a three-component tilt meter incorporated in the tools. In this case the images are plotted without orientation, since the coreholes are vertical and magnetic interference occurs from the casing and from the regular occurrence of rebar (at least in CH14-02).

Planar features intersecting the borehole wall appear as sinusoidal traces in the “unwrapped” televiewer image. Using the reference direction recorded during logging, sinusoids can be analyzed to estimate dips and dip directions of categorized features; however, orientation is not an objective of this investigation.

3.4 Borehole GPR

Ground penetrating radar (GPR) operates on the principle that electromagnetic waves, emitted into the ground by a transmitter (Tx) antenna, are partially reflected at subsurface interfaces and can be detected by a receiver (Rx) antenna. In this survey, a single probe contained both the transmitter and receiver antennas. Reflections arise due to contrasts in the dielectric constant of subsurface materials, due primarily to variations in soil moisture content. In particular, there is a strong reflectivity contrast between porous, partially saturated soils and relatively impervious crystalline bedrock or most utilities and buried metal such as rebar. Radar range or maximum penetration is controlled by the electrical conductivity of subsurface materials; as conductivity increases, intrinsic attenuation increases, reducing the effective radar sounding range. Conductivity is typically enhanced with increasing moisture content, depending on the concentration of dissolved salts and the fraction of clay minerals present.

The GSSI SIR-2 radar system used here incorporates precise timing electronics to measure the reflection transit-time, from transmitter to receiver, which depends on reflector range and radar signal velocity. A borehole radar profile is acquired by moving the antennas up the borehole as the radar system records a series of scans at equal time intervals (in this case, sixteen times per second). Resulting data are displayed as a series of oscilloscope-like traces having amplitude proportional to reflection strength. Given an estimate of radar velocity, which can be measured from GPR profiles, corresponding reflector depths may be determined. The particular borehole radar antenna used is omni-directional, meaning signals are sent out in and received from all directions, and thus locating a particular feature is not possible from a single borehole GPR profile.

The 100 MHz borehole antenna was lowered and raised on its cable by hand. The cable is marked at 1 m intervals. These marks serve to determine depth and corresponding marks were made on the GPR profiles to indicate the depth of the antenna in the corehole.

4.0 FIELD WORK

Corehole geophysical logging was conducted on March 25-26, 2014. Multiple GPR profiles were collected in each corehole, each time varying a signal processing parameter such as gain, filters or background removal. All logs and GPR profiles were collected from the bottom of the hole upwards to facilitate smooth data collection. The top of the acoustic televiewer logging interval corresponds to the static water level (SWL), and as such, acoustic televiewer data was not collected in the upper 8 m of CH14-03. Table 1 provides a summary of coverage for the coreholes logged in this investigation.

Table 1: Summary of Log Coverage

Hole	Total depth of hole (m)	Top of logging interval (m below ground surface)	Bottom of logging interval (m below ground surface)	Comments
CH14-02	20.4	1.2 (OTV) 2.15 (ATV) - SWL	20.4	Poor fluid clarity impaired optical log
CH14-03	13.0	1.9 (OTV) 8.68 (ATV) - SWL	12.9	

5.0 RESULTS AND INTERPRETATION

5.1 Televiewer Logs

Televiewer data processing and interpretation was performed using ALT WellCAD (v 4.4) software. Acoustic and optical televiewer logs are presented, along with the caliper log, apparent hardness log (calculated from the median acoustic amplitude), corehole orientation logs (tilt and azimuth), as well as the magnetic field log (which indicates any magnetic disturbances due to metal objects such as rebar). The metal casing in each hole greatly affects the top few metres of the magnetometer and azimuth logs.

Note that the borehole log depth scale is relative to ground surface.

5.2 Apparent Hardness Log

The apparent hardness log is derived from the acoustic televiewer amplitude log. The amplitude log represents the magnitude of the returned reflected signal; the harder and more competent the wall, the larger the amplitude of the returned signal. This magnitude is primarily dependent on the impedance contrast between the borehole fluid and formation.

WellCAD software was used to extract a median amplitude log from the amplitude image log (this provides a single median amplitude value for each depth slice, i.e., the median of the 144 points recorded around each 1.8 mm thick depth slice). This “median amplitude” log is the basis of Apparent Hardness. The Apparent Hardness log is typically produced by dividing the median amplitude log by a normalizing factor. This factor can change as more data becomes available from the site; the idea is to develop a site normalizing factor, or to normalize to a known response from a particular calibration or test borehole. In the investigation reported here, the log was scaled to a normalizing factor of 1500—the maximum amplitude measured within the steel casing from other sites.

The resulting Apparent Hardness log resembles a bedrock stratigraphic weathering profile. The Apparent Hardness log usually tracks well with Geotechnical Indices, such as RQD, TCR, SCR and FI. If a rock is heavily fractured, soft or washed out by the drilling process, the Apparent Rock Hardness will be lower. It should be noted that Geotechnical Indices are measurements made on a disturbed sample and the Apparent Rock Hardness log is an estimate from an *in situ* measurement of the borehole wall conditions.

This method of calculating an Apparent Hardness log from the acoustic televiewer log can be affected by several factors: 1) drilling induced fracturing, 2) decentralization of the tool during logging, and 3) geologic conditions such as the presence of gypsum layers or veins.

5.2.1 CH14-02

The acoustic televiewer amplitude log of CH14-02 shows variations in the concrete including layering and possible cold joints, clast size and shape, and proportion of aggregate/cement. Relative variations in hardness (primarily of the cement) are also apparent. The cement produces a brighter acoustic reflection as it increases in hardness with depth. Zones of softer cement are present at several depths. The thickness of these zones ranges from 1 cm to 15 cm. The caliper log shows a widening of the borehole, from the normal 12.7 cm to 13.7 cm, occurring between 6.7 m and 7.3 m depth. This zone causes the acoustic televiewer log to blur as the tool loses centralization at this interval.

Bedrock appears to occur at approximately 18.45 m depth below ground surface. The conglomerate bedrock appears to consist of finer, and more rounded, aggregate and harder matrix. At least three discrete fractures are visible in the bedrock – one at the interface at 18.45 m, one at 19.1 m, and a very fine crack at 19.3 m.

The optical televiewer log is mostly obscured by the poor clarity of the borehole fluid, particularly above 15 m. Below 15 m the OTV log also exhibits the bedrock interface, with the concrete being a lighter colour than the bedrock.

Both acoustic and optical televiewers measured several magnetic anomalies in this hole, indicating the presence of metal, most likely rebar. A total of 14 anomalies were identified; the shallowest at 10.8 m depth, with subsequent anomalies spaced at 0.26 m to 0.98 m from the one above it. The magnitude of these anomalies varies suggesting a variation in horizontal distance from the borehole. More subtle variations in magnetic field were not considered to be anomalies, and it is possible that some weak anomalies were not noted or were masked by stronger ones.

Note that three magnetic anomalies occur at or below the bedrock interface. These occurrences suggest continuation of reinforced concrete to at least 19.05 m depth some metres away from the borehole (within the range of the magnetometer).

Due to these magnetic anomalies distorting north-oriented televiewer logs, the logs for this hole are oriented to an arbitrary marker on the tool itself.

5.2.2 CH14-03

Acoustic and optical televiewer logs for CH14-03 show a similar structure to that observed in CH14-02. Light-coloured coarse aggregate concrete overlies darker (greenish-grey), finer aggregate conglomerate bedrock. The bedrock interface occurs at approximately 9.9 m below ground surface. Two significant fractures are visible in both logs within the bedrock: one at 10.65 m, and one at 11.65 m. Variations in the hardness of the cement are not as apparent compared to CH14-02, although no acoustic log is available above 8.7 m due to a lack of water in the corehole.

While some subtle variations in magnetic field are observed, there are no strong anomalies that would suggest rebar adjacent to the corehole. However, it is worth noting that the bottom of this hole, at 12.9 m is above most of the anomalies observed in CH14-02.

Televiewer logs for corehole CH14-03 are oriented to magnetic north based on the televiewers' onboard magnetometers.

5.3 Borehole GPR Results

GPR data were processed using the Reflex-W reflection processing software. Data processing included:

- Dewow Filter (8-12 ns moving average filter);
- Band pass filter (50-300 MHz);
- Background Removal Filter; and
- Gain (Energy Decay gain).

Resulting GPR data are generally noisy and do not provide a clear interpretation of thickness of the concrete wall, however, features are visible which are a typical response for rebar. Some of the difficulty in interpretation arises from the fact that the borehole antenna is omni-directional, and so it is not possible to determine the precise location or orientation of features. For example, a series of diffractions interpreted to be rebar could, in fact, be two sets of rebar, one on each side of the borehole.

GPR profiles from either borehole do not exhibit interpretable reflections from the concrete wall interfaces. There could be several reasons for this. One is that the highly reflective rebar masks other more subtle reflections. It is also possible that the difference in radar properties between the concrete and fill materials is insufficient to reflect enough energy back towards the antenna.

5.3.1 CH14-02

Most GPR profiles collected in CH14-02 exhibit a notable (regular) pattern of diffraction hyperbolas across the profile, occurring from approximately 2 m to 17.5 m below ground surface. These diffractions are spaced at intervals of approximately 40-80 cm and are characteristic of rebar. The spacing of these diffractions is slightly denser than the magnetic anomalies in the televiewer logs, although the range of rebar detection of GPR appears to be greater than that of the televiewer magnetometer. The diffraction pattern does not appear below approximately 18 m depth, which is the bedrock interface.

5.3.2 CH14-03

The GPR profiles collected in CH14-03 exhibit some notable features. At least two sets of diffraction patterns are visible which could be interpreted to be rebar. These diffractions vary in range from the corehole and in reflection strength. The first set is most apparent between 3.5 to 8 m depth below ground surface, and again within the bottom 1 m of the borehole. The diffractions appear at semi-regular intervals of approximately 25-35 cm.

The second diffraction pattern is less regular and distinct than the first one, and appears to range further away from the borehole with depth.

6.0 SUMMARY AND CONCLUSIONS

The borehole televiewer and GPR investigation reported here has confirmed the presence of rebar throughout the dam, as well as identified fractures in the bedrock and provided an in-situ characterization of the concrete in support of the geotechnical core logs and other geotechnical information.

Rebar was interpreted in both the GPR data and in magnetometer data from the borehole televiewers and to a lesser extent visually observed in the televiewer images at intervals that are consistent with the geotechnical log. Rebar appears more frequently in GPR profiles, due to the higher resolution and greater range of the radar survey.

In CH14-02, diffraction hyperbolas interpreted to be rebar were observed in the GPR profile from 2 m to 18 m below ground surface. In the televiewer data, magnetic anomalies indicative of rebar are observed from 10.8 m to the bottom of the corehole. In both cases, rebar appears to be spaced at semi-regular intervals; usually less than 1 m in the magnetometer log, and less than 0.5 m in the GPR profile.

In CH14-03, similar series of diffraction hyperbolas were observed in the GPR profile through most of the corehole, varying in intensity and range from the corehole. No evidence of rebar was seen in the televiewer image or magnetometer logs.

The GPR data were not able to characterize the thickness of the concrete wall or image the interface between concrete and fill.

7.0 CLOSURE

This memorandum has been prepared based on the information obtained for the purposes outlined above. Should additional site investigation data become available, Golder Associates should be requested to review this report in light of this information, and provide revised and/or additional recommendations as appropriate.

We trust that this report meets your immediate requirements. Please contact the undersigned should you have any questions or concerns.

GOLDER ASSOCIATES LTD.

Christian Sampaleanu, B.Sc.
Geophysicist

Rob Luzitano, M.Sc.
Senior Geophysicist

CIS/RDL/ja/jlj

Attachment 1: Televiewer Logs

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DRAFT

GEOPHYSICAL RECORD OF BOREHOLE: CH14-02

PROJECT REF. *13-1447-0516/7000*

LOCATION *Colliery Dams, Nanaimo, BC*

LOG DATE *March 26, 2014*

LOG REF. *Ground surface (Elev. 73.5 m)*

GEOPHYSICAL RECORD OF BOREHOLE: CH14-02

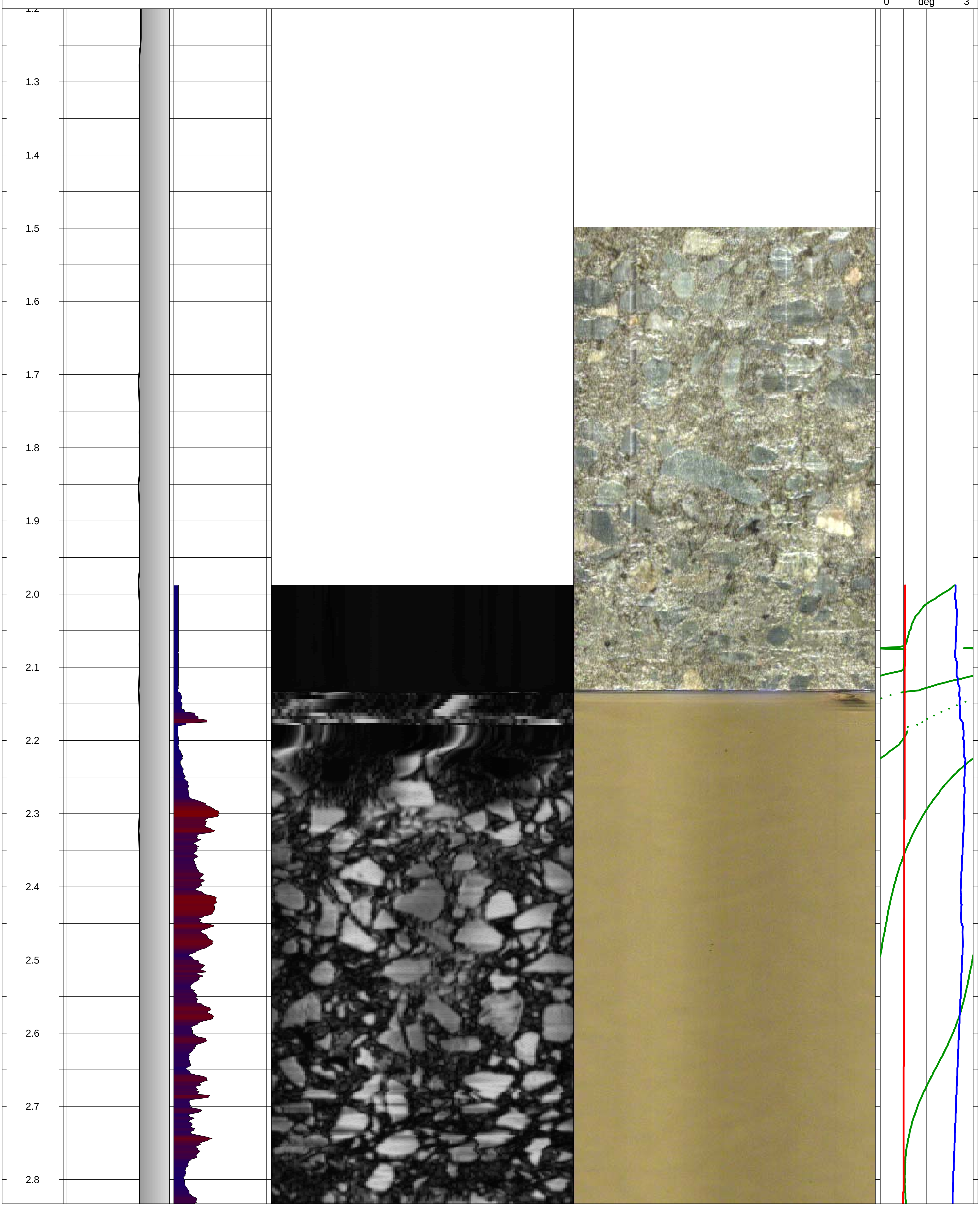
PROJECT REF. *13-1447-0516/7000*

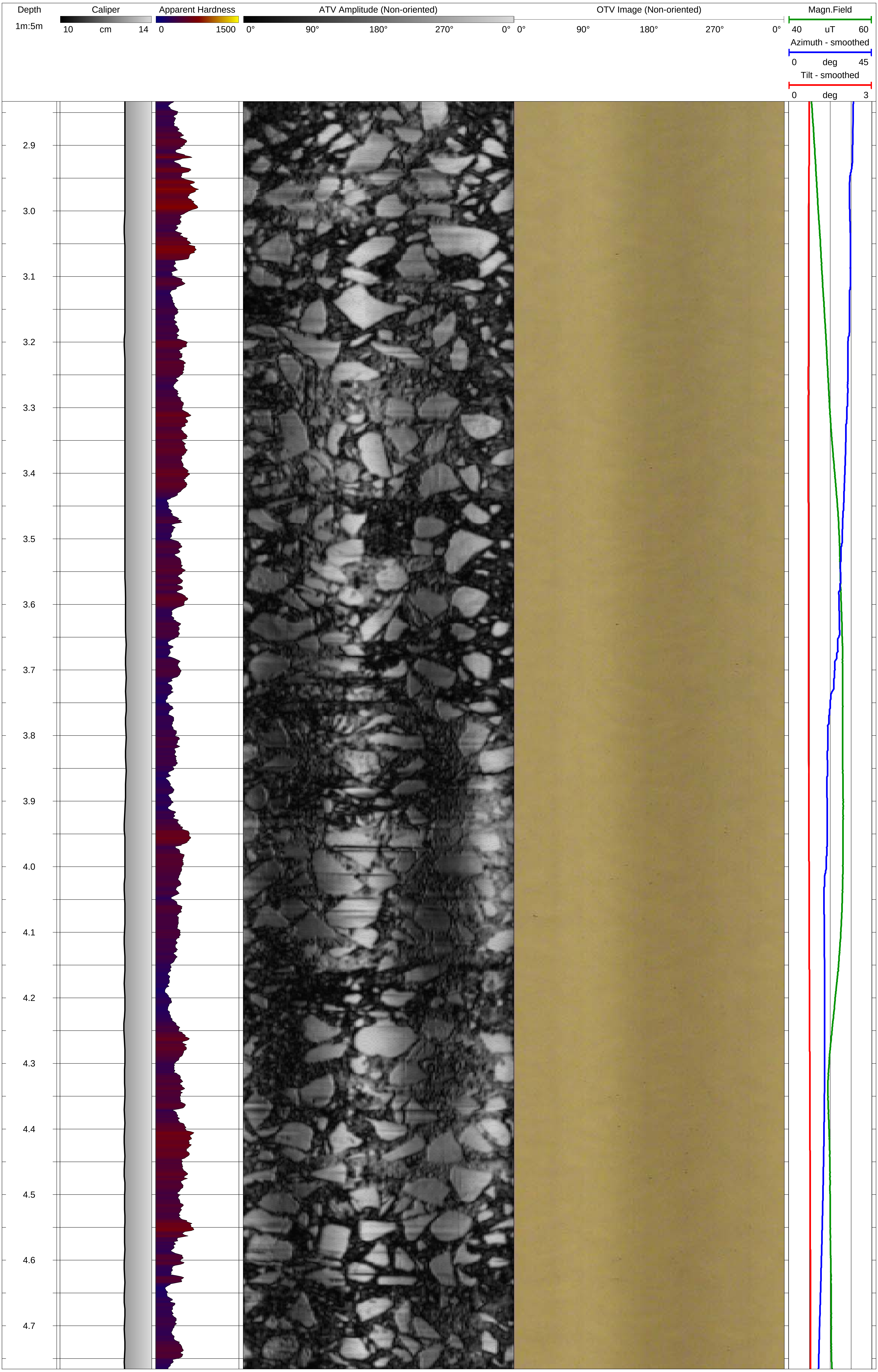
LOCATION *Colliery Dams, Nanaimo, BC*

LOG DATE *March 26, 2014*

LOG REF. *Ground surface (Elev. 73.5 m)*

Depth	Caliper	Apparent Hardness	ATV Amplitude (Non-oriented)	OTV Image (Non-oriented)	Magn.Field
1m:5m	10 cm 14	0 1500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	40 uT 60
					Azimuth - smoothed
					0 deg 45
					Tilt - smoothed
					0 deg 3

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Caliper
10 cm 14
Apparent Hardness
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OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
2.9
3.0
3.1
3.2
3.3
3.4
3.5
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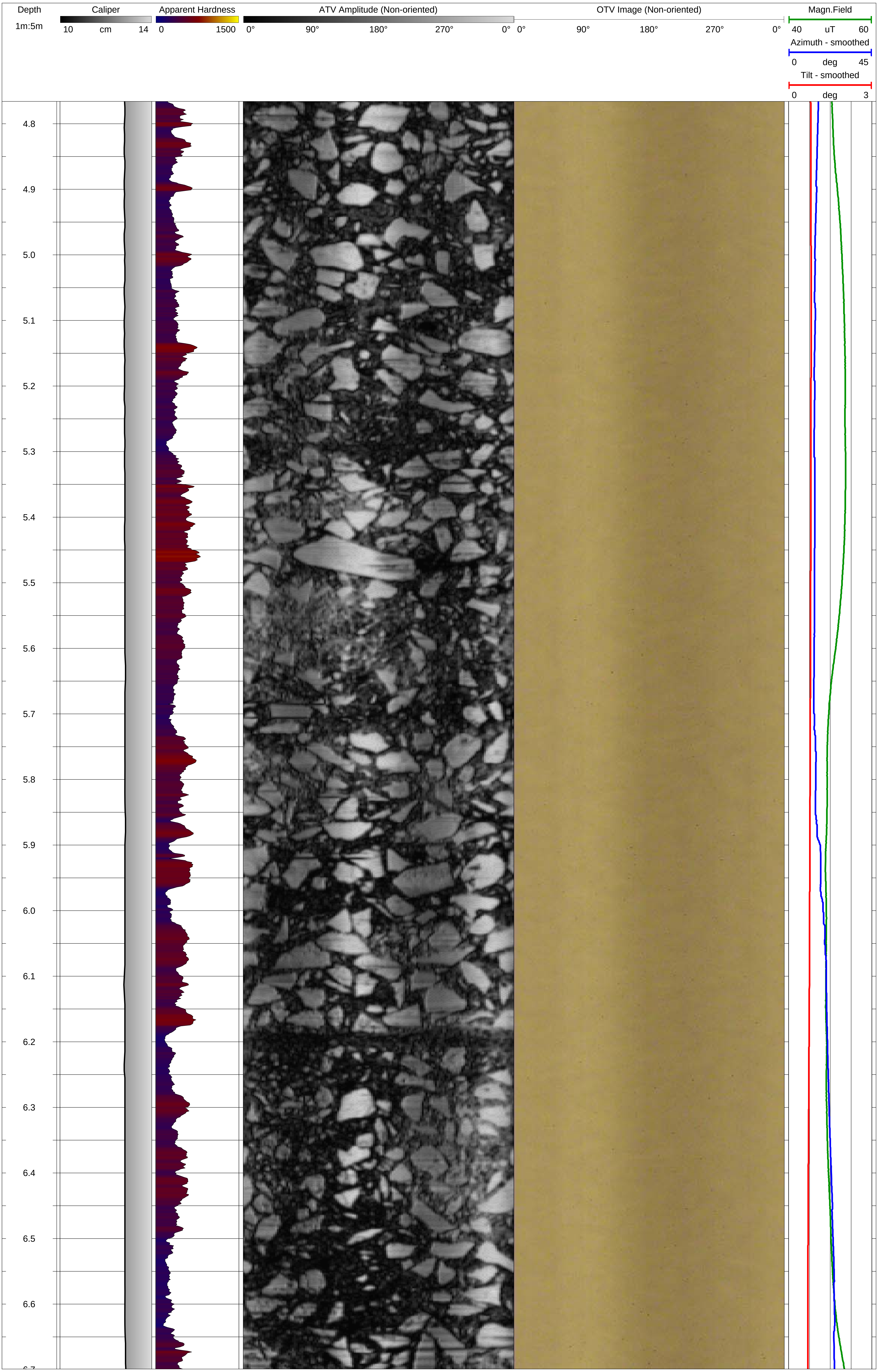
4.5
4.6
4.7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Caliper
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Apparent Hardness
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0° 90° 180° 270° 0°
OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
4.8
4.9
5.0
5.1
5.2
5.3
5.4
5.5
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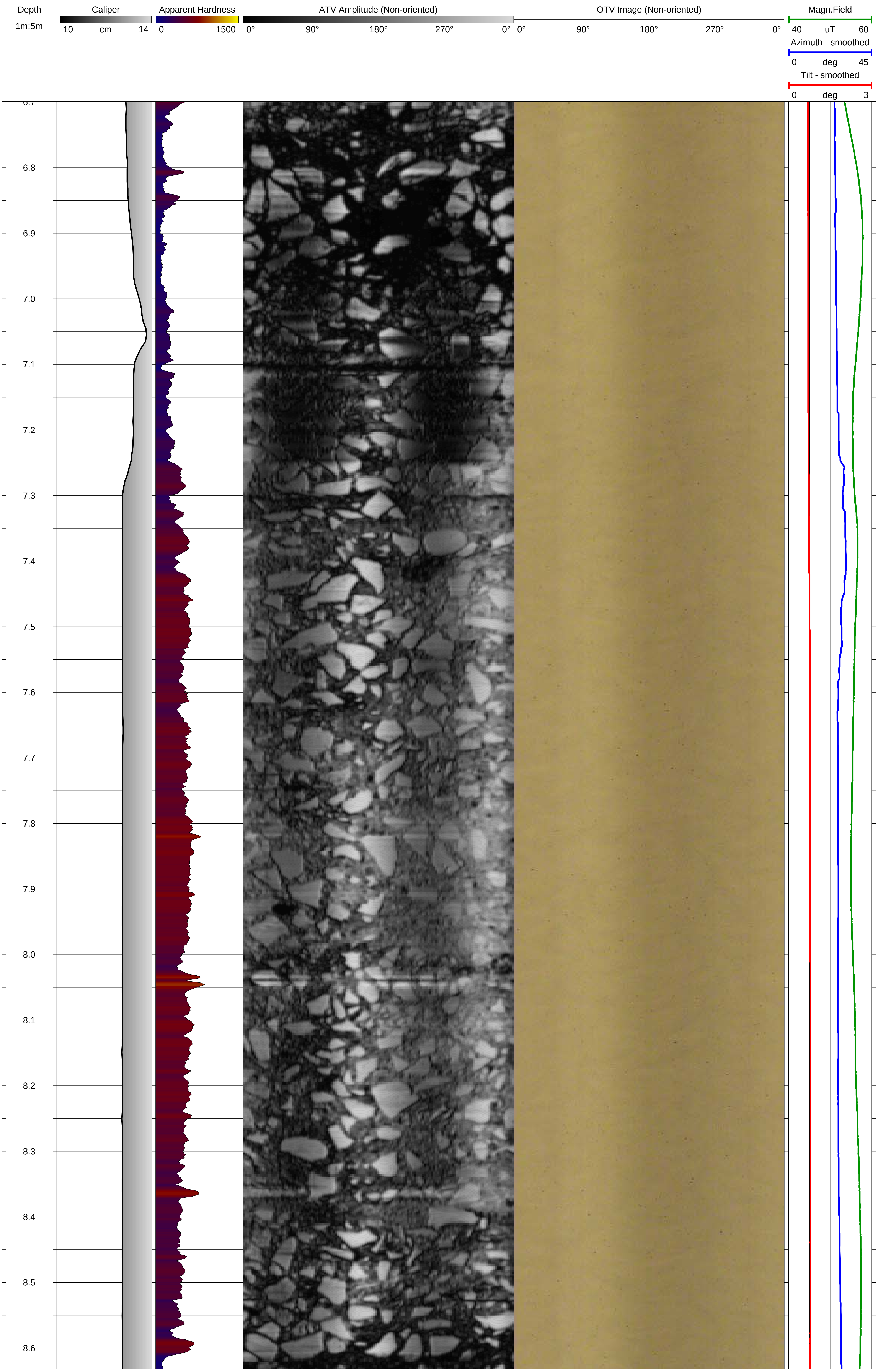
6.5
6.6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Caliper
10 cm 14
Apparent Hardness
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ATV Amplitude (Non-oriented)
0° 90° 180° 270° 0°
OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
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6.8
6.9
7.0
7.1
7.2
7.3
7.4
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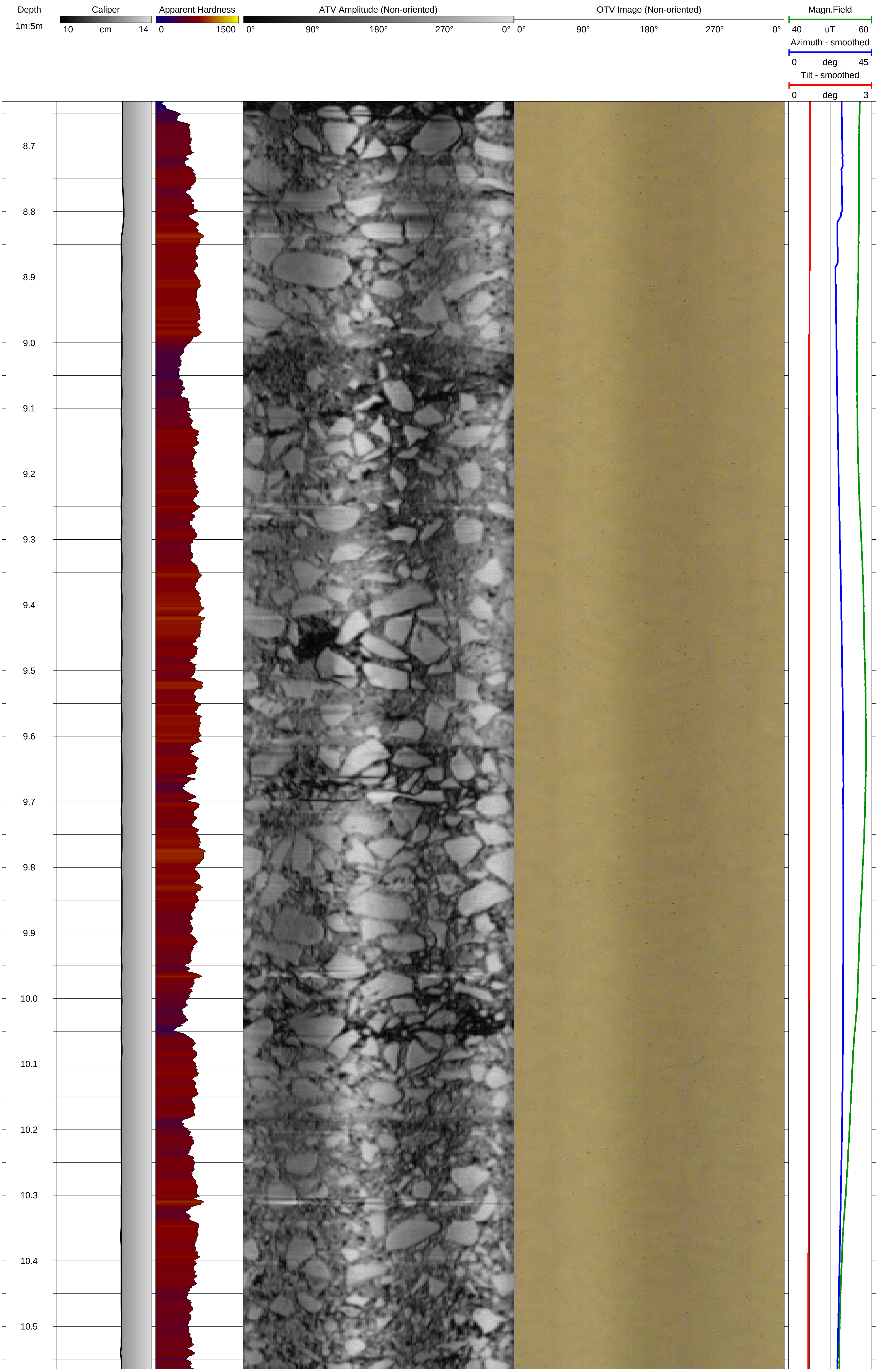
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Caliper
10 cm 14
Apparent Hardness
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OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
8.7
8.8
8.9
9.0
9.1
9.2
9.3
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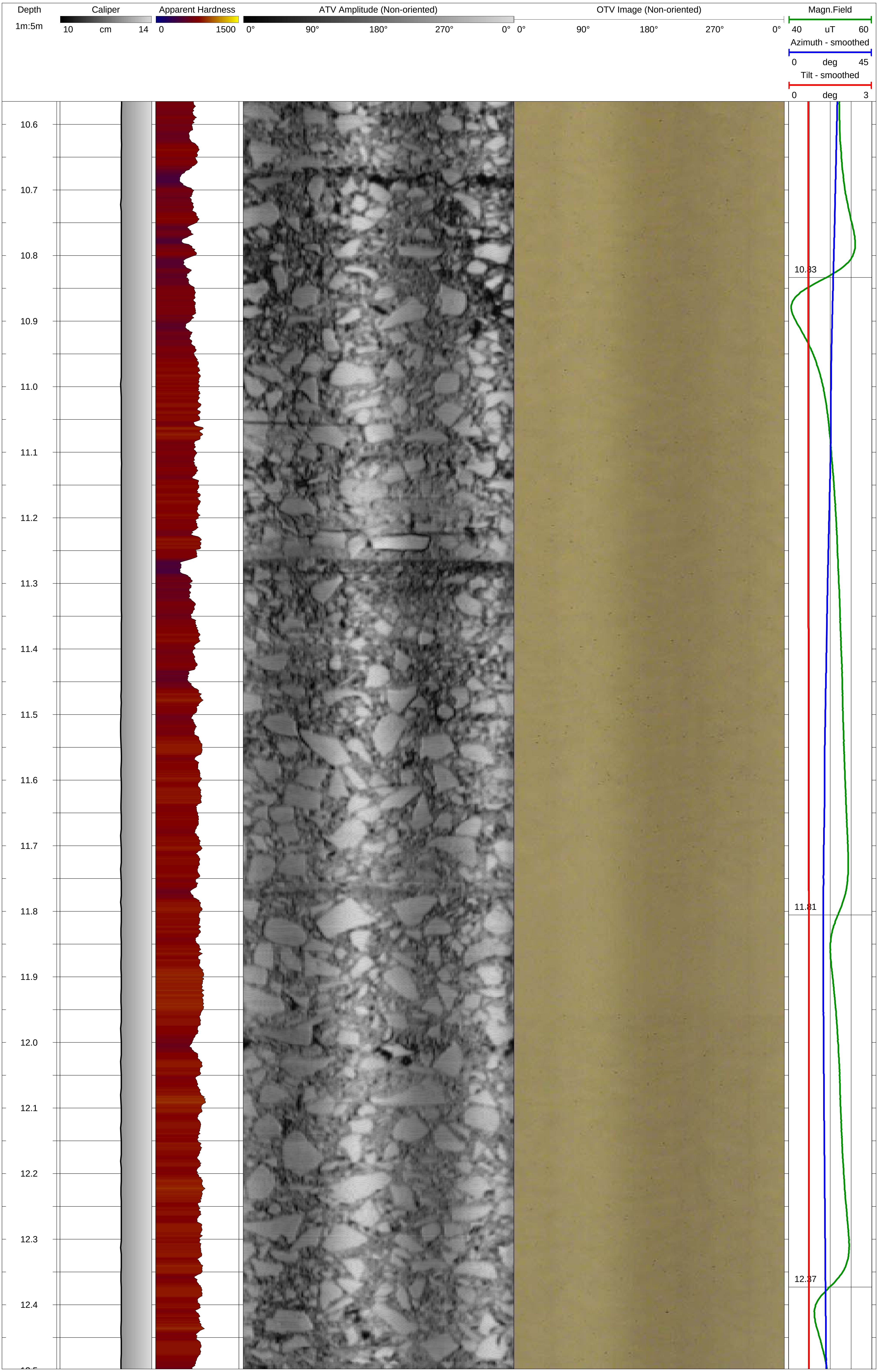
10.4
10.5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Apparent Hardness
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OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
10.6
10.7
10.8
10.9
11.0
11.1
11.2
11.3
11.4
11.5
11.6
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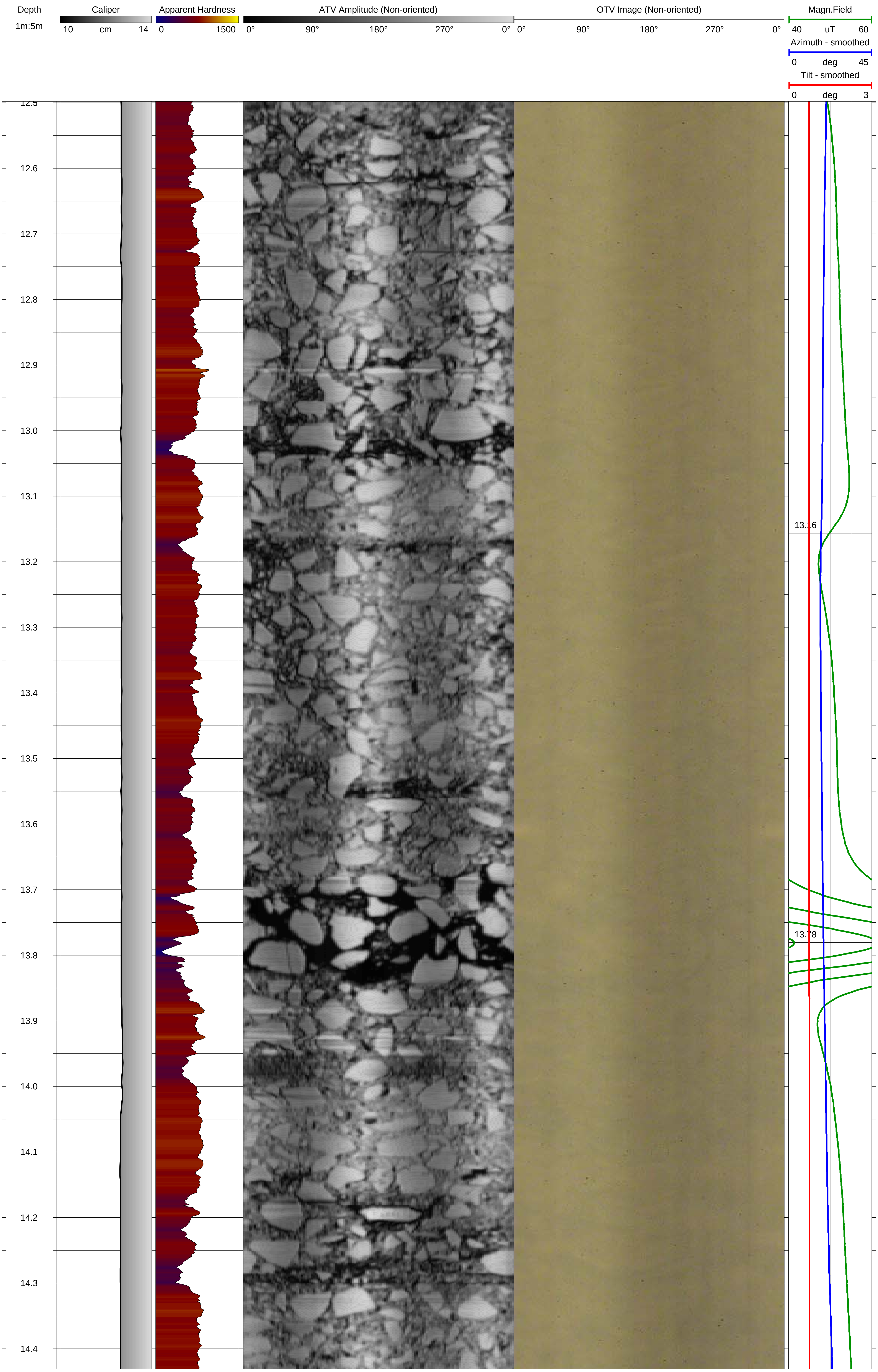
11.81
12.37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Apparent Hardness
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OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
12.5
12.6
12.7
12.8
12.9
13.0
13.1
13.2
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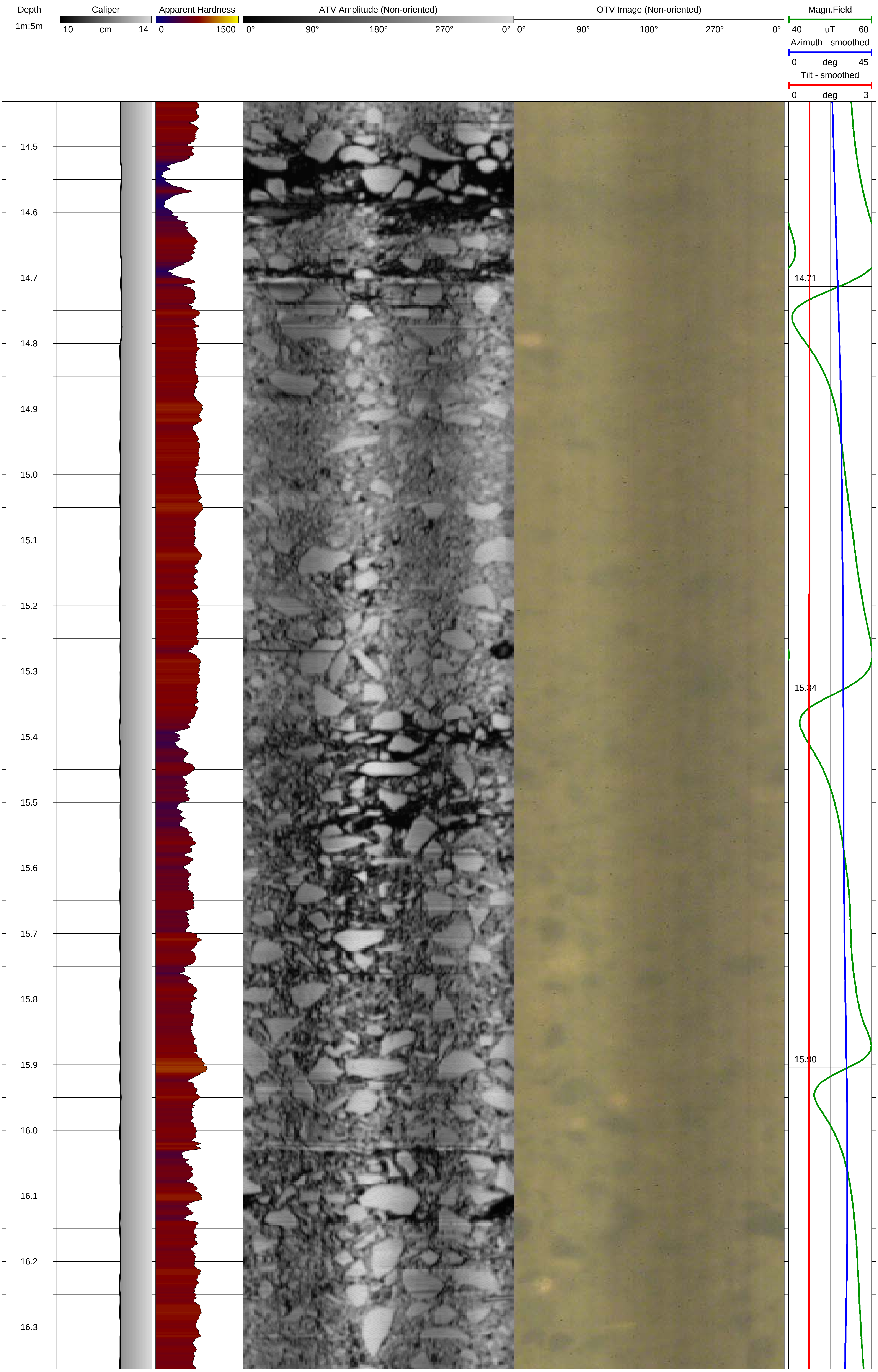
14.2
14.3
14.4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Caliper
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Apparent Hardness
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ATV Amplitude (Non-oriented)
0° 90° 180° 270° 0°
OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
14.5
14.6
14.7
14.8
14.9
15.0
15.1
15.2
15.3
15.4
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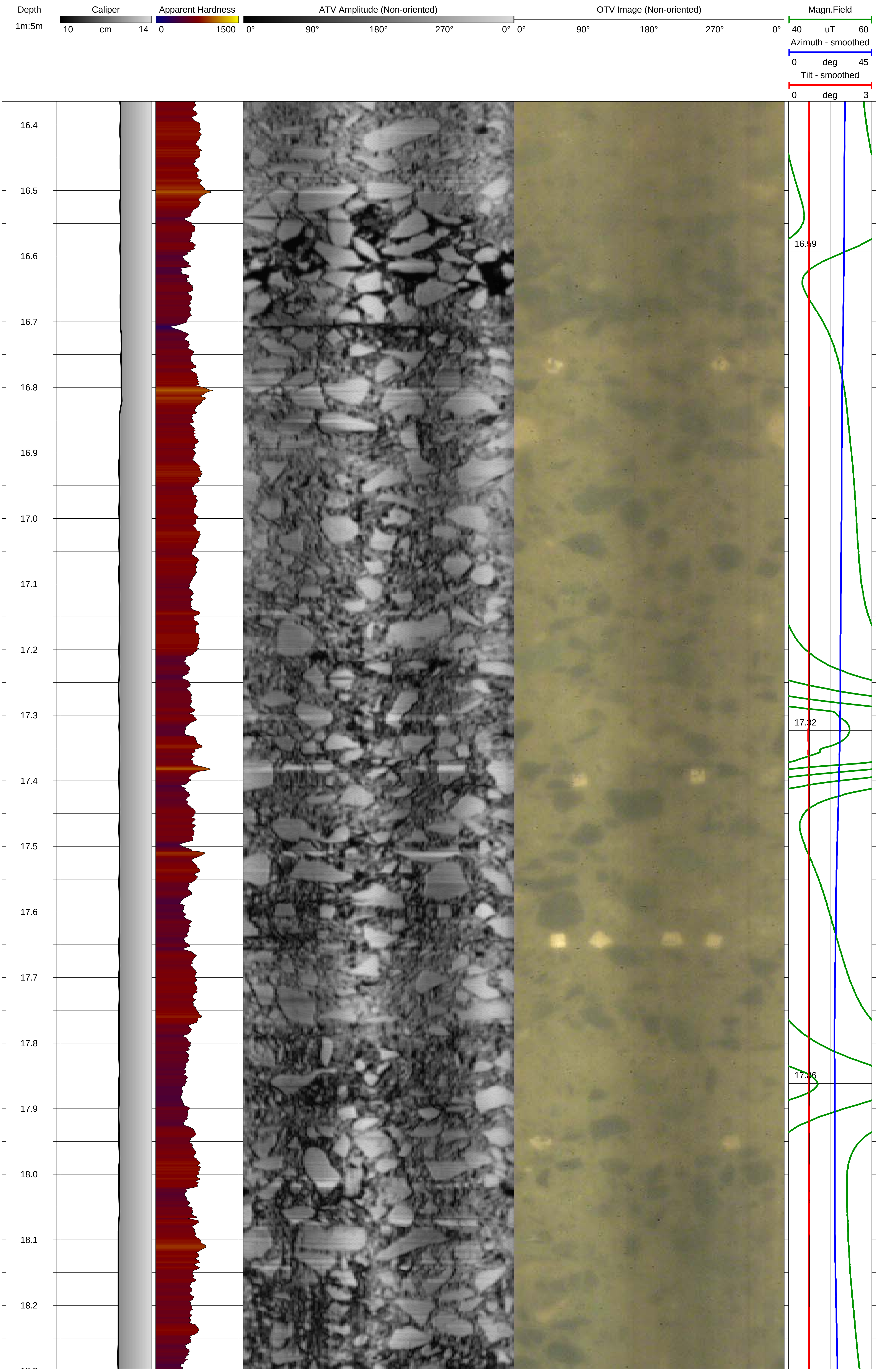
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1m:5m
Caliper
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Apparent Hardness
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OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
16.4
16.5
16.6
16.7
16.8
16.9
17.0
17.1
17.2
17.3
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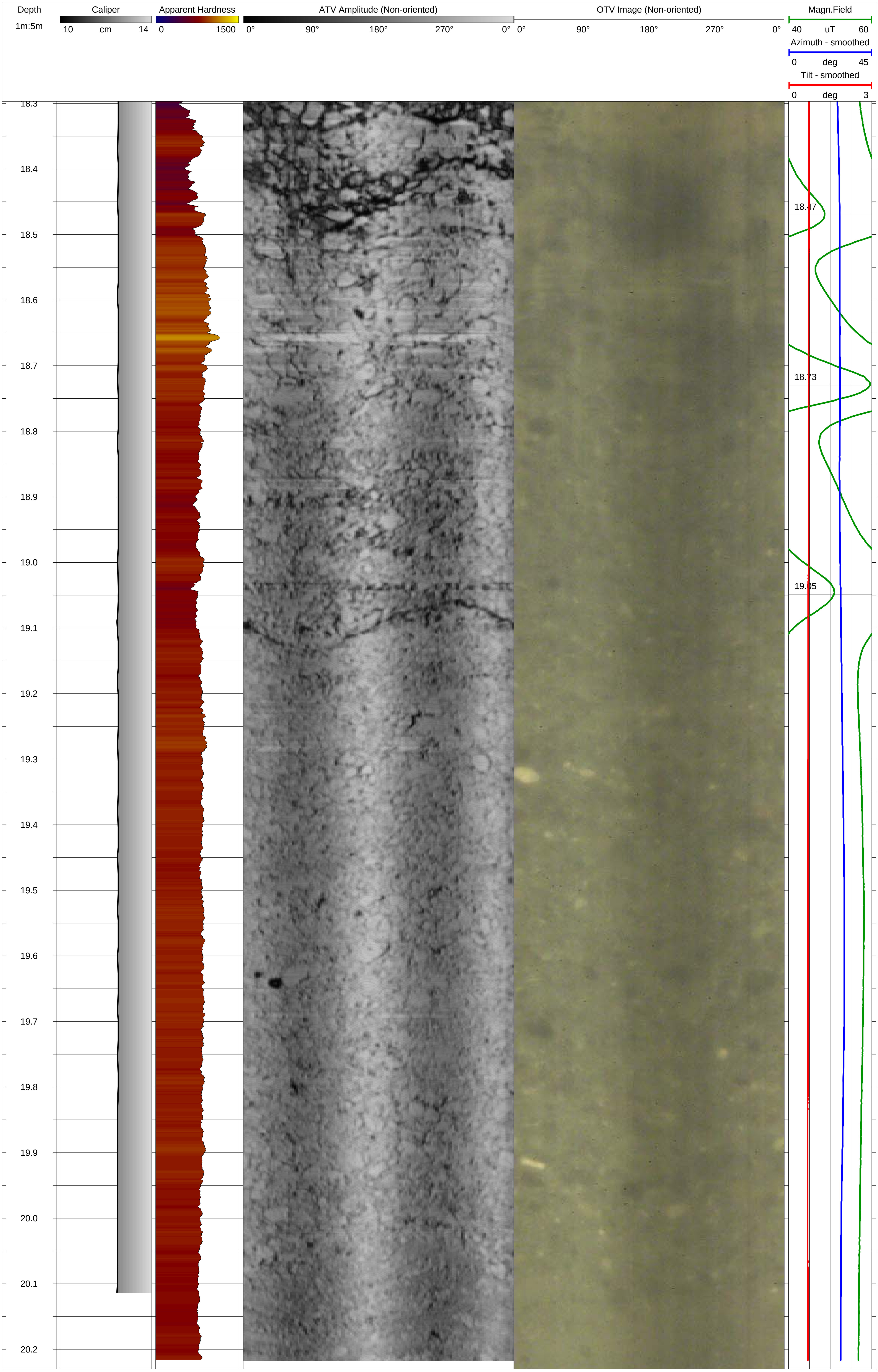

Depth
1m:5m
Caliper
10 cm 14
Apparent Hardness
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ATV Amplitude (Non-oriented)
0° 90° 180° 270° 0°
OTV Image (Non-oriented)
0° 90° 180° 270° 0°
Magn.Field
40 uT 60
Azimuth - smoothed
0 deg 45
Tilt - smoothed
0 deg 3
18.3
18.4
18.5
18.6
18.7
18.8
18.9
19.0
19.1
19.2
19.3
19.4
19.5
19.6
19.7
19.8
19.9
20.0
20.1
20.2
18.47
18.73
19.05

Depth	Caliper	Apparent Hardness	ATV Amplitude (Non-oriented)	OTV Image (Non-oriented)	Magn.Field
1m:5m	10 cm 14	0 1500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	40 uT 60 Azimuth - smoothed 0 deg 45 Tilt - smoothed 0 deg 3
20.3					

DRAFT

GEOPHYSICAL RECORD OF BOREHOLE: CH14-03

PROJECT REF. *13-1447-0516/7000*

LOCATION *Colliery Dams, Nanaimo*

LOG DATE *March 26, 2014*

LOG REF. *Ground surface (Elev. 73.5 m)*

GEOPHYSICAL RECORD OF BOREHOLE: CH14-03

PROJECT REF. *13-1447-0516/7000*

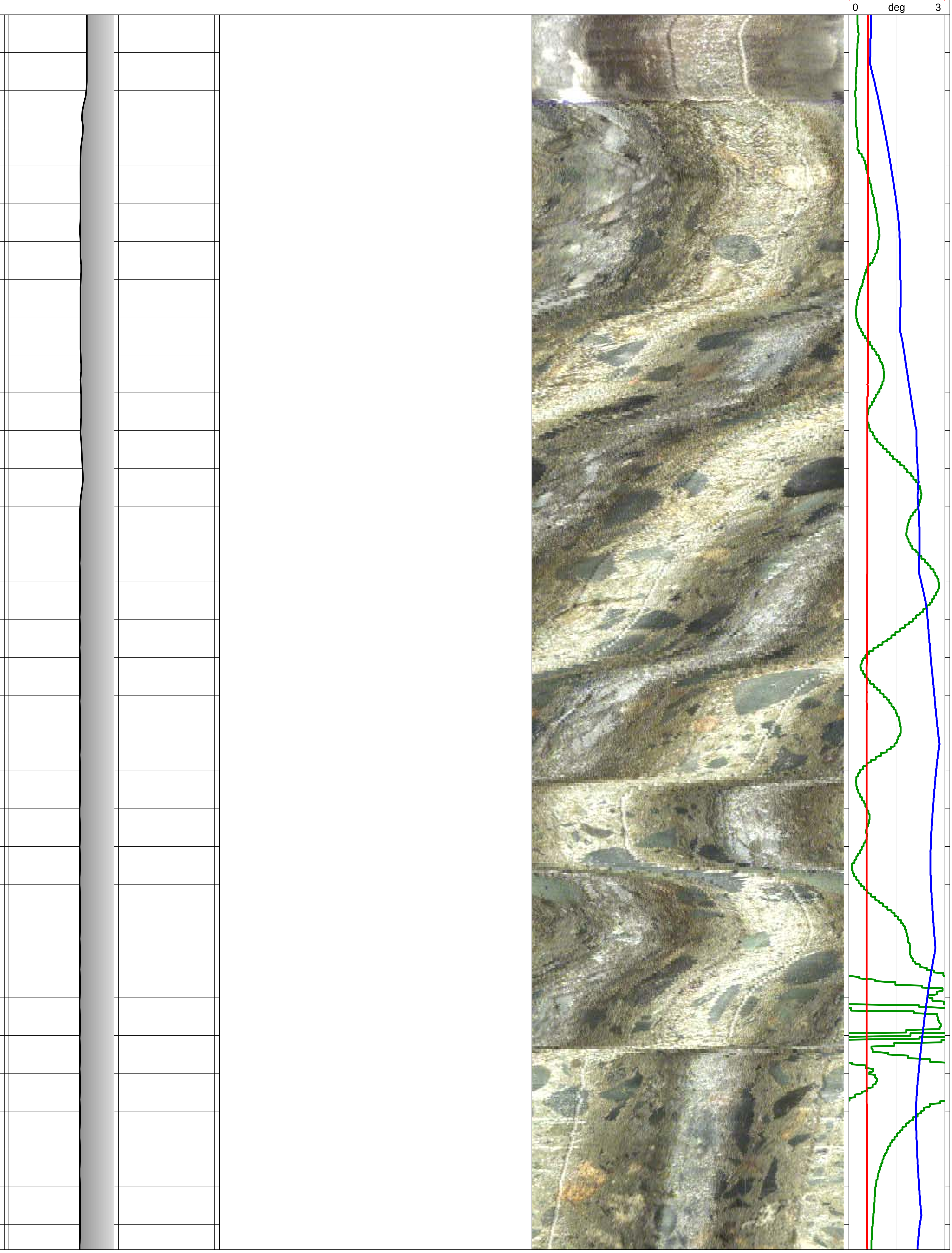
LOCATION *Colliery Dams, Nanaimo*

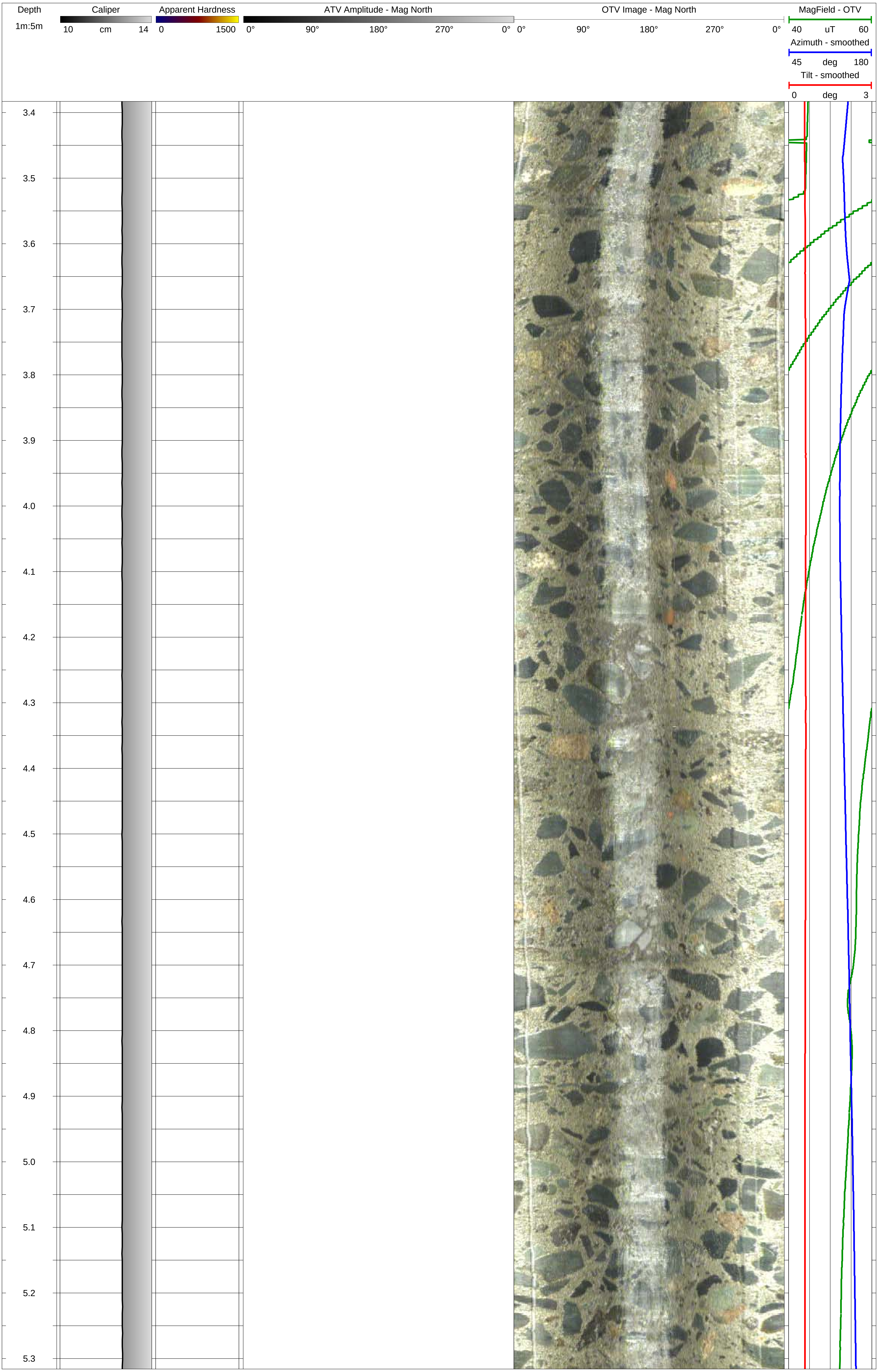
LOG DATE *March 26, 2014*

LOG REF. *Ground surface (Elev. 73.5 m)*

Depth 1m:5m	Caliper 10 cm 14	Apparent Hardness 0 1500	ATV Amplitude - Mag North 0° 90° 180° 270° 0°	OTV Image - Mag North 0° 90° 180° 270° 0°	MagField - OTV 40 uT 60; Azimuth - smoothed 45 deg 180; Tilt - smoothed 0 deg 3

1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3

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MagField - OTV
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Tilt - smoothed
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3.8
3.9
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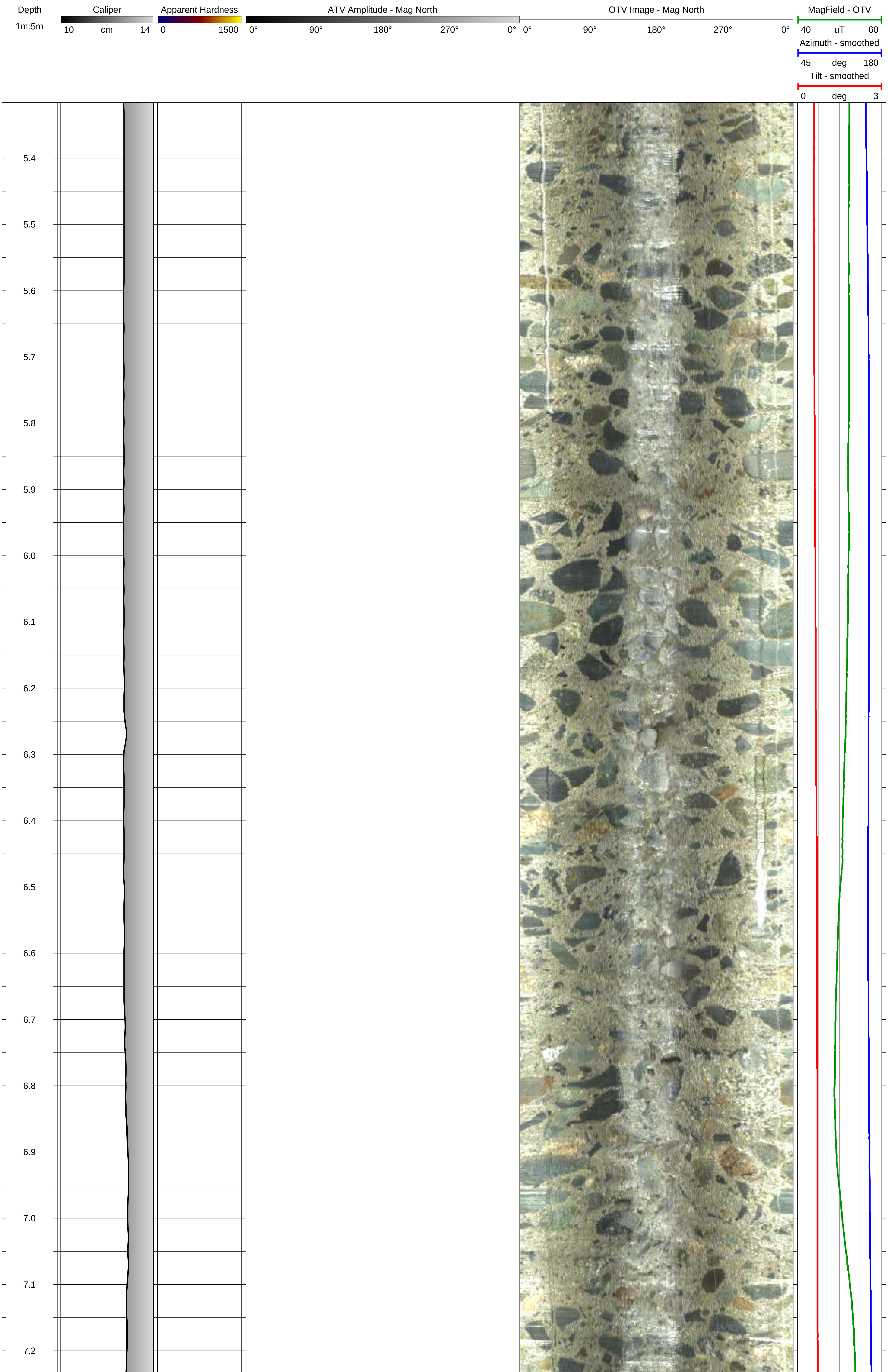
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OTV Image - Mag North
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MagField - OTV
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45 deg 180
Tilt - smoothed
0 deg 3
5.4
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5.7
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5.9
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6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
6.9
7.0
7.1
7.2

Depth	Caliper	Apparent Hardness	ATV Amplitude - Mag North	OTV Image - Mag North	MagField - OTV
1m:5m	10 cm 14	0 1500	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	40 uT 60
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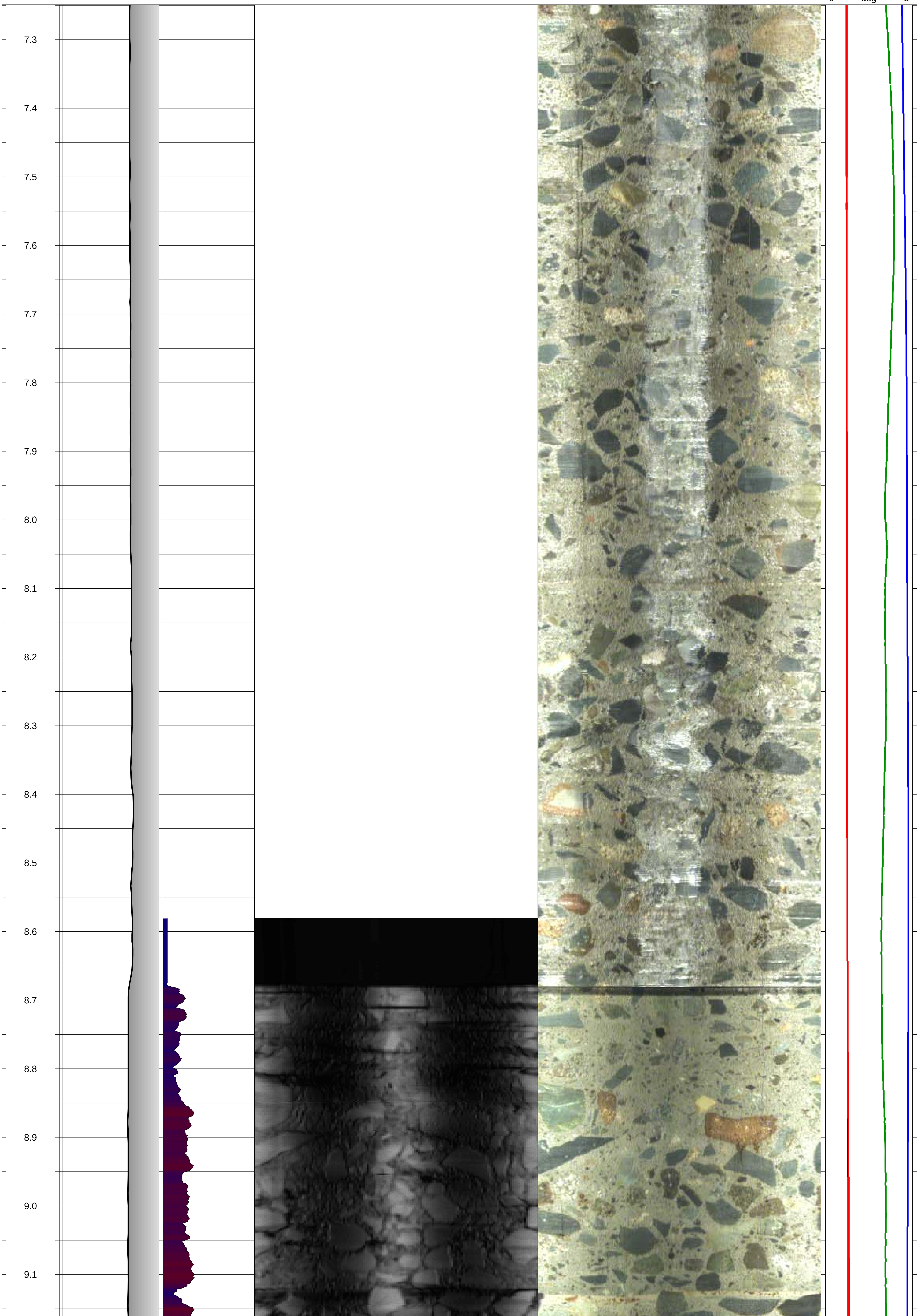
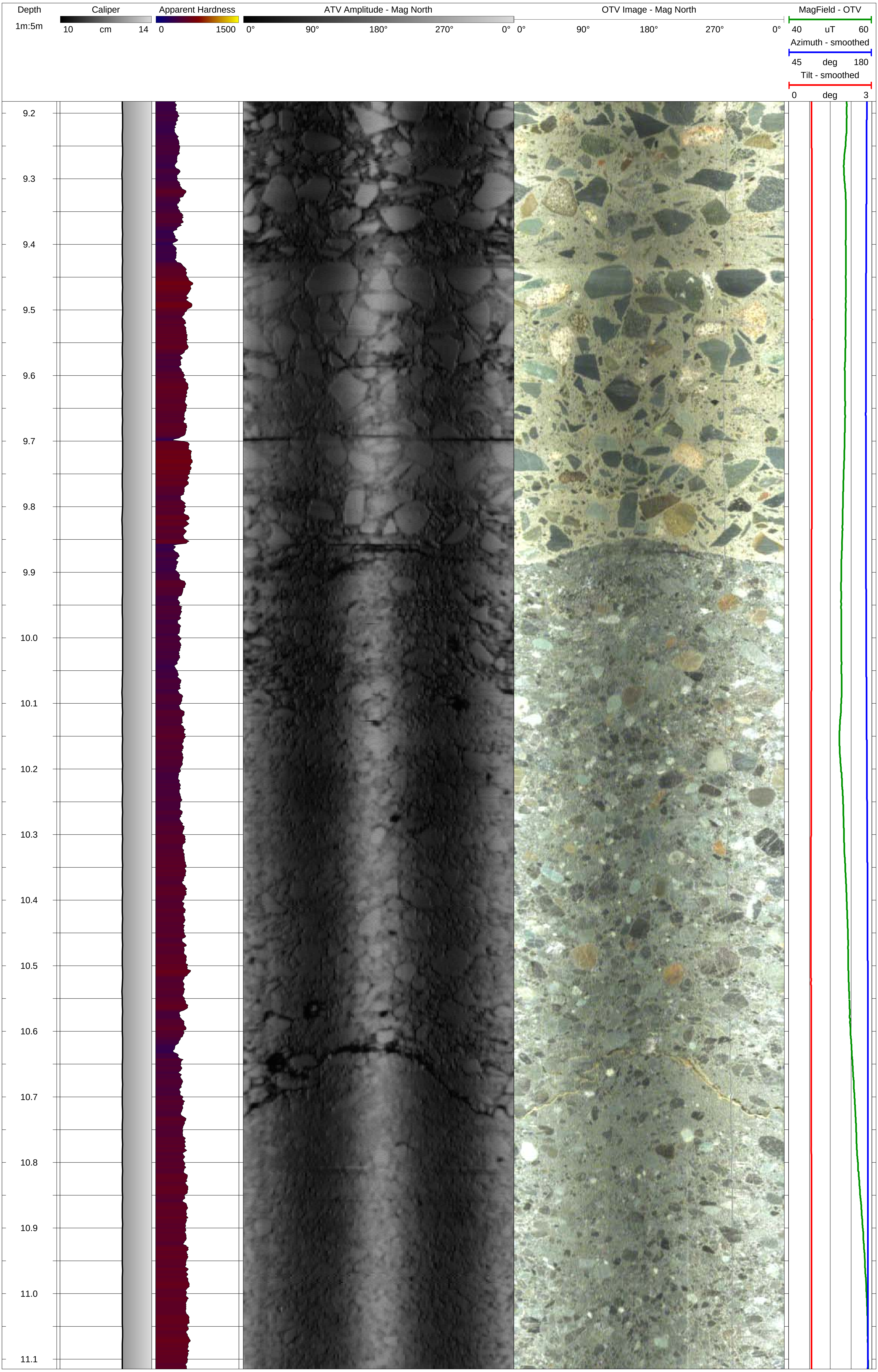
					Tilt - smoothed
					0 deg 3

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Caliper
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Apparent Hardness
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MagField - OTV
40 uT 60
Azimuth - smoothed
45 deg 180
Tilt - smoothed
0 deg 3
9.2
9.3
9.4
9.5
9.6
9.7
9.8
9.9
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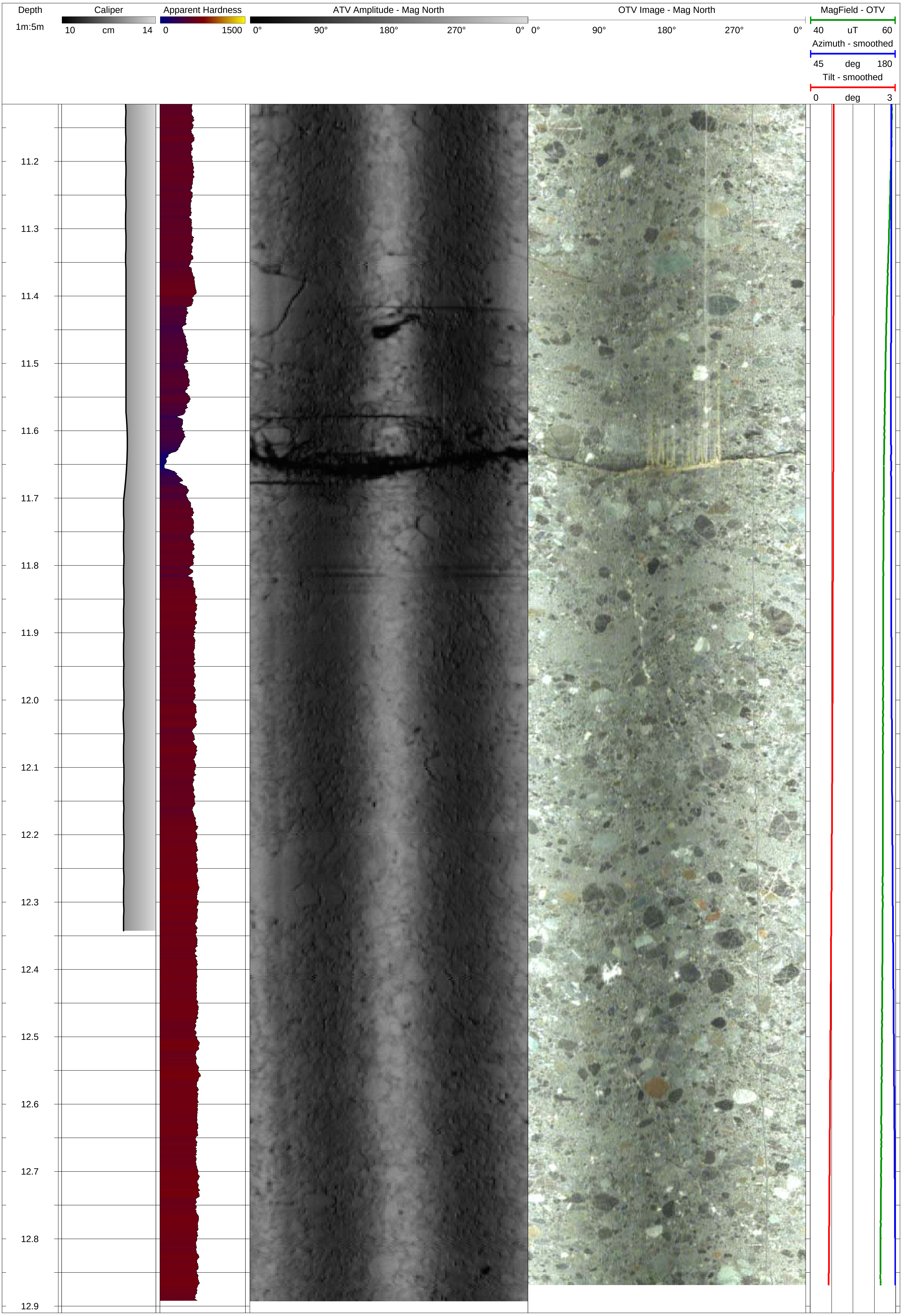
Depth
1m:5m
Caliper
10 cm 14
Apparent Hardness
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ATV Amplitude - Mag North
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MagField - OTV
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Azimuth - smoothed
45 deg 180
Tilt - smoothed
0 deg 3
11.2
11.3
11.4
11.5
11.6
11.7
11.8
11.9
12.0
12.1
12.2
12.3
12.4
12.5
12.6
12.7
12.8
12.9

Annex C Downhole Seismic Velocity of Lower Dam

Downhole Seismic Field Data Report

Colliery Dam, Nanaimo BC

***Prepared for*:**

Golder Associates

Job No: 14-02034

March 21st, 2014

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Richmond, BC V6V 1J8

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TABLE OF CONTENTS

APPENDICES

APPENDIX A – DST Summary and Results

APPENDIX B – DST Time Domain Traces

1.0 INTRODUCTION

The enclosed report presents the results of a downhole seismic test program conducted by ConeTec Investigations Ltd. for Golder Associates on March 21st, 2014 at Colliery Dam, Nanaimo British Columbia. The program consisted of a single test in a cased borehole to a depth of 18.8m.

2.0 FIELD EQUIPMENT AND PROCEDURES

2.1 Downhole Seismic Testing Procedures

Downhole seismic testing (DST) was conducted using a system comprising a surface source (steel beam), a downhole tool equipped with a triaxial geophone package, and a data acquisition system (see Figure 1). In the downhole tool the geophones are mounted on an internal block such that the orientation of the geophones can be maintained within the borehole through the use of a built in fluxgate compass and servo motor system. The equipment and procedure comply with ASTM D 7400 – 08, Standard Test Methods for Downhole Seismic Testing.

The test was performed by lowering the tool to the initial start depth in the cased borehole where it was then coupled to the side of the casing using a motor driven bow spring clamp. Once clamped in place, the two horizontal geophones were aligned parallel and perpendicular to the shear wave source. Doing so maintains the same orientation of the receivers throughout the test which eliminates any apparent phase changes due to rotation of the receivers.

To generate a shear wave, a steel beam was struck a number of times to generate a horizontally polarized shear wave (S wave) that traveled from the surface to the geophone package. The recorded signal from the horizontally oriented geophone parallel to the source was used to determine the arrival time of the shear wave. At each depth the geophone data was reviewed on the data acquisition computer and after sufficient data was recorded at a single depth the tool was lowered by a set increment (1 metre) to the next depth and the procedure was repeated. The depth of the source was also recorded at each test depth, so that travel times could be corrected for the change in raypath as the source wedge was driven deeper. The data is presented as a shear wave velocity profile at the test increments. The time domain traces used for the travel time picks are provided for reference.

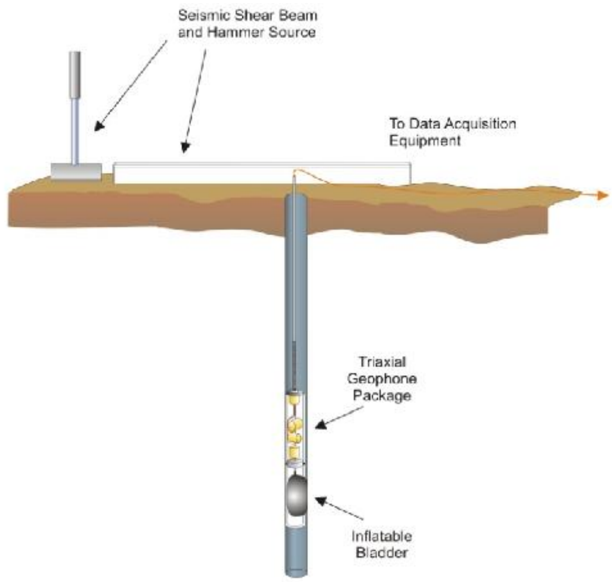


Figure 1 – Typical downhole seismic testing equipment

3.0 TEST RESULTS

3.1 Downhole Seismic Test Results

A summary of the testing performed and the shear wave velocity data, presented in tabular and graphical format, is provided in Appendix A. Images of the time domain traces used for the shear wave picks for all locations are provided for reference in Appendix B. The traces provide a visual representation of the shear wave arrivals and an indication of the data quality. The depth of the data is referenced to the existing ground surface at the time of testing.

4.0 CLOSING

We trust that the information presented in this report is sufficient for your purposes. If you have any questions regarding the contents of this report, please contact our office.

Sincerely,

ConeTec Investigations Ltd.

APPENDIX A

DST – Summary and Results

Job No:	14-02034
Client:	Golder Associates
Project Title:	Colliery Dam, Nanaimo BC
Date:	28-Mar-14

Downhole Seismic Summary

Sounding ID	Location	Date	Northing (m)	Easting (m)	Comments
SH14-05	Colliery Dam	03/21/14	5444555	429858	max depth 18.8m

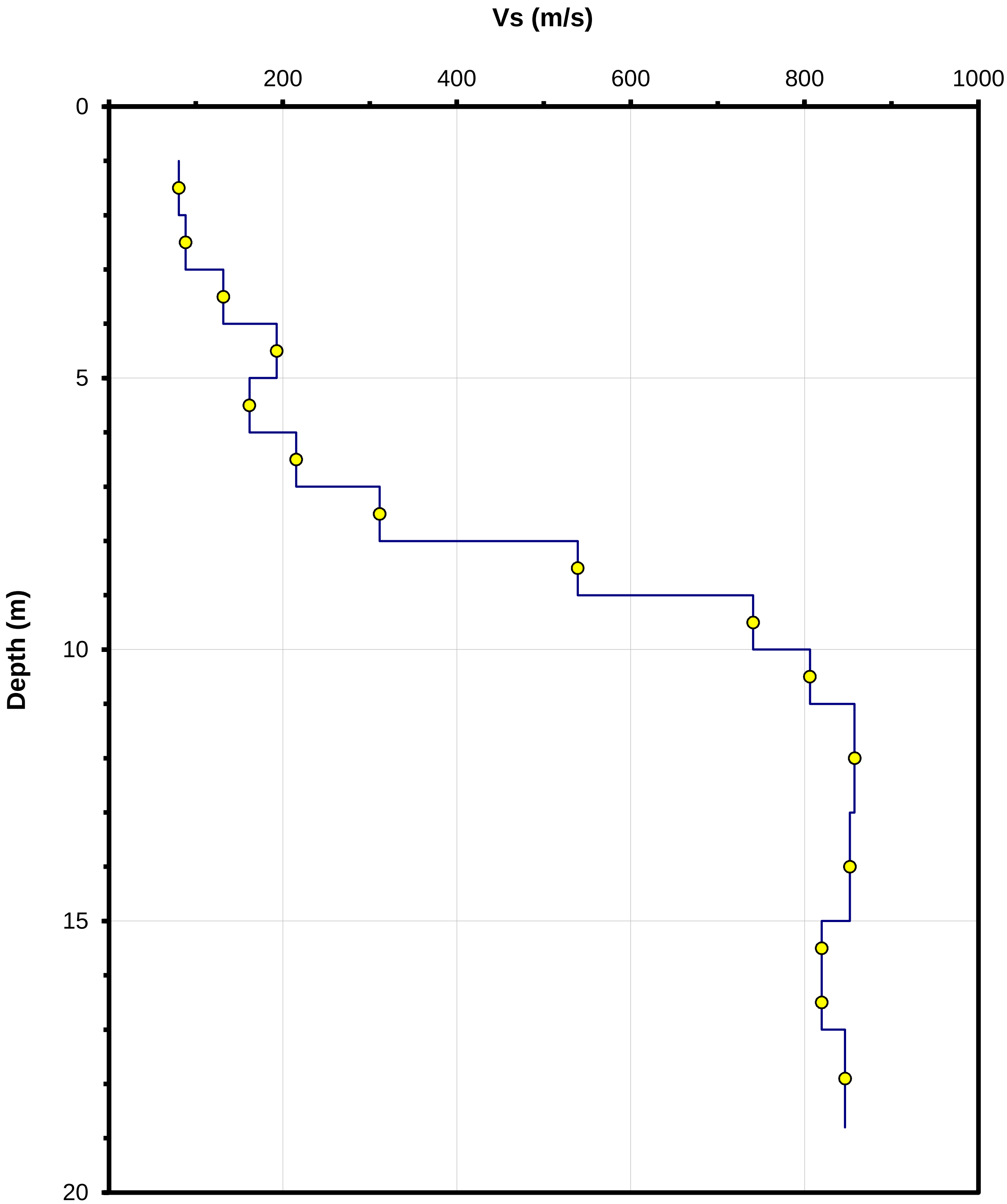
Coordinates were obtained with a handheld GPS, datum: WGS 84 / UTM Zone 10 North.

Job No.:	14-02034
Client:	Golder Associates
Project:	Colliery Dam, Nanaimo BC
Sounding:	SH14-05
Date:	21-Mar-14
Receivers:	Geostuff BHG-3 - Triaxial 15 Hz geophones
Seismograph:	Geometrics Geode
Seismic Source:	Beam
Source Offset (m):	1.00
Source Depth (m):	0.00
Geophone Offset (m):	0.00

Downhole Seismic - S Wave

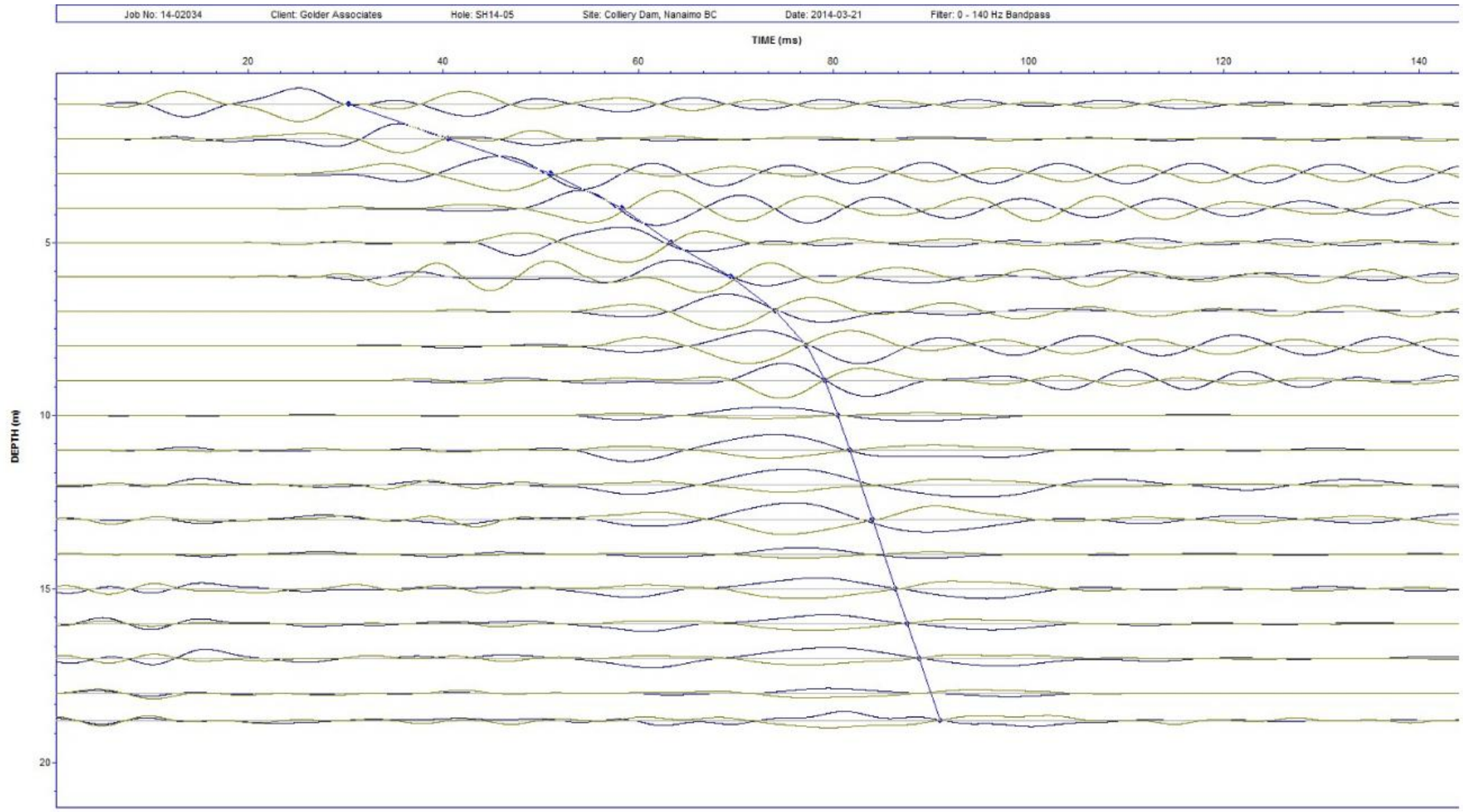
Geophone Depth (m)	Ray Path (m)	Depth Interval (m)	Time Interval (ms)	Vs (m/s)	Mid Layer (m)
1.00	1.41				
2.00	2.24	0.82	10.21	81	1.50
3.00	3.16	0.93	10.49	88	2.50
4.00	4.12	0.96	7.31	132	3.50
5.00	5.10	0.98	5.06	193	4.50
6.00	6.08	0.98	6.09	162	5.50
7.00	7.07	0.99	4.59	215	6.50
8.00	8.06	0.99	3.18	311	7.50
9.00	9.06	0.99	1.84	539	8.50
10.00	10.05	0.99	1.34	741	9.50
11.00	11.05	1.00	1.23	806	10.50
13.00	13.04	1.99	2.32	858	12.00
15.00	15.03	1.99	2.34	852	14.00
16.00	16.03	1.00	1.22	820	15.50
17.00	17.03	1.00	1.22	820	16.50
18.80	18.83	1.80	2.12	847	17.90

Job No: 14-02034
Client: Golder Associates
Project: Colliery Dam, Nanaimo BC
Sounding: SH14-05
Date: Mar 21, 2014



APPENDIX B

DST – Time Domain Records



SH14-05 Time Domain Traces

APPENDIX C

Appendix C Geotechnical Investigation of Lower Dam

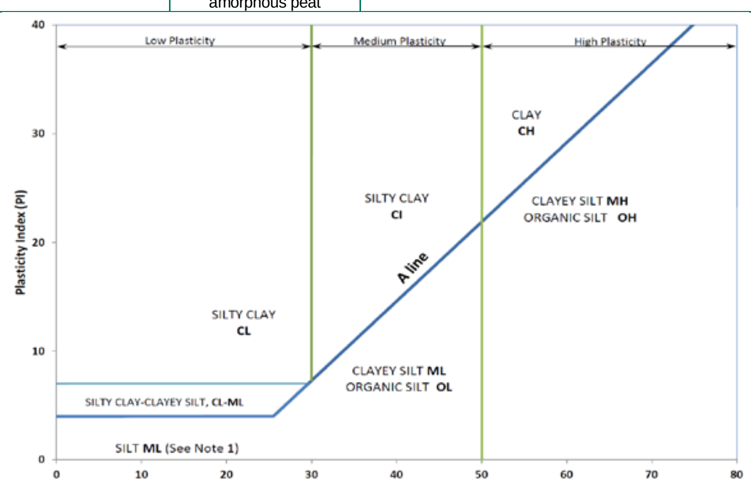
Annex A Record of Testholes

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators: Dilatancy	Field Indicators: Dry Strength	Field Indicators: Shine Test	Field Indicators: Thread Diameter	Field Indicators: Toughness (of 3 mm thread)	Organic Content	USCS Group Symbol	Primary Name
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.
For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.
For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.
A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c'	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes:
1. $\tau = c' + \sigma' \tan\phi'$
2. shear strength = (compressive strength)/2

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446453.29 E: 430010.17

RECORD OF BOREHOLE: SH14-04

DRILLING DATE: 02/13/2014

SHEET 1 OF 3
DATUM: NAD 83

Drilling Rig: Sonic ATV Rig; Drilling Method: Sonic

ELEV. / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	GRAVEL	SAND	FINES	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
73.50	Ground Surface						
73.35 / 0.15	ASPHALT						Flush mount well cover
	FILL - **(SP)** SAND, some gravel to gravelly, some silt; brown-grey; moist.						
	CINDERS AND SLAG FILL - **(SP)** SAND, fine to coarse, trace to some gravel, fine to coarse, some silt to silty; grey to black; moist.	G1	GS	2	75	22	Pea Gravel
		E1	GS				
		E2/4	GS				Bentonite Chips
		G2	GS				
		E3	GS				
69.84 / 3.66	RANDOM VARIABLE FILL - **(SP)** SAND and GRAVEL, fine to coarse, sub-rounded to sub-angular, trace to some silt; brown; moist.						Pea Gravel
		G3	GS	47	48	5	51 mm PVC Standpipe
67.71 / 5.79	ROCKFILL, rounded to sub-angular, trace coarse gravel; grey.						Bentonite Chips
							Pea Gravel

Runs 1–7 (recovery shown graphically).

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446453.29 E: 430010.17

RECORD OF BOREHOLE: SH14-04

DRILLING DATE: 02/13/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES – NUMBER	SAMPLES – TYPE	RUN No.	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
10	Sonic ATV Rig	Sonic	ROCKFILL, rounded to sub-angular, trace coarse gravel; grey. *(continued)*				7	
11							8	Pea Gravel
								51 mm Slotted PVC Screen
12			- trace to some sand, trace gravel below approximately 12.2 m.					Filter Sand
			FILL - CONCRETE WASTE.	61.00 / 12.50			9	
13								
14							10	
15							11	
16			TILL-LIKE FILL - **(GM)** sandy SILTY GRAVEL to **(SM/GP)** SILTY SAND and GRAVEL, medium to coarse sand, fine to coarse gravel, trace to some plastic fines; brown; with cobbles, moist.	57.04 / 16.46				Bentonite Chips
17			- 100mm thick grey layer encountered at approximate 16.5 m depth. - moist to wet from approximately 16.5 m to 18.0 m. - becomes grey at approximately 18 m.		G4	GS	12	
18					G5	GS	13	
19			FILL - **(ML)** gravelly sandy SILT, fine to coarse, sub-angular gravel; grey; dry.	54.15 / 53.99 / 19.51	G6	GS	14	
20								

Column headings: BLOWS/0.3m; RUN – RECOVERY % (80 60 40 20); ICE DESCRIPTION; GRADATION % – GRAVEL, SAND, FINES; SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80); WATER CONTENT % (Wp ⊢—○W—⊣ Wl; field est. - ◎ lab - ○ ice est. - ⬠; 10 20 30 40); ADDITIONAL LAB. TESTING; STRATA PLOT.

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

File:GINT_GAL_NATIONALIM Output Form:BC_BOREHOLE (SONIC) (AUTO) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB matrobertson 4/30/14

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446453.29 E: 430010.17

RECORD OF BOREHOLE: SH14-04

DRILLING DATE: 02/13/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	ICE DESCRIPTION	GRAVEL	SAND	FINES	SHEAR STRENGTH Cu, kPa / WATER CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
20	Sonic ATV Rig	Sonic	fresh, massive; grey to dark grey; pebbles and granules, medium strong, CONGLOMERATE, clast supported, clasts typically sub-rounded. *(continued)*		52.47				14								Bentonite Chips
21			End of Borehole.		21.03												
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

Shear strength legend: nat V. + Q - ● rem V. ⊕ U - ○; scale 20 40 60 80
Water content legend: Wp ⊢—○W—⊣ Wl; field est. - ◎ lab - ○ ice est. - ⬠; scale 10 20 30 40

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

RECORD OF BOREHOLE: SH14-05

DATUM: NAD 83

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446460.84 E: 430007.43

DRILLING DATE: 02/11/2014 - 02/12/2014

DRILLING RIG: Sonic ATV Rig
DRILLING METHOD: Sonic

DEPTH (m)	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	RUN No.	GRAVEL	SAND	FINES	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
	Ground Surface	73.50							
0	ASPHALT	73.35 / 0.15			1				Flush mount well cover
	FILL - **(SM)** SILTY SAND, fine to coarse, some fine gravel; brown; moist.								
	CINDERS AND SLAG FILL - **(SP/GP)** SAND, fine to coarse, trace gravel, some silt to silty; to **(ML)** sandy SILT, some gravel; black; moist.		E1	GS	1				
3			E2	GS	2				Grout
			G1	GS	2				
			E3	GS	2				
5					3				76 mm PVC Standpipe
			G2	GS	3	1	71	28	
			E4	GS	3				
6.4	RANDOM VARIABLE FILL - **(SC)** gravelly CLAYEY SAND, fine to coarse sand, fine to coarse gravel; brown; moist. - 89 mm thick sub-angular cobble encountered at approximately 6.4 m depth.	67.10 / 6.40			4				
			E5	GS	4				
8					5				
9	- 102 mm thick sub-angular cobble encountered at approximately 8.8 m depth.		G3	GS	6	21	43	36	
9.45	ROCKFILL, rounded to sub-angular; grey. - broken up from 9.4 m to 10.3 m.	64.05 / 9.45			6				
10									

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

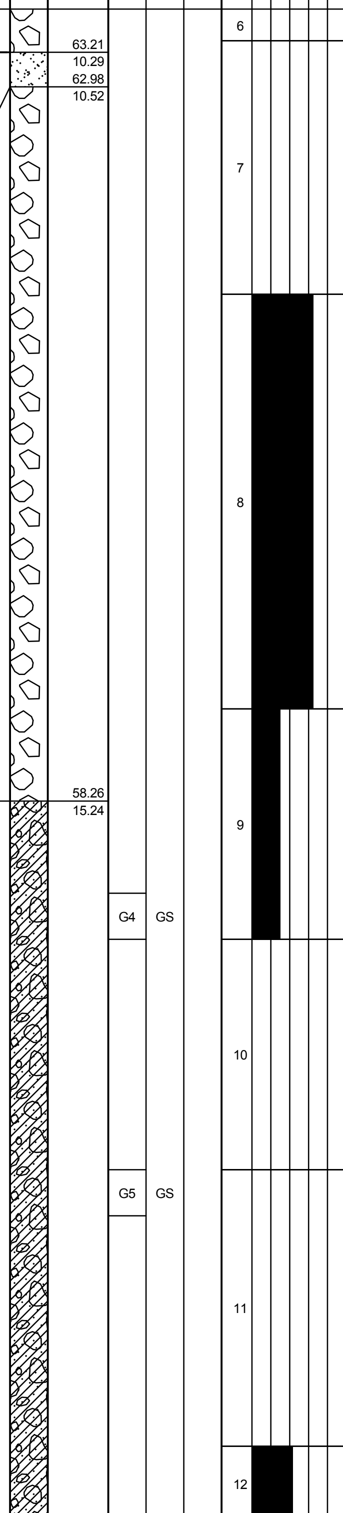
PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446460.84 E: 430007.43

RECORD OF BOREHOLE: SH14-05

DRILLING DATE: 02/11/2014 - 02/12/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/0.3m	RUN No.	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
10	Sonic ATV Rig	Sonic	ROCKFILL, rounded to sub-angular; grey. *(continued)*	63.21 / 10.29				6	
			FILL - **(SC)** CLAYEY SAND, fine to coarse, some gravel to gravelly, fine to coarsel grey; moist.	62.98 / 10.52					
11			ROCKFILL, rounded to sub-angular; grey.					7	
12–14								8	
15			TILL-LIKE FILL - **(GC/GP)** CLAYEY SANDY GRAVEL to **(ML)** sandy CLAYEY SILT, some gravel, fine to coarse; grey; moist.	58.26 / 15.24				9	76 mm PVC Standpipe
16					G4	GS			Grout
17								10	
18			- 0.3 m thick layer of sand, grading to sandy gravel, fine to medium, trace to some fines, encountered at approximately 17.7 m depth.		G5	GS		11	
19			- with cobbles below approximately 19.2 m. - cobbles in a sand matrix encountered between 20.6 m and 21.0 m depth.					12	Bentonite Chips
20									



CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446460.84 E: 430007.43

RECORD OF BOREHOLE: SH14-05

DRILLING DATE: 02/11/2014 - 02/12/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	RUN No.	RECOVERY %	ICE DESCRIPTION	GRAVEL	SAND	FINES	SHEAR STRENGTH Cu, kPa / WATER CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
20	Sonic ATV Rig	Sonic	TILL-LIKE FILL - **(GC/GP)** CLAYEY SANDY GRAVEL to **(ML)** sandy CLAYEY SILT, some gravel, fine to coarse; grey; moist. *(continued)*						12								Bentonite Chips
21					52.01 / 21.49	G6	GS		13								
22			fresh, massive; grey to dark grey; pebbles and granules, medium strong CONGLOMERATE, clast supported, clasts typically sub-rounded.		51.10 / 22.40												
			End of Borehole.														
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

Shear strength legend: nat V. + Q - ●; rem V. ⊕ U - ○; scale 20 40 60 80
Water content legend: Wp ⊢—○W—⊣ Wl; field est. - ◎; lab - ○; ice est. - ⬠; scale 10 20 30 40

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446469.88 E: 430004.15

RECORD OF BOREHOLE: SH14-06

DRILLING DATE: 02/14/2014

DATUM: NAD 83

Drilling Rig: Sonic ATV Rig; Drilling Method: Sonic

Depth (m)	Description	Elev. / Depth (m)	Sample Number	Sample Type	Run No.	Gravel	Sand	Fines	Piezometer / Standpipe Installation
0	Ground Surface	73.50							
	ASPHALT	0.03							Concrete
	FILL - **(SP/GP)** SAND and GRAVEL, fine to coarse, sub-angular to sub-rounded; grey; moist.	73.04 / 0.46			1				
	CINDERS AND SLAG FILL - **(SP)** SAND, fine to coarse, some fine gravel, some silt to silty, sub-angular; grey to black; moist. - 50 mm thick light brown layer encountered at approximately 0.5 m.								Bentonite Chips
			E1	GS	2				
			G1	GS		2	66	32	
3									Pea Gravel
		69.84 / 3.66	E2	GS					
	RANDOM VARIABLE FILL - **(SP)** SILT and SAND, fine to coarse, some gravel to **(SP/GP)** sandy GRAVEL, fine to coarse, sub-rounded to sub-angular, trace to some silt; brown; moist.				3				
			G2	GS		19	41	40	
	- 76 mm thick sub-rounded cobble encountered at approximately 5.2 m.	67.71 / 5.79							Bentonite Chips
	RANDOM VARIABLE FILL - **(GC)** sandy CLAYEY GRAVEL, fine to coarse sand, fine to coarse sub-rounded to angular gravel; brown; moist.				4				
	- with cobbles below approximately 7.6 m depth.		G3	GS					
	- trace to some plastic fines encountered between 7.9 m and 8.5 m.				5				Pea Gravel
	- becomes mottled grey below approximately 8.8 m. - 152 mm sub-angular cobble encountered at approximately 9.1 m.	63.98 / 9.53			6				
	CONGLOMERATE ROCKFILL, rounded to sub-angular; grey.								
10									

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446469.88 E: 430004.15

RECORD OF BOREHOLE: SH14-06

DRILLING DATE: 02/14/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	RUN No.	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
10	Sonic ATV Rig	Sonic	CONGLOMERATE ROCKFILL, rounded to sub-angular; grey. *(continued)*		6	Pea Gravel
11						Bentonite Chips
12					7	
13						
14			- core broken up from approximately 13.4 m to 15.4 m.		8	
15						
16			- slight cohesive behavior observed in fines matrix within rockfill between 16.6 m and 16.9 m.	56.58 / 16.92	9	Pea Gravel
17			FILL - **(SP)** SAND, fine to coarse, some fine gravel to gravelly, trace to some silt; grey; moist. - 0.2 m thick layer of sand, some silt to silty, trace to some plastic fines encountered at approximately 17.4 m.	55.97 / 17.53	10	
18			fresh, massive; grey to dark grey; pebbles and granules, medium strong CONGLOMERATE, clast supported, clasts typically sub-rounded.		11	
19					12	Bentonite Seal
20						

Other column headings: STRATA PLOT; SAMPLES (NUMBER, TYPE, BLOWS/0.3m); RUN RECOVERY % (80 60 40 20); ICE DESCRIPTION; GRADATION % (GRAVEL, SAND, FINES); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○; 20 40 60 80); WATER CONTENT % (Wp —○W— Wl; field est. - ◎, lab - ○, ice est. - ⬠; 10 20 30 40); ADDITIONAL LAB. TESTING

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446469.88 E: 430004.15

RECORD OF BOREHOLE: SH14-06

DRILLING DATE: 02/14/2014

DATUM: NAD 83

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	RUN No.	RECOVERY %	ICE DESCRIPTION	GRAVEL	SAND	FINES	SHEAR STRENGTH Cu, kPa / WATER CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
20	Sonic ATV Rig	Sonic	fresh, massive; grey to dark grey; pebbles and granules, medium strong CONGLOMERATE, clast supported, clasts typically sub-rounded. *(continued)*		52.47				12								Bentonite Seal
21			End of Borehole.		21.03												
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

Shear strength legend: nat V. + Q - ●; rem V. ⊕ U - ○; scale 20 40 60 80
Water content legend: Wp ⊢—○W—⊣ Wl; field est. - ◎; lab - ○; ice est. - ⬠; scale 10 20 30 40
Recovery scale: 80 60 40 20

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Berm

RECORD OF TEST PIT: TP14-01

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■) 20 40 60 80; WATER CONTENT PERCENT Wp ├─○W─┤ Wl, NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand Shovel	TOPSOIL FILL - **(ML)** CLAYEY SILT, some organics (roots), trace to some sand, trace gravel; brown; w>PL.		0.00											
		FILL - **(SP/GP)** SAND and GRAVEL, fine to coarse, trace silt; brown-grey to grey; with cobbles, moist, dense.			1	GS									
					2	GS									
1		End of Test Pit.		0.99											
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

RECORD OF TEST PIT: TP14-01B

PROJECT No.: 13-1447-0516 / 7000 / 7300
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Berm

SHEET 1 OF 1
DATUM: NAD 83

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa / WATER CONTENT PERCENT	GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	TOPSOIL FILL - **(ML)** CLAYEY SILT, some organics (roots), trace to some sand, trace gravel; brown; w>PL.													
		CINDERS AND SLAG FILL		0.30											
		End of Test Pit.													
1															
2															
3															
4															
5															

Shear strength legend: nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■ ; scale 20 40 60 80
Water content: Wp ⊢—○W—⊣ Wl ; NP - Non-Plastic ; scale 10 20 30 40

DEPTH SCALE
1 : 40

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Berm

RECORD OF TEST PIT: TP14-02

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE - DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION % GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	TOPSOIL FILL - **(ML)** CLAYEY SILT, some organics (roots), trace to some sand, trace gravel; brown; w>PL.		0.08											
		FILL - **(SP/GP)** SAND and GRAVEL, fine to coarse, trace silt; brown-grey to grey; with cobbles, moist, dense.		0.61											
		End of Test Pit.													
1															
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Berm

RECORD OF TEST PIT: TP14-02B

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○; Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl; NP - Non-Plastic 10 20 30 40	GRADATION % GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand – Shovel	TOPSOIL FILL - **(ML)** CLAYEY SILT, some organics (roots), trace to some sand, trace gravel; brown; w>PL.		0.08											
		CINDERS AND SLAG FILL		0.30											
		End of Test Pit.													
1															
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Dam

RECORD OF TEST PIT: TP14-03

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○; Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl; NP - Non-Plastic 10 20 30 40	GRADATION % GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand Shovel	TOPSOIL FILL - **(ML)** SANDY SILT, some gravel to gravelly, some organics (rootlets); dark brown to black; with cobbles, moist.		0.00											
		(SP) SAND, fine, some gravel, trace organics (rootlets); light grey to brown mottled orange; with cobbles, moist. - becomes gravelly beyond approximately 0.61 m depth.		0.30	1	GS									
1					2	GS									
		End of Test Pit.		1.07											
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Dam

RECORD OF TEST PIT: TP14-04

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa / WATER CONTENT PERCENT	GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	TOPSOIL FILL - **(ML)** SANDY SILT, some gravel to gravelly, some organics (rootlets); dark brown to black; with cobbles, moist. - geogrid encountered at approximately 0.33 m depth.		0.00											
		CINDERS AND SLAG FILL		0.10	1	GS									
1		**(SP/GP)** SAND and GRAVEL, fine to coarse, with cobbles, rounded to sub-angular; brown; moist.		0.91	2	GS									
		End of Test Pit.		1.30											
2															
3															
4															
5															

Shear strength legend: nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■ (20, 40, 60, 80)

Water content: Wp ⊢ ○W ⊣ Wl (10, 20, 30, 40); NP - Non-Plastic

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Walkway of Spillway

RECORD OF TEST PIT: TP14-05

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	POSSIBLE FILL - **(SP)** SAND, fine to coarse, some organics, some silt, trace to some gravel; grey-brown to brown; moist.		0.00											
		POSSIBLE FILL - **(SM/GM)** SILTY SAND and GRAVEL, fine to coarse gravel; grey-brown to brown; moist.		0.23											
1		**(SP)** SAND, fine to coarse, some gravel to gravelly, trace to some silt, trace organics (roots); brown; with rounded to sub-angular cobbles, moist. - 0.23 m thick cobble encountered at approximately 1.2 m depth.		0.53											
2		- a stake was hammered into the ground from 1.52 m to a depth of approximatley 1.78 m. End of Test Pit.		1.52											
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

RECORD OF TEST PIT: TP14-06

SHEET 1 OF 1

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Toe of Dam

EXCAVATION DATE: April 01, 2014

DATUM: NAD 83

INCLINATION: -90°

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa / WATER CONTENT PERCENT	GRADATION %: GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	**(ML)** SILT, some sand to sandy, some organics (roots), trace gravel; brown to black; moist.		0.00											
		(SP) SAND, fine to coarse, some silt, some gravel to gravelly, some organics (roots), with cobbles; brown; moist. - less roots encountered below approximately 0.5 m depth.		0.15											
1		End of Test Pit.		0.91											
2															
3															
4															
5															

Shear strength legend: nat V. + Q - ● ; rem V. ⊕ U - ○ ; Pocket Pen - ■ ; scale 20 40 60 80
Water content: Wp ⊢—○W—⊣ Wl ; NP - Non-Plastic ; scale 10 20 30 40

DEPTH SCALE
1 : 40

Golder Associates

LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Crest of Berm

RECORD OF TEST PIT: TP14-07

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○; Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl; NP - Non-Plastic 10 20 30 40	GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	FILL - **(SP/GP)** SAND and GRAVEL, fine to coarse, some silt to silty, with cobbles, with organics; brown to brown-grey; moist.		0.00											
		CINDERS AND SLAG FILL		0.23	1	GS									
1		End of Test Pit.		0.91											
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Toe of Dam

RECORD OF TEST PIT: TP14-08

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○; Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl; NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand Shovel	**(ML)** SILT, some sand, some organics (roots), some gravel; brown to black, moist.		0.00											
		(SP) SAND, fine to coarse, trace to some silt, some gravel to gravelly, some organics (roots), with cobbles; brown; moist. - less roots encountered below approximately 0.6 m.		0.15											
1		End of Test Pit.		1.02											
2															
3															
4															
5															

DEPTH SCALE

1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

File:GINT_GAL_NATIONALIM Output Form:BC_TESTPIT WITH PHOTO Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB matrobertson 4/25/14

PROJECT No.: 13-1447-0516 / 7000 / 7300

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Walkway of Spillway

RECORD OF TEST PIT: TP14-09

EXCAVATION DATE: April 01, 2014

INCLINATION: -90°

SHEET 1 OF 1

DATUM: NAD 83

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○ Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp —○W— Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	SAND	FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface													
0	Dug by Hand / Shovel	POSSIBLE FILL - **(SP)** gravelly SAND, fine to coarse gravel, some silt to silty, some organics (roots), with cobbles; brown-grey; moist.		0.00											
		(SP/GP) gravelly SAND to SAND and GRAVEL, fine to coarse, trace to some silt, with cobbles; brown; moist. - 51 mm thick black organic layer encountered at approximately 0.4 m depth. - less roots encountered below approximately 0.8 m. - seepage encountered at approximately 1.0 m depth.		0.23											
1		End of Test Pit.		1.12											
2															
3															
4															
5															

DEPTH SCALE

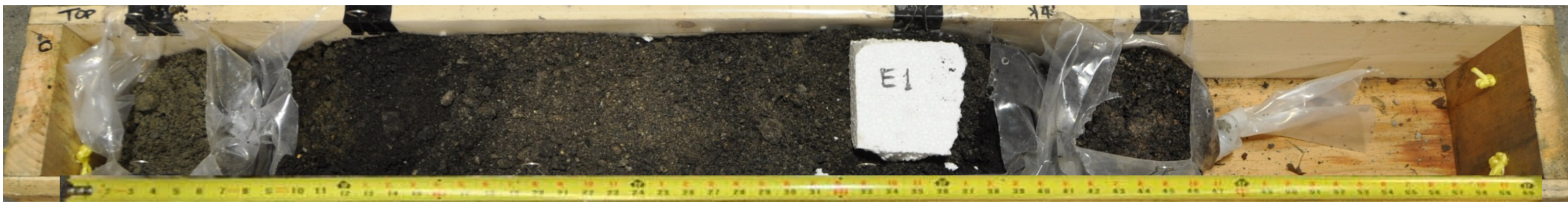
1 : 40

Golder Associates

LOGGED: TM

CHECKED: AC

Annex B Sonic Drilling Core Photos



Box 1 of 11: 0.00 m to 1.2 m (0 ft to 4.0 ft)

Box 2 of 11: 1.2 m to 4.3 m (4.0 ft to 14.0 ft)

Box 3 of 11: 4.3 m to 8.8 m (14.0 ft to 29.0 ft)

Box 4 of 11: 8.8 m to 12.3 m (29.0 ft to 40.5 ft)

Box 5 of 11: 12.3 m to 14.0 m (40.5 ft to 46.0 ft)

PROJECT
CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE
SH14-04
SONIC CORE PHOTOGRAPHS
BOXES 1 TO 5 OF 11, 0 m to 14.0 m (0 ft to 46.0 ft)

Golder Associates

PROJECT No.	13-1447-0516		Phase / Task No. 7000/7300	
DESIGN	TM	25FEB14	SCALE NTS	REV.
CADD	TM	06MAR14		
CHECK			**FIGURE C-1**	
REVIEW				

Box 6 of 11: 14.0 m to 14.9 m (46.0 ft to 49.0 ft)

Box 7 of 11: 14.9 m to 15.8 m (49.0 ft to 52.0 ft)

Box 8 of 11: 15.8 m to 18.0 m (52.0 ft to 59.0 ft)

Box 9 of 11: 18.0 m to 19.5 m (59.0 ft to 64.0 ft)

Box 10 of 11: 19.5 m to 20.5 m (64.0 ft to 67.25 ft)

PROJECT

CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE

SH14-04
SONIC CORE PHOTOGRAPHS
BOXES 6 TO 10 OF 11, 14.0 m to 20.5 m (46.0 ft to 67.25 ft)

Golder Associates

PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
DESIGN	TM	25FEB14	SCALE NTS	REV.
CADD	TM	06MAR14	
CHECK			**FIGURE C-2**
REVIEW			

Box 11 of 11: 20.5 m to 21.0 m (67.25 ft to 69.0 ft)

PROJECT	CITY OF NANAIMO COLLIERY DAMS PARK – LOWER DAM NANAIMO, B.C.			
TITLE	SH14-04 SONIC CORE PHOTOGRAPHS BOXES 11 TO 11 OF 11, 20.5m to 21.0 m (67.25 ft to 69.0 ft)			
Golder Associates	PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
	DESIGN	TM	25FEB14	SCALE NTS	REV.
	CADD	TM	06MAR14	FIGURE C-3
	CHECK			
	REVIEW			

Box 1 of 7: 0.00 m to 4.3 m (0 ft to 14.0 ft)

Box 2 of 7: 4.3 m to 8.8 m (14.0 ft to 29.0 ft)

Box 3 of 7: 8.8 m to 11.1 m (29.0 ft to 36.5 ft)

Box 4 of 7: 11.1 m to 14.6 m (36.5 ft to 48.0 ft)

Box 5 of 7: 14.6 m to 17.7 m (48.0 ft to 58.0 ft)

PROJECT
CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE
SH14-05
SONIC CORE PHOTOGRAPHS
BOXES 1 TO 5 OF 7, 0 m to 17.7 m (0 ft to 58.0 ft)

Golder Associates

PROJECT No.	13-1447-0516	Phase / Task No. 7000/7300	
DESIGN	TM	26FEB14	SCALE NTS	REV.
CADD	TM	06MAR14	
CHECK			**FIGURE C-4**
REVIEW			

Box 6 of 7: 17.7 m to 20.6 m (58.0 ft to 67.5 ft)

Box 7 of 7: 20.6 m to 22.4 m (67.5 ft to 73.5 ft)

PROJECT

CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE

SH14-05
SONIC CORE PHOTOGRAPHS
BOXES 6 TO 7 OF 7, 17.7 m to 22.4 m (58.0 ft to 73.5 ft)

PROJECT No. 13-1447-0516			Phase / Task No. 7000/7300
DESIGN	TM	26FEB14	SCALE NTS REV.
CADD	TM	06MAR14	
CHECK			**FIGURE C-5**
REVIEW			

Golder Associates

Box 1 of 13: 0.00 m to 2.7 m (0 ft to 9.0 ft)

Box 2 of 13: 2.7 m to 4.6 m (9.0 ft to 15.0 ft)

Box 3 of 13: 4.6 m to 6.1 m (15.0 ft to 20.0 ft)

Box 4 of 13: 6.1 m to 7.3 m (20.0 ft to 24.0 ft)

Box 5 of 13: 7.3 m to 8.8 m (24.0 ft to 29.0 ft)

PROJECT
CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE
SH14-06
SONIC CORE PHOTOGRAPHS
BOXES 1 TO 5 OF 13, 0 m to 8.8 m (0 ft to 29.0 ft)

Golder Associates

PROJECT No. 13-1447-0516			Phase / Task No. 7000/7300
DESIGN	TM	25FEB14	SCALE NTS REV.
CADD	TM	06MAR14	
CHECK			**FIGURE C-6**
REVIEW			

O:\Active_2013\1447\13-1447-0516 Nanaimo Colliery Dams Nanaimo\5.0 Work in Progress\Phase 7000 FIELD INVESTIGATION\7300 Geotechnical Drilling\Photos\Core Photos

Box 6 of 13: 8.8 m to 10.2 m (29.0 ft to 33.5 ft)

Box 7 of 13: 10.2 m to 11.6 m (33.5 ft to 38.0 ft)

Box 8 of 13: 11.6 m to 13.4 m (38.0 ft to 44.0 ft)

Box 9 of 13: 13.4 m to 15.4 m (44.0 ft to 50.5 ft)

Box 10 of 13: 15.4 m to 16.9 m (50.5 ft to 55.5 ft)

PROJECT	CITY OF NANAIMO COLLIERY DAMS PARK – LOWER DAM NANAIMO, B.C.			
TITLE	**SH14-06** **SONIC CORE PHOTOGRAPHS** **BOXES 6 TO 10 OF 13, 8.8 m to 16.9 m (29.0 ft to 55.5 ft)**			
Golder Associates	PROJECT No. 13-1447-0516			Phase / Task No. 7000/7300
	DESIGN	TM	25FEB14	SCALE NTS REV.
	CADD	TM	06MAR14	**FIGURE C-7**
	CHECK			
	REVIEW			

Box 11 of 13: 16.9 m to 18.0 m (55.5 ft to 59.0 ft)

Box 12 of 13: 18.0 m to 19.4 m (59.0 ft to 63.5 ft)

Box 13 of 13: 19.4 m to 21.0 m (63.5 ft to 69.0 ft)

PROJECT	CITY OF NANAIMO COLLIERY DAMS PARK – LOWER DAM NANAIMO, B.C.			
TITLE	**SH14-06** **SONIC CORE PHOTOGRAPHS** **BOXES 11 TO 13 OF 13, 16.9 m to 21.0 m (55.5 ft to 69.0 ft)**			
Golder Associates	PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
	DESIGN	TM	25FEB14	SCALE NTS	REV.
	CADD	TM	06MAR14	**FIGURE C-8**
	CHECK			
	REVIEW			

Annex C Laboratory Testing Results

GOLDER ASSOCIATES LTD.
ATTN: Jenna Girdner
500 - 4260 Still Creek Drive
Burnaby na NA

Date Received: 14-MAR-14
Report Date: 31-MAR-14 13:49 (MT)
Version: FINAL

Client Phone: --

Certificate of Analysis

Lab Work Order #:	**L1432674**
Project P.O. #:	NOT SUBMITTED
Job Reference:	13-1447-0516/7000/7300
C of C Numbers:	10-368653
Legal Site Desc:	

Amber Springer
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1432674-1	L1432674-2	L1432674-3	L1432674-4	L1432674-5
	Description	Soil	Soil	Soil	Soil	Soil
	Sampled Date	13-MAR-14	13-MAR-14	13-MAR-14	13-MAR-14	13-MAR-14
	Sampled Time					
	Client ID	SH14-04 G1	SH14-04 G3	SH14-05 G2	SH14-05 G3	SH14-06 G1
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve	SEE ATTACHED	SEE ATTACHED	SEE ATTACHED	SEE ATTACHED	SEE ATTACHED
	pH (1:9) (pH)	8.02			7.33	
	Specific Gravity (kg/L)	0.950			1.93	
Leachable Anions & Nutrients	Sulfate (SO4) (mg/L)	28.3			24.6	
	Sulfate (SO4) (mg/kg)	255			222	

ALS ENVIRONMENTAL ANALYTICAL REPORT

		Sample ID	L1432674-6				
		Description	Soil				
		Sampled Date	13-MAR-14				
		Sampled Time					
		Client ID	SH14-06 G2				
Grouping	**Analyte**						
SOIL							
Physical Tests	Grain Size Curve		SEE ATTACHED				
	pH (1:9) (pH)		6.52				
	Specific Gravity (kg/L)		1.32				
Leachable Anions & Nutrients	Sulfate (SO4) (mg/L)		31.6				
	Sulfate (SO4) (mg/kg)		284				

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
GRAIN SIZE-SK	Soil	Grain Size Analysis	SSIR-51 METHOD 3.2.1

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

ALS Test Code	Matrix	Test Description	Method Reference**
PH-1:9-CL	Soil	pH (1:9 H2O)	APHA 4500 H-Electrode on 1:9 extr.
SO4-1:9-CL	Soil	Sulfate (1:9 H2O)	AEUB Guide 58-29.7 - Ion Chromatography
SPECGRAV-CL	Soil	Specific Gravity	CSSS-Gravimetric

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA

Chain of Custody Numbers:

10-368653

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1432674   Report Date: 31-MAR-14

Client: GOLDER ASSOCIATES LTD.
500 - 4260 Still Creek Drive
Burnaby na NA

Contact: Jenna Girdner

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-1:9-CL	**Soil**							
Batch R2813311								
WG1851786-1 DUP		**L1432674-6**						
pH (1:9)		6.52	6.59	J	pH	0.07	0.3	31-MAR-14
SO4-1:9-CL	**Soil**							
Batch R2810255								
WG1849078-3 DUP		**L1432674-6**						
Sulfate (SO4)		31.6	31.5		mg/L	0.3	30	24-MAR-14
WG1849078-2 LCS								
Sulfate (SO4)			103.4		%		70-130	24-MAR-14
WG1849078-1 MB								
Sulfate (SO4)			<6.0		mg/L		6	24-MAR-14
SPECGRAV-CL	**Soil**							
Batch R2809572								
WG1848487-1 DUP		**L1432674-6**						
Specific Gravity		1.32	1.31		kg/L	0.8	20	24-MAR-14

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

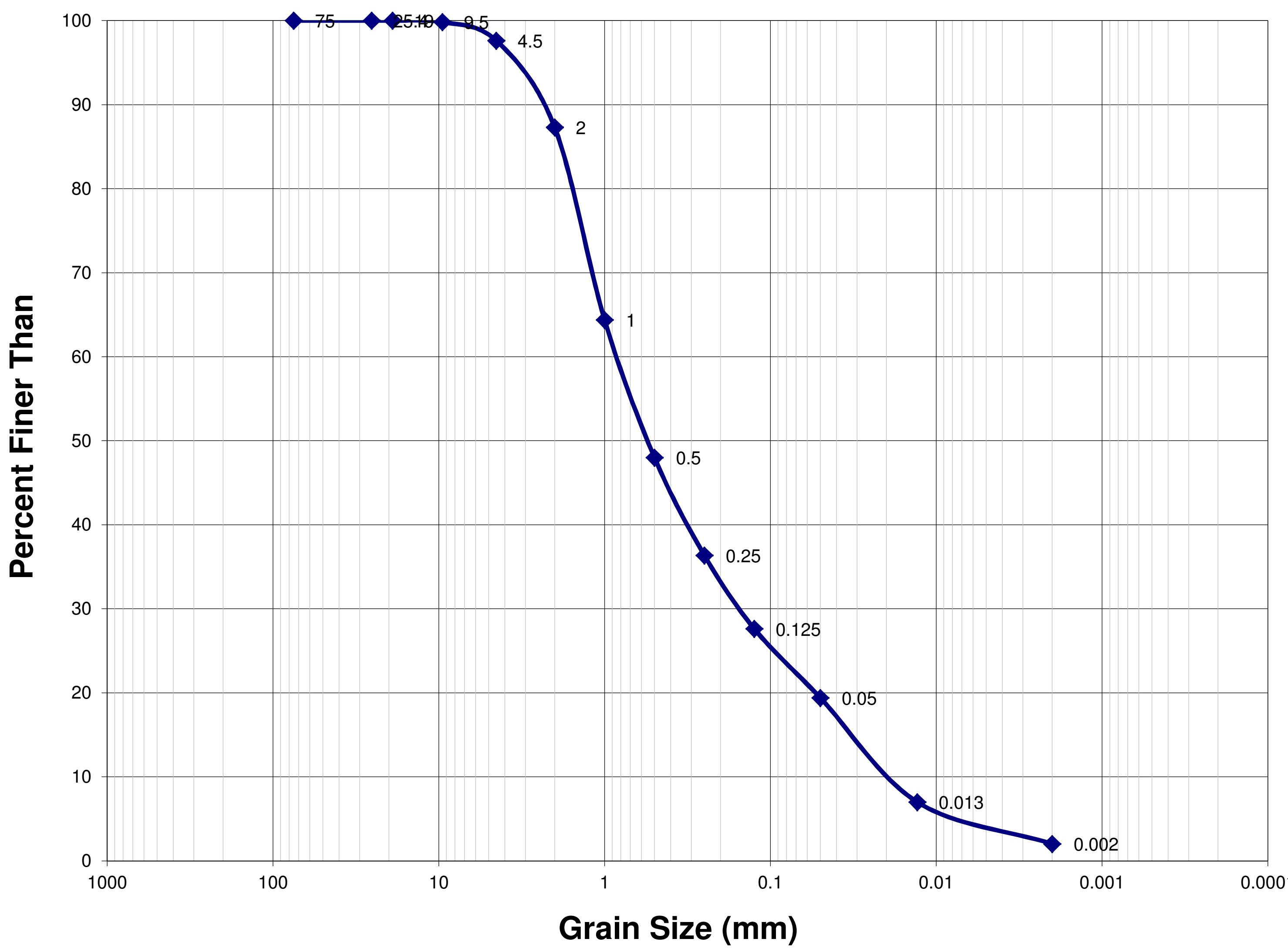
Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-04 G1
Lab ID: L1432674-1

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	2
Coarse Sand	2.0mm - 4.75mm	10
Medium Sand	0.425mm - 2.0mm	39
Fine Sand	0.075mm - 0.425mm	26
Fines	< 0.075mm	22

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	13
Sand	0.05mm - 2mm	68
Silt	0.002mm - 0.05mm	17
Clay	< 0.002mm	2

Texture Loamy sand

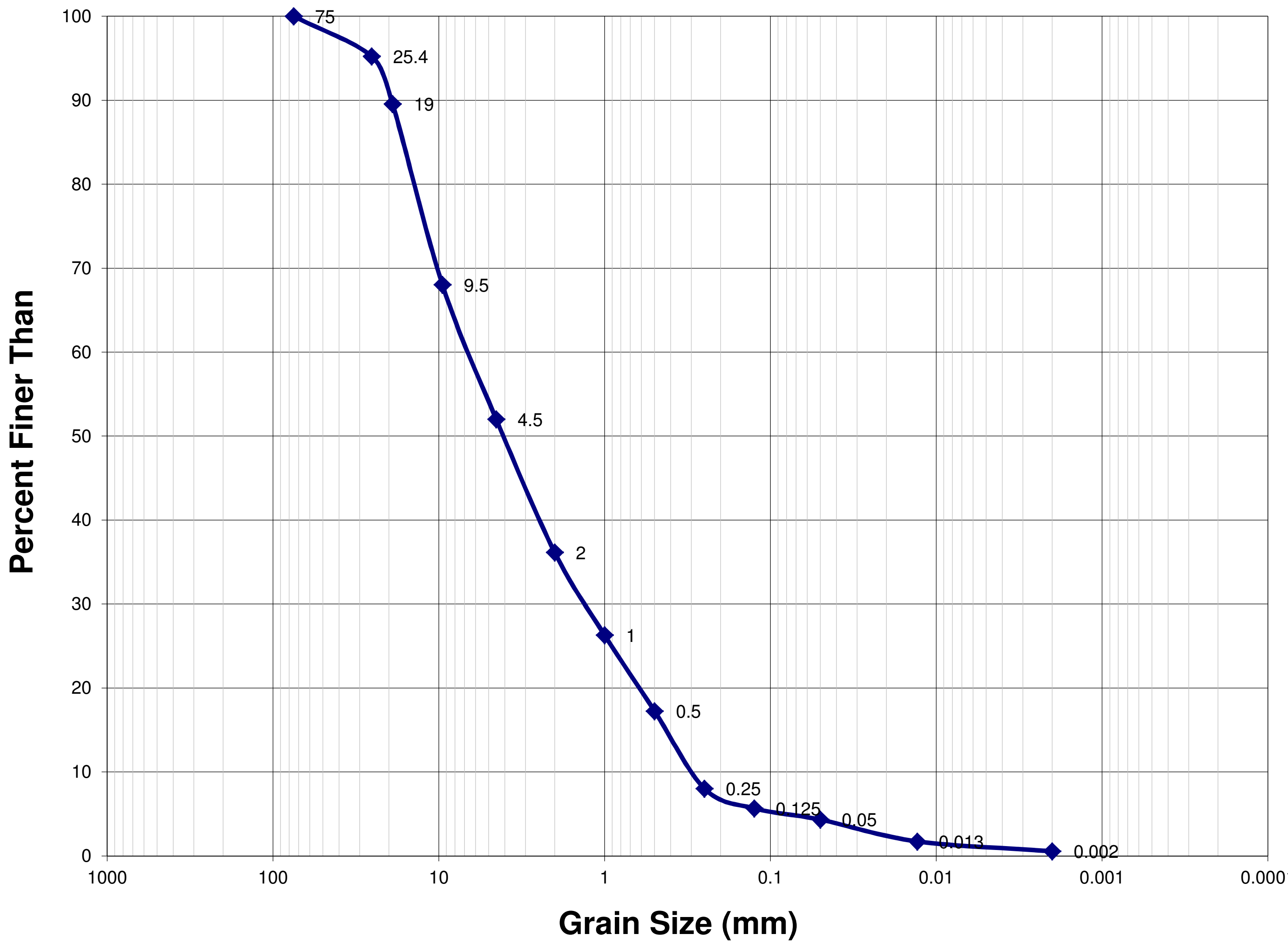
Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-04 G3
Lab ID: L1432674-2

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	47
Coarse Sand	2.0mm - 4.75mm	17
Medium Sand	0.425mm - 2.0mm	19
Fine Sand	0.075mm - 0.425mm	12
Fines	< 0.075mm	5

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	64
Sand	0.05mm - 2mm	32
Silt	0.002mm - 0.05mm	4
Clay	< 0.002mm	1

Texture Sand

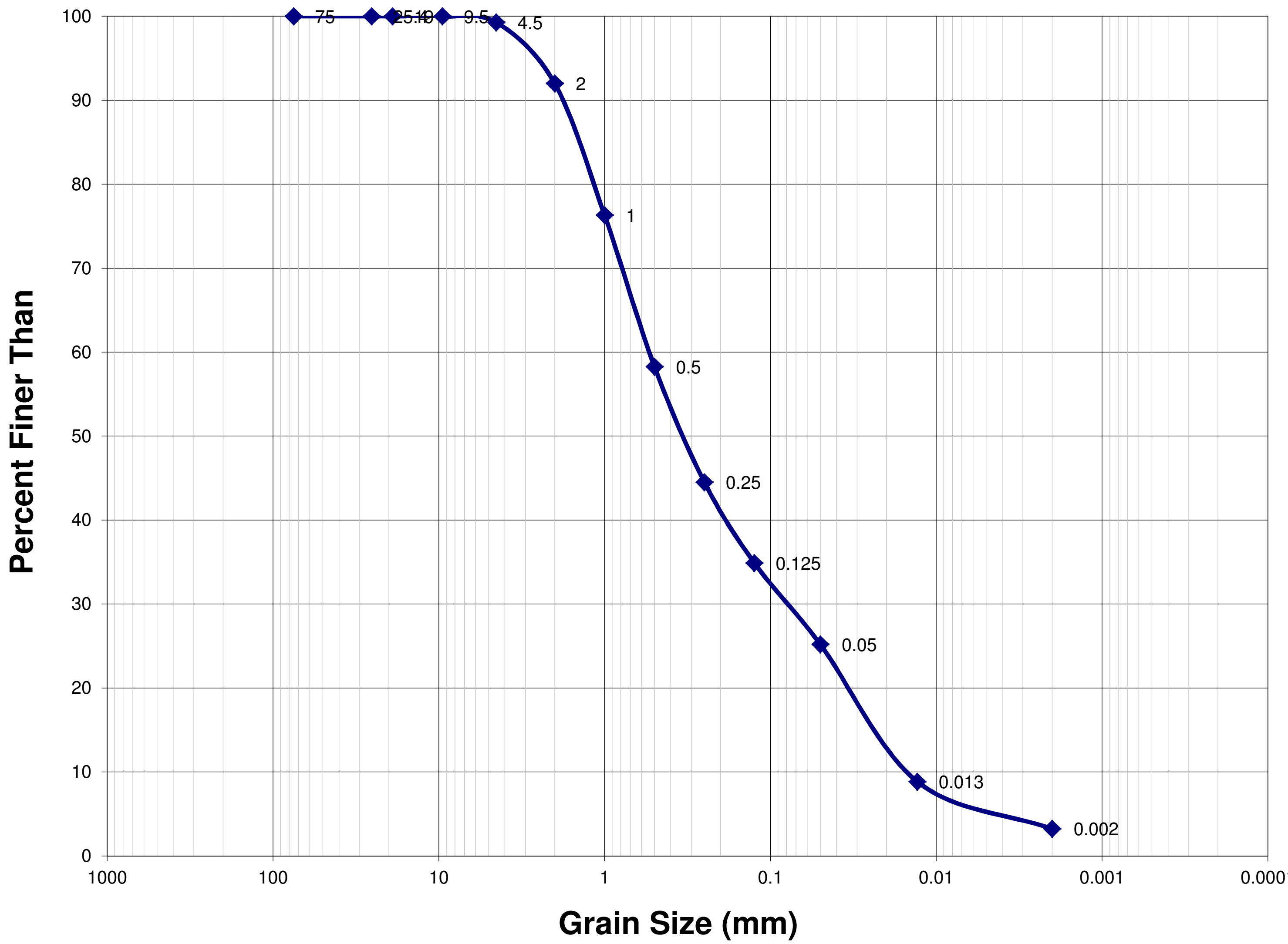
Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-05 G2
Lab ID: L1432674-3

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	1
Coarse Sand	2.0mm - 4.75mm	7
Medium Sand	0.425mm - 2.0mm	34
Fine Sand	0.075mm - 0.425mm	30
Fines	< 0.075mm	28

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	8
Sand	0.05mm - 2mm	67
Silt	0.002mm - 0.05mm	22
Clay	< 0.002mm	3

Texture Sandy loam

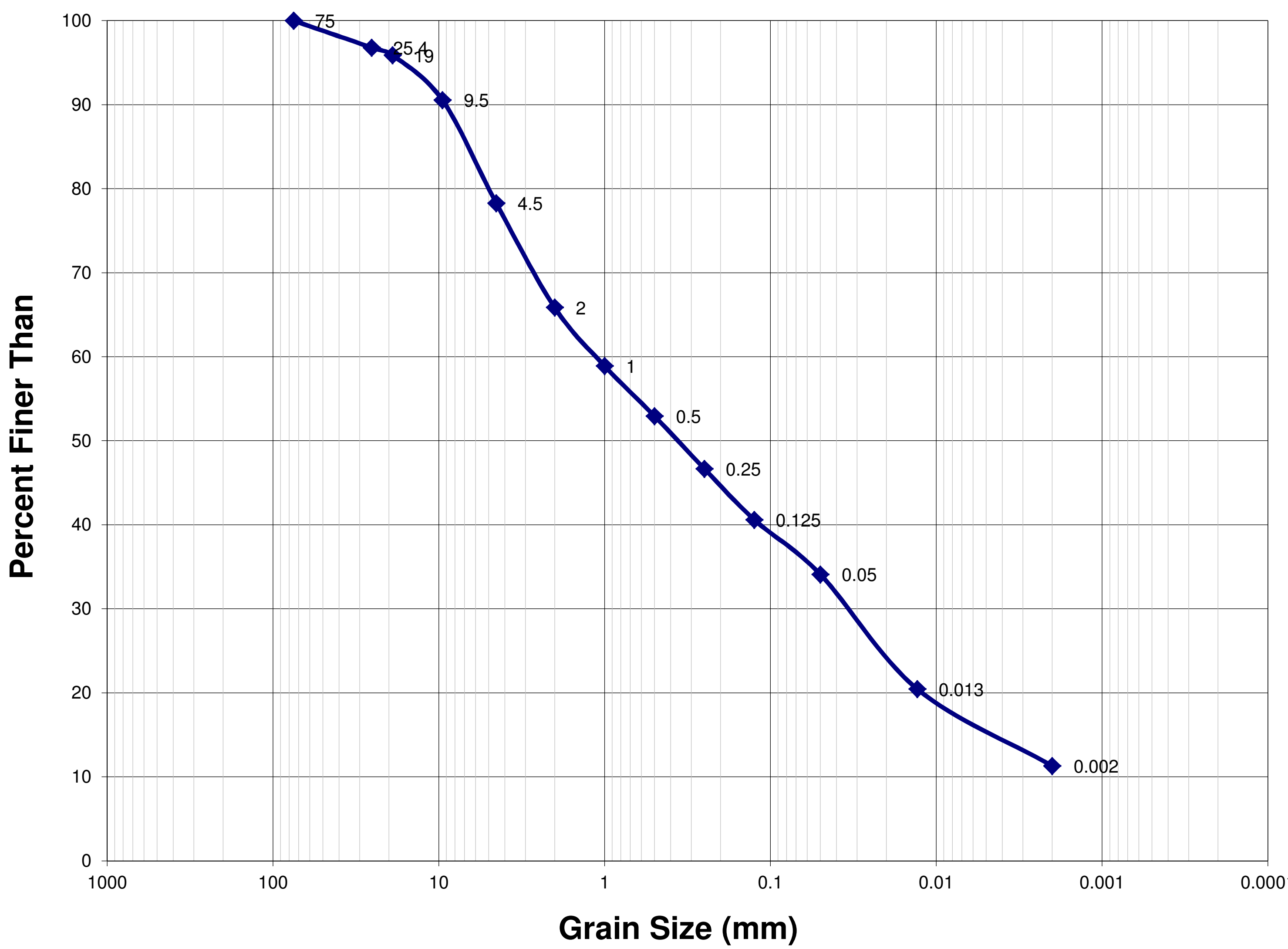
Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-05 G3
Lab ID: L1432674-4

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	21
Coarse Sand	2.0mm - 4.75mm	13
Medium Sand	0.425mm - 2.0mm	13
Fine Sand	0.075mm - 0.425mm	17
Fines	< 0.075mm	36

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	34
Sand	0.05mm - 2mm	32
Silt	0.002mm - 0.05mm	23
Clay	< 0.002mm	11

Texture Loam

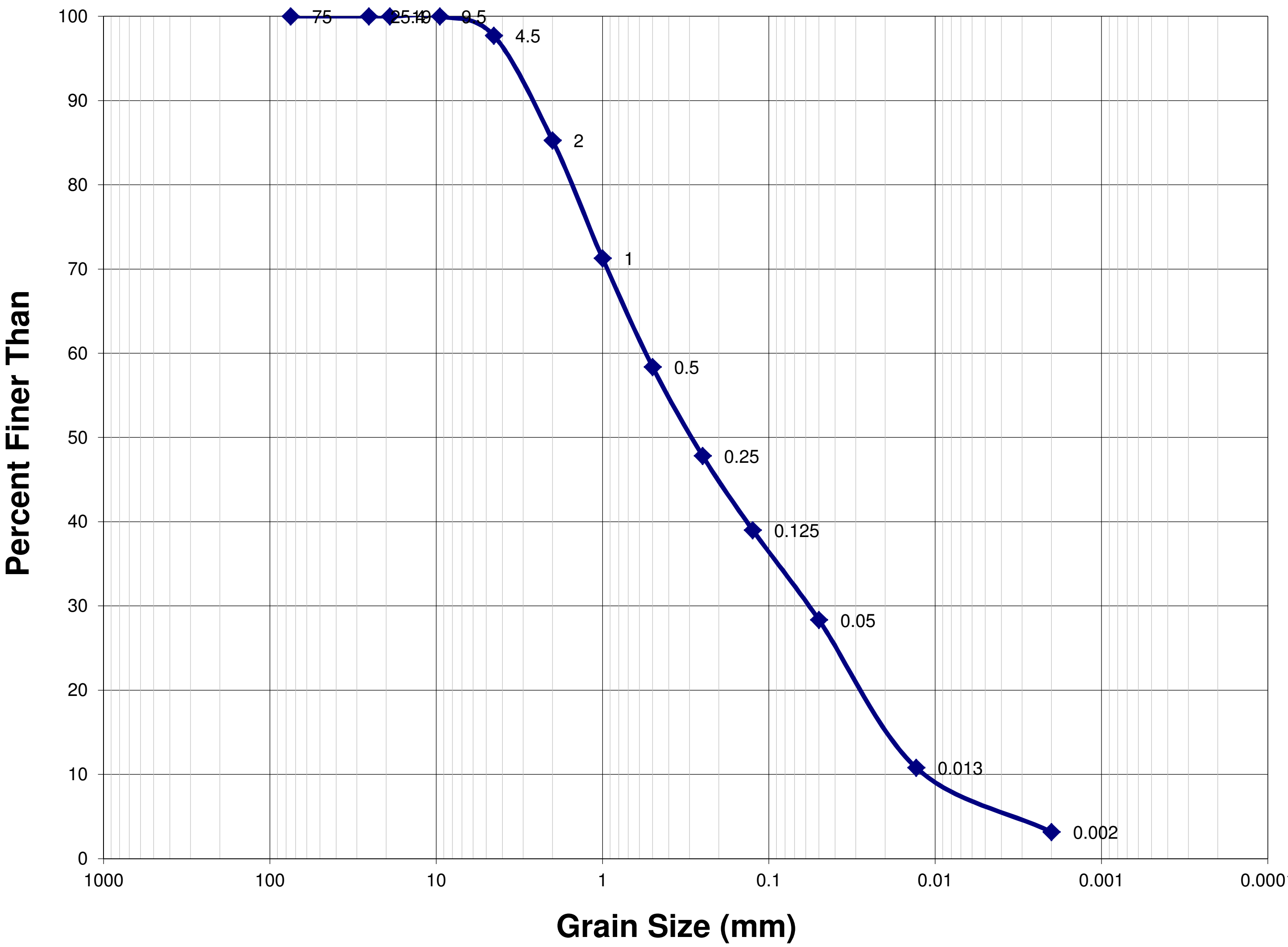
Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-06 G1
Lab ID: L1432674-5

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	2
Coarse Sand	2.0mm - 4.75mm	13
Medium Sand	0.425mm - 2.0mm	27
Fine Sand	0.075mm - 0.425mm	26
Fines	< 0.075mm	32

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	15
Sand	0.05mm - 2mm	57
Silt	0.002mm - 0.05mm	25
Clay	< 0.002mm	3

Texture Sandy loam

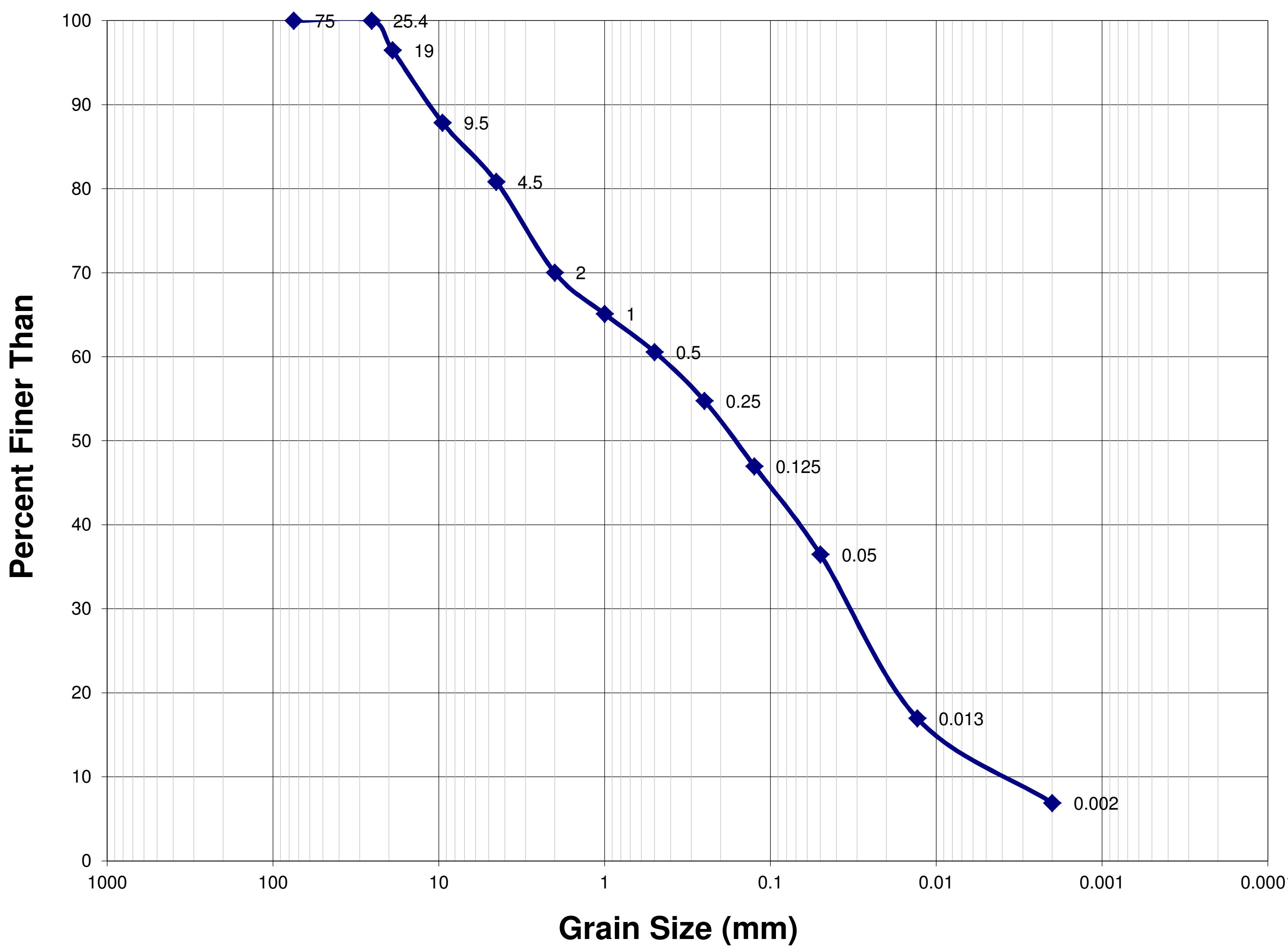
Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: SH14-06 G2
Lab ID: L1432674-6

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	19
Coarse Sand	2.0mm - 4.75mm	11
Medium Sand	0.425mm - 2.0mm	9
Fine Sand	0.075mm - 0.425mm	21
Fines	< 0.075mm	40

Canadian Soil Survey Committee (CSSC)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	30
Sand	0.05mm - 2mm	34
Silt	0.002mm - 0.05mm	30
Clay	< 0.002mm	7

Texture Loam

Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

L1432674-COFC

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

COC # 10-368653

Report To	
Company:	Golder Associates Ltd.
Contact:	Jenna Girdner
Address:	500-4260 Still Creek Drive Burnaby BC V5C 6C6
Phone:	604-297-2045 Fax: 604-298-5253
Invoice To	Same as Report ? ☑ Yes ☐ No
Hardcopy of Invoice with Report?	☑ Yes ☐ No
Company:	
Contact:	
Address:	
Phone:	Fax:
Lab Work Order # (lab use only)	

Report Format / Distribution	
☑ Standard ☐ Other	
☑ PDF ☑ Excel ☐ Digital ☐ Fax	
Email 1:	jenna_girdner@golder.com
Email 2:	acrowley@golder.com
Email 3:	
Client / Project Information	
Job #:	13-1447-0516/7000/7300
PO / AFE:	
LSD:	
Quote #:	
ALS Contact:	Sampler:

Service Requested (Rush for routine analysis subject to availability)

- ◉ Regular (Standard Turnaround Times - Business Days)
- ○ Priority (2-4 Business Days) - 50% Surcharge - Contact ALS to Confirm TAT
- ○ Emergency (1-2 Bus. Days) - 100% Surcharge - Contact ALS to Confirm TAT
- ○ Same Day or Weekend Emergency - Contact ALS to Confirm TAT

Analysis Request

Please indicate below Filtered, Preserved or both (F, P, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	detailed particle size analysis with gradation plot, GRAIN SIZE-SK	Sulphate content in soil	Number of Containers
	SH14-04 G1	13/3/2014		Soil	X	X	1
	SH14-04 G3	13/3/2014		Soil	X		1
	SH14-05 G2	13/3/2014		Soil	X		1
	SH14-05 G3	13/3/2014		Soil	X	X	1
	SH14-06 G1	13/3/2014		Soil	X		1
	SH14-06 G2	13/3/2014		Soil	X	X	1

Special Instructions / Regulations with water or land use (CCME-Freshwater Aquatic Life/BC CSR - Commercial/AB Tier 1 - Natural, etc) / Hazardous Details

Please individually bag the soil that is retained on each sieve and send back to Golder for further testing.

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as provided on a separate Excel tab.

Also provided on another Excel tab are the ALS location addresses, phone numbers and sample container / preservation / holding time table for common analyses.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date (dd-mmm-yy)	Time (hh-mm)	Received by:	Date:	Time:	Temperature: °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

L1432674-COFC

[redacted]

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Report To	**Report Format / Distribution**	**Service Request:**(Rush subject to availability - Contact ALS to confirm TAT)
Company:	Standard: Other (specify):	Regular (Standard Turnaround Times - Business Days)
Contact:	Select: PDF Excel Digital Fax	Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
Address:	Email 1:	Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
	Email 2:	Same Day or Weekend Emergency - Contact ALS to confirm TAT
Phone: Fax:		**Analysis Request**
Invoice To Same as Report ? (circle) Yes or No (if No, provide details)	**Client / Project Information**	(Indicate Filtered or Preserved, F/P)
Copy of Invoice with Report? (circle) Yes or No	Job #:	
Company:	PO / AFE:	
Contact:	LSD:	
Address:		
Phone: Fax:	Quote #:	
Lab Work Order # (lab use only)	**ALS Contact:** **Sampler:**	

Sample #	**Sample Identification** (This description will appear on the report)	**Date** (dd-mmm-yy)	**Time** (hh:mm)	**Sample Type**													Number of Containers

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Samples received without C of C

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by: YC	Date: Mar14	Time: 16:40	Temperature: 21.2 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

GOLDER ASSOCIATES LTD.
ATTN: Jim Laidlaw
500 - 4260 Still Creek Drive
Burnaby BC V5C 6C6

Date Received: 20-FEB-14
Report Date: 18-MAR-14 14:15 (MT)
Version: FINAL REV. 3

Client Phone: 604-298-6623

Certificate of Analysis

Lab Work Order #: L1424625

Project P.O. #: NOT SUBMITTED
Job Reference: 13-1447-0516
C of C Numbers:
Legal Site Desc:

Comments: The composite sample in this report was created with equal volumes of the following samples:

L1421658 - 1, 2, 3, 4, 5
L1423043 - 1, 2, 3
L1423044 - 1, 2

11-MAR-2014 SPLP Arsenic has been re-processed to provide a lower detection limit.
18-MAR-2014 Grain Size Analysis added, see end of report.

Amber Springer
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve	SEE ATTACHED				
	Moisture (%)	19.2				
	pH (1:2 soil:water) (pH)	8.17				
Metals	Aluminum (Al) (mg/kg)	15400				
	Antimony (Sb) (mg/kg)	0.67				
	Arsenic (As) (mg/kg)	49.6				
	Barium (Ba) (mg/kg)	229				
	Beryllium (Be) (mg/kg)	0.51				
	Bismuth (Bi) (mg/kg)	<0.20				
	Cadmium (Cd) (mg/kg)	0.108				
	Calcium (Ca) (mg/kg)	34000				
	Chromium (Cr) (mg/kg)	31.1				
	Cobalt (Co) (mg/kg)	10.1				
	Copper (Cu) (mg/kg)	47.5				
	Iron (Fe) (mg/kg)	20200				
	Lead (Pb) (mg/kg)	8.56				
	Lithium (Li) (mg/kg)	19.1				
	Magnesium (Mg) (mg/kg)	2920				
	Manganese (Mn) (mg/kg)	294				
	Mercury (Hg) (mg/kg)	0.206				
	Molybdenum (Mo) (mg/kg)	2.76				
	Nickel (Ni) (mg/kg)	58.3				
	Phosphorus (P) (mg/kg)	326				
	Potassium (K) (mg/kg)	740				
	Selenium (Se) (mg/kg)	0.49				
	Silver (Ag) (mg/kg)	<0.10				
	Sodium (Na) (mg/kg)	280				
	Strontium (Sr) (mg/kg)	215				
	Thallium (Tl) (mg/kg)	0.148				
	Tin (Sn) (mg/kg)	<2.0				
	Titanium (Ti) (mg/kg)	731				
	Uranium (U) (mg/kg)	0.610				
	Vanadium (V) (mg/kg)	101				
	Zinc (Zn) (mg/kg)	33.4				
SPLP Metals	Extraction Solution Initial pH (pH)	4.99				
	Final pH (pH)	7.67				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
SOIL						
SPLP Metals	Aluminum (Al)-Leachable (mg/L)	<0.20				
	Antimony (Sb)-Leachable (mg/L)	<0.20				
	Arsenic (As)-Leachable (mg/L)	0.00309				
	Barium (Ba)-Leachable (mg/L)	<0.50				
	Beryllium (Be)-Leachable (mg/L)	<0.0050				
	Bismuth (Bi)-Leachable (mg/L)	<0.20				
	Boron (B)-Leachable (mg/L)	<0.10				
	Cadmium (Cd)-Leachable (mg/L)	<0.010				
	Calcium (Ca)-Leachable (mg/L)	134				
	Chromium (Cr)-Leachable (mg/L)	<0.050				
	Cobalt (Co)-Leachable (mg/L)	<0.010				
	Copper (Cu)-Leachable (mg/L)	<0.010				
	Iron (Fe)-Leachable (mg/L)	<0.030				
	Lead (Pb)-Leachable (mg/L)	<0.050				
	Lithium (Li)-Leachable (mg/L)	<0.010				
	Magnesium (Mg)-Leachable (mg/L)	1.47				
	Manganese (Mn)-Leachable (mg/L)	<0.0050				
	Mercury (Hg)-Leachable (mg/L)	<0.0010				
	Molybdenum (Mo)-Leachable (mg/L)	<0.030				
	Nickel (Ni)-Leachable (mg/L)	<0.050				
	Phosphorus (P)-Leachable (mg/L)	<0.30				
	Potassium (K)-Leachable (mg/L)	<2.0				
	Selenium (Se)-Leachable (mg/L)	<0.20				
	Silicon (Si)-Leachable (mg/L)	3.09				
	Silver (Ag)-Leachable (mg/L)	<0.050				
	Sodium (Na)-Leachable (mg/L)	<2.0				
	Strontium (Sr)-Leachable (mg/L)	0.437				
	Thallium (Tl)-Leachable (mg/L)	<0.20				
	Tin (Sn)-Leachable (mg/L)	<0.030				
	Titanium (Ti)-Leachable (mg/L)	0.014				
	Vanadium (V)-Leachable (mg/L)	<0.030				
	Zinc (Zn)-Leachable (mg/L)	<0.10				
Hydrocarbons	EPH10-19 (mg/kg)	1210				
	EPH19-32 (mg/kg)	1620				
	LEPH (mg/kg)	1200				
	HEPH (mg/kg)	1610				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.20 DLM				
	Acenaphthylene (mg/kg)	<0.40 DLM				
	Anthracene (mg/kg)	0.429				
	Benz(a)anthracene (mg/kg)	0.438				
	Benzo(a)pyrene (mg/kg)	0.163				
	Benzo(b)fluoranthene (mg/kg)	0.364				
	Benzo(g,h,i)perylene (mg/kg)	0.088				
	Benzo(k)fluoranthene (mg/kg)	<0.060 DLM				
	Chrysene (mg/kg)	0.384				
	Dibenz(a,h)anthracene (mg/kg)	<0.050				
	Fluoranthene (mg/kg)	0.393				
	Fluorene (mg/kg)	<0.30 DLM				
	Indeno(1,2,3-c,d)pyrene (mg/kg)	0.055				
	2-Methylnaphthalene (mg/kg)	14.5				
	Naphthalene (mg/kg)	10.9				
	Phenanthrene (mg/kg)	2.85				
	Pyrene (mg/kg)	0.497				
	Surrogate: Acenaphthene d10 (%)	109.5				
	Surrogate: Chrysene d12 (%)	71.8				
	Surrogate: Naphthalene d8 (%)	93.1				
	Surrogate: Phenanthrene d10 (%)	81.5				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1424625-1 Soil COMPOSITE				
Grouping	**Analyte**					
WASTE						
Polycyclic Aromatic Hydrocarbons	Acenapthene (ug/L)	<0.020				
	Acenaphthylene (ug/L)	<0.020				
	Anthracene (ug/L)	<0.020				
	Benzo(a)anthracene (ug/L)	<0.020				
	Benzo(a)pyrene (ug/L)	<0.010				
	Benzo(b)fluoranthene (ug/L)	<0.020				
	Benzo(g,h,i)perylene (ug/L)	<0.020				
	Benzo(k)fluoranthene (ug/L)	<0.020				
	Chrysene (ug/L)	<0.020				
	Dibenzo(ah)anthracene (ug/L)	<0.020				
	Fluoranthene (ug/L)	<0.020				
	Fluorene (ug/L)	<0.020				
	Indeno(1,2,3-cd)pyrene (ug/L)	<0.020				
	1-Methylnaphthalene (ug/L)	0.026				
	2-Methylnaphthalene (ug/L)	0.031				
	Naphthalene (ug/L)	0.046				
	Phenanthrene (ug/L)	0.026				
	Pyrene (ug/L)	<0.020				
	Surrogate: 2-Fluorobiphenyl (%)	87.2				
	Surrogate: d14-Terphenyl (%)	98.0				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Calcium (Ca)-Leachable	MS-B	L1424625-1
Matrix Spike	Magnesium (Mg)-Leachable	MS-B	L1424625-1
Matrix Spike	Silicon (Si)-Leachable	MS-B	L1424625-1
Matrix Spike	Strontium (Sr)-Leachable	MS-B	L1424625-1

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
EPH-TUMB-FID-VA	Soil	EPH in Solids by Tumbler and GCFID	BC MOE EPH GCFID

Analysis is in accordance with BC MOE Lab Manual method "Extractable Petroleum Hydrocarbons in Solids by GC/FID", v2.1, July 1999. Soil samples are extracted with a 1:1 mixture of hexane and acetone using a rotary extraction technique modified from EPA 3570 prior to gas chromatography with flame ionization detection (GC-FID). EPH results include Polycyclic Aromatic Hydrocarbons (PAH) and are therefore not equivalent to Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH).

GRAIN SIZE-SK	Soil	Grain Size Analysis	SSIR-51 METHOD 3.2.1

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

HG-SPLP-CVAFS-VA	Soil	Mercury by CVAFS (SPLP)	EPA 1312/245.7

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

HG-WW-200.2-CVAF-VA	Soil	Hg in Soil by CVAFS	EPA 200.2/245.7

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, sieved (wet sample) through a 2 mm (10 mesh) sieve, and a representative subsample of the material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis is by atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

LEPH/HEPH-CALC-VA	Soil	LEPHs and HEPHs	BC MOE LABORATORY MANUAL (2005)

Light and Heavy Extractable Petroleum Hydrocarbons in Solids. These results are determined according to the British Columbia Ministry of Environment, Lands, and Parks Analytical Method for Contaminated Sites "Calculation of Light and Heavy Extractable Petroleum Hydrocarbons in Solids or Water". According to this method, LEPH and HEPH are calculated
by subtracting selected Polycyclic Aromatic Hydrocarbon results from Extractable Petroleum Hydrocarbon results. To calculate LEPH, the individual results for Naphthalene and Phenanthrene are subtracted from EPH(C10-19). To calculate HEPH, the individual results for Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenz(a,h)anthracene, Indeno(1,2,3-c,d)pyrene, and Pyrene
are subtracted from EPH(C19-32). Analysis of Extractable Petroleum Hydrocarbons adheres to all prescribed elements of the BCMELP method "Extractable Petroleum Hydrocarbons in Solids by GC/FID" (Version 2.1, July 20, 1999).

MET-SPLP-ICP-VA	Soil	Metals by ICPOES (SPLP)	EPA 1312/6010B

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fiber filter and analyzed using inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-SPLP-MS-VA	Soil	Metals by ICPMS (SPLP)	EPA 1312/6020A

Reference Information

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using inductively coupled plasma - mass spectrometry (EPA Method 6020A).

MET-WW-200.2-CCMS-VA Soil Metals in Soil by CRC ICPMS EPA 200.2/6020A

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, sieved (wet sample) through a 2 mm (10 mesh) sieve, and a representative subsample of the material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

MOISTURE-SIEVE-VA Soil Moisture for CSR Metals Calculations ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

MOISTURE-VA Soil Moisture content ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

PAH-SPLP-WT Waste Leachable PAH for O.Reg 153/04 SW846 8270

PAH-TMB-H/A-MS-VA Soil PAH - Rotary Extraction (Hexane/Acetone) EPA 3570/8270

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3570 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PH-WW-1:2-DI-MAN-VA Soil pH in Soil (1:2 Soil:Water Ext.) (WET) BC WLAP METHOD: PH, ELECTROMETRIC, SOIL

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the wet sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water, where the samples moisture is accounted for. The pH of the solution is then measured using a standard pH probe.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Environmental

Quality Control Report

Client: GOLDER ASSOCIATES LTD.
500 - 4260 Still Creek Drive
Burnaby BC V5C 6C6

Contact: Jim Laidlaw

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EPH-TUMB-FID-VA	**Soil**							
Batch R2796505								
WG1836681-3 IRM		**ALS PHC2 RM**						
EPH10-19			101.8		%		70-130	27-FEB-14
EPH19-32			102.9		%		70-130	27-FEB-14
WG1836681-1 MB								
EPH10-19			<200		mg/kg		200	27-FEB-14
EPH19-32			<200		mg/kg		200	27-FEB-14
HG-SPLP-CVAFS-VA	**Soil**							
Batch R2797307								
WG1835844-2 DUP		**L1424625-1**						
Mercury (Hg)-Leachable		<0.0010	<0.0010	RPD-NA	mg/L	N/A	30	26-FEB-14
WG1835844-1 MB								
Mercury (Hg)-Leachable			<0.0010		mg/L		0.001	26-FEB-14
WG1835844-3 MS		**L1424625-1**						
Mercury (Hg)-Leachable			100.3		%		70-130	26-FEB-14
HG-WW-200.2-CVAF-VA	**Soil**							
Batch R2797904								
WG1836549-14 CRM		**VA-CANMET-TILL1**						
Mercury (Hg)			96.4		%		70-130	27-FEB-14
WG1836549-15 CRM		**VA-NRC-STSD1**						
Mercury (Hg)			95.4		%		70-130	27-FEB-14
WG1836549-11 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	27-FEB-14
WG1836549-12 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	27-FEB-14
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-2 DUP		**L1424625-1**						
Aluminum (Al)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Antimony (Sb)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Barium (Ba)-Leachable		<0.50	<0.50	RPD-NA	mg/L	N/A	30	26-FEB-14
Beryllium (Be)-Leachable		<0.0050	<0.0050	RPD-NA	mg/L	N/A	30	26-FEB-14
Bismuth (Bi)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Boron (B)-Leachable		<0.10	<0.10	RPD-NA	mg/L	N/A	30	26-FEB-14
Cadmium (Cd)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Calcium (Ca)-Leachable		134	131		mg/L	2.2	30	26-FEB-14
Chromium (Cr)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Cobalt (Co)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14

Quality Control Report

Workorder: L1424625   Report Date: 18-MAR-14

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-2 DUP		**L1424625-1**						
Copper (Cu)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Iron (Fe)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Lead (Pb)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Lithium (Li)-Leachable		<0.010	0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Magnesium (Mg)-Leachable		1.47	1.47		mg/L	0.1	30	26-FEB-14
Manganese (Mn)-Leachable		<0.0050	<0.0050	RPD-NA	mg/L	N/A	30	26-FEB-14
Molybdenum (Mo)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Nickel (Ni)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Phosphorus (P)-Leachable		<0.30	<0.30	RPD-NA	mg/L	N/A	30	26-FEB-14
Potassium (K)-Leachable		<2.0	<2.0	RPD-NA	mg/L	N/A	30	26-FEB-14
Selenium (Se)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Silicon (Si)-Leachable		3.09	3.10		mg/L	0.2	30	26-FEB-14
Silver (Ag)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Sodium (Na)-Leachable		<2.0	<2.0	RPD-NA	mg/L	N/A	30	26-FEB-14
Strontium (Sr)-Leachable		0.437	0.437		mg/L	0.1	30	26-FEB-14
Thallium (Tl)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Tin (Sn)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Titanium (Ti)-Leachable		0.014	0.014		mg/L	4.4	30	26-FEB-14
Vanadium (V)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Zinc (Zn)-Leachable		<0.10	<0.10	RPD-NA	mg/L	N/A	30	26-FEB-14
WG1835844-1 MB								
Aluminum (Al)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Antimony (Sb)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Barium (Ba)-Leachable			<0.50		mg/L		0.5	26-FEB-14
Beryllium (Be)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Bismuth (Bi)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Boron (B)-Leachable			<0.10		mg/L		0.1	26-FEB-14
Cadmium (Cd)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Calcium (Ca)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Chromium (Cr)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Cobalt (Co)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Copper (Cu)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Iron (Fe)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Lead (Pb)-Leachable			<0.050		mg/L		0.05	26-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-1 MB								
Lithium (Li)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Magnesium (Mg)-Leachable			<0.10		mg/L		0.1	26-FEB-14
Manganese (Mn)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Molybdenum (Mo)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Nickel (Ni)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Phosphorus (P)-Leachable			<0.30		mg/L		0.3	26-FEB-14
Potassium (K)-Leachable			<2.0		mg/L		2	26-FEB-14
Selenium (Se)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Silicon (Si)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Silver (Ag)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Sodium (Na)-Leachable			<2.0		mg/L		2	26-FEB-14
Strontium (Sr)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Thallium (Tl)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Tin (Sn)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Titanium (Ti)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Vanadium (V)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Zinc (Zn)-Leachable			<0.10		mg/L		0.1	26-FEB-14
WG1835844-3 MS		**L1424625-1**						
Aluminum (Al)-Leachable			106.9		%		70-130	26-FEB-14
Antimony (Sb)-Leachable			103.4		%		70-130	26-FEB-14
Beryllium (Be)-Leachable			101.4		%		70-130	26-FEB-14
Bismuth (Bi)-Leachable			104.2		%		70-130	26-FEB-14
Boron (B)-Leachable			106.8		%		70-130	26-FEB-14
Cadmium (Cd)-Leachable			101.8		%		70-130	26-FEB-14
Calcium (Ca)-Leachable			N/A	MS-B	%		-	26-FEB-14
Chromium (Cr)-Leachable			102.9		%		70-130	26-FEB-14
Cobalt (Co)-Leachable			102.9		%		70-130	26-FEB-14
Copper (Cu)-Leachable			105.8		%		70-130	26-FEB-14
Iron (Fe)-Leachable			112.8		%		70-130	26-FEB-14
Lead (Pb)-Leachable			100.5		%		70-130	26-FEB-14
Lithium (Li)-Leachable			112.6		%		70-130	26-FEB-14
Magnesium (Mg)-Leachable			N/A	MS-B	%		-	26-FEB-14
Manganese (Mn)-Leachable			102.3		%		70-130	26-FEB-14
Molybdenum (Mo)-Leachable			102.0		%		70-130	26-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-3 MS		**L1424625-1**						
Nickel (Ni)-Leachable			102.1		%		70-130	26-FEB-14
Phosphorus (P)-Leachable			104.1		%		70-130	26-FEB-14
Potassium (K)-Leachable			112.6		%		70-130	26-FEB-14
Selenium (Se)-Leachable			105.3		%		70-130	26-FEB-14
Silicon (Si)-Leachable			N/A	MS-B	%		-	26-FEB-14
Silver (Ag)-Leachable			101.6		%		70-130	26-FEB-14
Sodium (Na)-Leachable			102.8		%		70-130	26-FEB-14
Strontium (Sr)-Leachable			N/A	MS-B	%		-	26-FEB-14
Thallium (Tl)-Leachable			101.6		%		70-130	26-FEB-14
Tin (Sn)-Leachable			93.5		%		70-130	26-FEB-14
Titanium (Ti)-Leachable			102.3		%		70-130	26-FEB-14
Vanadium (V)-Leachable			103.7		%		70-130	26-FEB-14
Zinc (Zn)-Leachable			102.3		%		70-130	26-FEB-14
MET-SPLP-MS-VA	**Soil**							
Batch R2802885								
WG1835844-2 DUP		**L1424625-1**						
Arsenic (As)-Leachable		0.00309	0.00301		mg/L	2.7	30	10-MAR-14
WG1835844-1 MB								
Arsenic (As)-Leachable			<0.00010		mg/L		0.0001	10-MAR-14
WG1835844-3 MS		**L1424625-1**						
Arsenic (As)-Leachable			106.5		%		70-130	10-MAR-14
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-4 CRM		**VA-CANMET-TILL1**						
Aluminum (Al)			99.3		%		70-130	28-FEB-14
Antimony (Sb)			87.3		%		70-130	28-FEB-14
Arsenic (As)			102.9		%		70-130	28-FEB-14
Barium (Ba)			101.4		%		70-130	28-FEB-14
Beryllium (Be)			0.43		mg/kg		0.34-0.74	28-FEB-14
Bismuth (Bi)			89.2		%		70-130	28-FEB-14
Cadmium (Cd)			88.9		%		70-130	28-FEB-14
Calcium (Ca)			91.4		%		70-130	28-FEB-14
Chromium (Cr)			103.3		%		70-130	28-FEB-14
Cobalt (Co)			98.6		%		70-130	28-FEB-14
Copper (Cu)			94.5		%		70-130	28-FEB-14

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-4 CRM		**VA-CANMET-TILL1**						
Iron (Fe)			95.6		%		70-130	28-FEB-14
Lead (Pb)			80.9		%		70-130	28-FEB-14
Lithium (Li)			77.8		%		70-130	28-FEB-14
Magnesium (Mg)			98.5		%		70-130	28-FEB-14
Manganese (Mn)			98.8		%		70-130	28-FEB-14
Molybdenum (Mo)			0.59		mg/kg		0.24-1.24	28-FEB-14
Nickel (Ni)			99.4		%		70-130	28-FEB-14
Phosphorus (P)			96.5		%		70-130	28-FEB-14
Potassium (K)			105.8		%		70-130	28-FEB-14
Selenium (Se)			0.31		mg/kg		0.12-0.52	28-FEB-14
Silver (Ag)			0.19		mg/kg		0.12-0.32	28-FEB-14
Sodium (Na)			113.0		%		70-130	28-FEB-14
Strontium (Sr)			88.2		%		70-130	28-FEB-14
Thallium (Tl)			0.104		mg/kg		0.075-0.175	28-FEB-14
Tin (Sn)			0.9		mg/kg		0-3	28-FEB-14
Titanium (Ti)			103.4		%		70-130	28-FEB-14
Uranium (U)			92.8		%		70-130	28-FEB-14
Vanadium (V)			103.5		%		70-130	28-FEB-14
Zinc (Zn)			100.1		%		70-130	28-FEB-14
WG1837121-5 CRM		**VA-NRC-STSD1**						
Aluminum (Al)			105.9		%		70-130	28-FEB-14
Antimony (Sb)			99.1		%		70-130	28-FEB-14
Arsenic (As)			102.0		%		70-130	28-FEB-14
Barium (Ba)			100.3		%		70-130	28-FEB-14
Beryllium (Be)			111.9		%		70-130	28-FEB-14
Cadmium (Cd)			100.7		%		70-130	28-FEB-14
Calcium (Ca)			105.5		%		70-130	28-FEB-14
Chromium (Cr)			102.6		%		70-130	28-FEB-14
Cobalt (Co)			100.2		%		70-130	28-FEB-14
Copper (Cu)			102.3		%		70-130	28-FEB-14
Iron (Fe)			102.1		%		70-130	28-FEB-14
Lead (Pb)			99.9		%		70-130	28-FEB-14
Lithium (Li)			106.9		%		70-130	28-FEB-14
Magnesium (Mg)			100.0		%		70-130	28-FEB-14

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-5 CRM		**VA-NRC-STSD1**						
Manganese (Mn)			100.1		%		70-130	28-FEB-14
Molybdenum (Mo)			100.8		%		70-130	28-FEB-14
Nickel (Ni)			102.5		%		70-130	28-FEB-14
Phosphorus (P)			102.2		%		70-130	28-FEB-14
Potassium (K)			105.5		%		70-130	28-FEB-14
Selenium (Se)			100.1		%		70-130	28-FEB-14
Silver (Ag)			104.0		%		70-130	28-FEB-14
Sodium (Na)			104.7		%		70-130	28-FEB-14
Strontium (Sr)			104.1		%		70-130	28-FEB-14
Thallium (Tl)			100.5		%		70-130	28-FEB-14
Tin (Sn)			99.8		%		70-130	28-FEB-14
Titanium (Ti)			112.3		%		70-130	28-FEB-14
Vanadium (V)			104.5		%		70-130	28-FEB-14
Zinc (Zn)			103.2		%		70-130	28-FEB-14
WG1837121-3 DUP		**L1424625-1**						
Aluminum (Al)		15400	15700		mg/kg	1.9	40	28-FEB-14
Antimony (Sb)		0.67	0.79		mg/kg	17	30	28-FEB-14
Arsenic (As)		49.6	40.4		mg/kg	21	30	28-FEB-14
Barium (Ba)		229	238		mg/kg	4.0	40	28-FEB-14
Beryllium (Be)		0.51	0.51		mg/kg	0.8	30	28-FEB-14
Bismuth (Bi)		<0.20	<0.20	RPD-NA	mg/kg	N/A	30	28-FEB-14
Cadmium (Cd)		0.108	0.113		mg/kg	4.8	30	28-FEB-14
Calcium (Ca)		34000	33200		mg/kg	2.4	30	28-FEB-14
Chromium (Cr)		31.1	32.5		mg/kg	4.1	30	28-FEB-14
Cobalt (Co)		10.1	9.81		mg/kg	3.3	30	28-FEB-14
Copper (Cu)		47.5	56.4		mg/kg	17	30	28-FEB-14
Iron (Fe)		20200	21700		mg/kg	6.8	30	28-FEB-14
Lead (Pb)		8.56	11.5		mg/kg	29	40	28-FEB-14
Lithium (Li)		19.1	19.9		mg/kg	4.0	30	28-FEB-14
Magnesium (Mg)		2920	3110		mg/kg	6.2	30	28-FEB-14
Manganese (Mn)		294	327		mg/kg	10	30	28-FEB-14
Molybdenum (Mo)		2.76	3.14		mg/kg	13	40	28-FEB-14
Nickel (Ni)		58.3	61.0		mg/kg	4.6	30	28-FEB-14
Phosphorus (P)		326	428		mg/kg	27	30	28-FEB-14

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-3 DUP		**L1424625-1**						
Potassium (K)		740	790		mg/kg	6.7	40	28-FEB-14
Selenium (Se)		0.49	0.65		mg/kg	30	30	28-FEB-14
Silver (Ag)		<0.10	0.11	RPD-NA	mg/kg	N/A	40	28-FEB-14
Sodium (Na)		280	270		mg/kg	6.3	40	28-FEB-14
Strontium (Sr)		215	248		mg/kg	14	40	28-FEB-14
Thallium (Tl)		0.148	0.176		mg/kg	17	30	28-FEB-14
Tin (Sn)		<2.0	<2.0	RPD-NA	mg/kg	N/A	40	28-FEB-14
Titanium (Ti)		731	674		mg/kg	8.2	40	28-FEB-14
Uranium (U)		0.610	0.706		mg/kg	15	30	28-FEB-14
Vanadium (V)		101	97.7		mg/kg	3.0	30	28-FEB-14
Zinc (Zn)		33.4	36.3		mg/kg	8.1	30	28-FEB-14
WG1837121-1 MB								
Aluminum (Al)			<50		mg/kg		50	28-FEB-14
Antimony (Sb)			<0.10		mg/kg		0.1	28-FEB-14
Arsenic (As)			<0.050		mg/kg		0.05	28-FEB-14
Barium (Ba)			<0.50		mg/kg		0.5	28-FEB-14
Beryllium (Be)			<0.20		mg/kg		0.2	28-FEB-14
Bismuth (Bi)			<0.20		mg/kg		0.2	28-FEB-14
Cadmium (Cd)			<0.050		mg/kg		0.05	28-FEB-14
Calcium (Ca)			<50		mg/kg		50	28-FEB-14
Chromium (Cr)			<0.50		mg/kg		0.5	28-FEB-14
Cobalt (Co)			<0.10		mg/kg		0.1	28-FEB-14
Copper (Cu)			<0.50		mg/kg		0.5	28-FEB-14
Iron (Fe)			<50		mg/kg		50	28-FEB-14
Lead (Pb)			<0.50		mg/kg		0.5	28-FEB-14
Lithium (Li)			<5.0		mg/kg		5	28-FEB-14
Magnesium (Mg)			<20		mg/kg		20	28-FEB-14
Manganese (Mn)			<1.0		mg/kg		1	28-FEB-14
Molybdenum (Mo)			<0.50		mg/kg		0.5	28-FEB-14
Nickel (Ni)			<0.50		mg/kg		0.5	28-FEB-14
Phosphorus (P)			<50		mg/kg		50	28-FEB-14
Potassium (K)			<100		mg/kg		100	28-FEB-14
Selenium (Se)			<0.20		mg/kg		0.2	28-FEB-14
Silver (Ag)			<0.10		mg/kg		0.1	28-FEB-14

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch **R2798489**								
WG1837121-1 **MB**								
Sodium (Na)			<100		mg/kg		100	28-FEB-14
Strontium (Sr)			<0.50		mg/kg		0.5	28-FEB-14
Thallium (Tl)			<0.050		mg/kg		0.05	28-FEB-14
Tin (Sn)			<2.0		mg/kg		2	28-FEB-14
Titanium (Ti)			<1.0		mg/kg		1	28-FEB-14
Uranium (U)			<0.050		mg/kg		0.05	28-FEB-14
Vanadium (V)			<0.20		mg/kg		0.2	28-FEB-14
Zinc (Zn)			<1.0		mg/kg		1	28-FEB-14
WG1837121-2 **MB**								
Aluminum (Al)			<50		mg/kg		50	28-FEB-14
Antimony (Sb)			<0.10		mg/kg		0.1	28-FEB-14
Arsenic (As)			<0.050		mg/kg		0.05	28-FEB-14
Barium (Ba)			<0.50		mg/kg		0.5	28-FEB-14
Beryllium (Be)			<0.20		mg/kg		0.2	28-FEB-14
Bismuth (Bi)			<0.20		mg/kg		0.2	28-FEB-14
Cadmium (Cd)			<0.050		mg/kg		0.05	28-FEB-14
Calcium (Ca)			<50		mg/kg		50	28-FEB-14
Chromium (Cr)			<0.50		mg/kg		0.5	28-FEB-14
Cobalt (Co)			<0.10		mg/kg		0.1	28-FEB-14
Copper (Cu)			<0.50		mg/kg		0.5	28-FEB-14
Iron (Fe)			<50		mg/kg		50	28-FEB-14
Lead (Pb)			<0.50		mg/kg		0.5	28-FEB-14
Lithium (Li)			<5.0		mg/kg		5	28-FEB-14
Magnesium (Mg)			<20		mg/kg		20	28-FEB-14
Manganese (Mn)			<1.0		mg/kg		1	28-FEB-14
Molybdenum (Mo)			<0.50		mg/kg		0.5	28-FEB-14
Nickel (Ni)			<0.50		mg/kg		0.5	28-FEB-14
Phosphorus (P)			<50		mg/kg		50	28-FEB-14
Potassium (K)			<100		mg/kg		100	28-FEB-14
Selenium (Se)			<0.20		mg/kg		0.2	28-FEB-14
Silver (Ag)			<0.10		mg/kg		0.1	28-FEB-14
Sodium (Na)			<100		mg/kg		100	28-FEB-14
Strontium (Sr)			<0.50		mg/kg		0.5	28-FEB-14
Thallium (Tl)			<0.050		mg/kg		0.05	28-FEB-14

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-2 MB								
Tin (Sn)			<2.0		mg/kg		2	28-FEB-14
Titanium (Ti)			<1.0		mg/kg		1	28-FEB-14
Uranium (U)			<0.050		mg/kg		0.05	28-FEB-14
Vanadium (V)			<0.20		mg/kg		0.2	28-FEB-14
Zinc (Zn)			<1.0		mg/kg		1	28-FEB-14
MOISTURE-VA	**Soil**							
Batch R2797649								
WG1836679-2 LCS								
Moisture			99.8		%		70-130	26-FEB-14
WG1836679-1 MB								
Moisture			<0.25		%		0.25	26-FEB-14
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2797995								
WG1836681-4 IRM		**ALS PAH1 RM**						
Acenaphthene			70.7		%		60-130	27-FEB-14
Acenaphthylene			126.6		%		60-130	27-FEB-14
Anthracene			125.0		%		60-130	27-FEB-14
Benz(a)anthracene			116.8		%		60-130	27-FEB-14
Benzo(a)pyrene			99.1		%		60-130	27-FEB-14
Benzo(b)fluoranthene			129.3		%		60-130	27-FEB-14
Benzo(g,h,i)perylene			94.5		%		60-130	27-FEB-14
Benzo(k)fluoranthene			107.4		%		60-130	27-FEB-14
Chrysene			118.7		%		60-130	27-FEB-14
Dibenz(a,h)anthracene			109.5		%		60-130	27-FEB-14
Fluoranthene			123.8		%		60-130	27-FEB-14
Fluorene			77.7		%		60-130	27-FEB-14
Indeno(1,2,3-c,d)pyrene			100.0		%		60-130	27-FEB-14
2-Methylnaphthalene			97.2		%		60-130	27-FEB-14
Naphthalene			99.0		%		50-130	27-FEB-14
Phenanthrene			118.4		%		60-130	27-FEB-14
Pyrene			123.5		%		60-130	27-FEB-14
WG1836681-1 MB								
Acenaphthene			<0.0050		mg/kg		0.005	27-FEB-14
Acenaphthylene			<0.0050		mg/kg		0.005	27-FEB-14
Anthracene			<0.0040		mg/kg		0.004	27-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2797995								
WG1836681-1 MB								
Benz(a)anthracene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(a)pyrene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(b)fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Chrysene			<0.010		mg/kg		0.01	27-FEB-14
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	27-FEB-14
Fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Fluorene			<0.010		mg/kg		0.01	27-FEB-14
Indeno(1,2,3-c,d)pyrene			<0.010		mg/kg		0.01	27-FEB-14
2-Methylnaphthalene			<0.010		mg/kg		0.01	27-FEB-14
Naphthalene			<0.010		mg/kg		0.01	27-FEB-14
Phenanthrene			<0.010		mg/kg		0.01	27-FEB-14
Pyrene			<0.010		mg/kg		0.01	27-FEB-14
Surrogate: Naphthalene d8			74.8		%		50-130	27-FEB-14
Surrogate: Acenaphthene d10			76.7		%		60-130	27-FEB-14
Surrogate: Phenanthrene d10			77.6		%		60-130	27-FEB-14
Surrogate: Chrysene d12			88.0		%		60-130	27-FEB-14
PH-WW-1:2-DI-MAN-VA	**Soil**							
Batch R2797958								
WG1836549-13 DUP		**L1424625-1**						
pH (1:2 soil:water)		8.17	8.09	J	pH	0.08	0.3	27-FEB-14
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1837346-1 CVS								
1-Methylnaphthalene			99.2		%		50-150	28-FEB-14
2-Methylnaphthalene			102.2		%		50-150	28-FEB-14
Acenapthene			103.8		%		50-150	28-FEB-14
Acenaphthylene			104.9		%		50-150	28-FEB-14
Anthracene			107.8		%		50-150	28-FEB-14
Benzo(a)anthracene			105.1		%		50-150	28-FEB-14
Benzo(a)pyrene			104.6		%		50-150	28-FEB-14
Benzo(b)fluoranthene			105.2		%		50-150	28-FEB-14
Benzo(g,h,i)perylene			92.9		%		50-150	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1837346-1 CVS								
Benzo(k)fluoranthene			99.2		%		50-150	28-FEB-14
Chrysene			109.7		%		50-150	28-FEB-14
Dibenzo(ah)anthracene			106.2		%		50-150	28-FEB-14
Fluoranthene			103.9		%		50-150	28-FEB-14
Fluorene			104.8		%		50-150	28-FEB-14
Indeno(1,2,3-cd)pyrene			100.6		%		50-150	28-FEB-14
Naphthalene			107.9		%		50-150	28-FEB-14
Phenanthrene			102.6		%		50-150	28-FEB-14
Pyrene			112.4		%		50-150	28-FEB-14
WG1836846-2 LCS								
1-Methylnaphthalene			78.5		%		50-150	28-FEB-14
2-Methylnaphthalene			79.2		%		50-150	28-FEB-14
Acenapthene			85.9		%		50-150	28-FEB-14
Acenaphthylene			86.9		%		50-150	28-FEB-14
Anthracene			89.6		%		50-150	28-FEB-14
Benzo(a)anthracene			86.7		%		50-150	28-FEB-14
Benzo(a)pyrene			86.2		%		50-150	28-FEB-14
Benzo(b)fluoranthene			75.5		%		50-150	28-FEB-14
Benzo(g,h,i)perylene			80.1		%		50-150	28-FEB-14
Benzo(k)fluoranthene			81.1		%		50-150	28-FEB-14
Chrysene			91.1		%		50-150	28-FEB-14
Dibenzo(ah)anthracene			88.1		%		50-150	28-FEB-14
Fluoranthene			90.1		%		50-150	28-FEB-14
Fluorene			88.8		%		50-150	28-FEB-14
Indeno(1,2,3-cd)pyrene			84.8		%		50-150	28-FEB-14
Naphthalene			84.0		%		50-150	28-FEB-14
Phenanthrene			88.7		%		50-150	28-FEB-14
Pyrene			97.6		%		50-150	28-FEB-14
WG1836846-1 MB								
1-Methylnaphthalene			<0.020		ug/L		0.02	28-FEB-14
2-Methylnaphthalene			<0.020		ug/L		0.02	28-FEB-14
Acenapthene			<0.020		ug/L		0.02	28-FEB-14
Acenaphthylene			<0.020		ug/L		0.02	28-FEB-14
Anthracene			<0.020		ug/L		0.02	28-FEB-14
Benzo(a)anthracene			<0.020		ug/L		0.02	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1836846-1 MB								
Benzo(a)pyrene			<0.010		ug/L		0.01	28-FEB-14
Benzo(b)fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Benzo(g,h,i)perylene			<0.020		ug/L		0.02	28-FEB-14
Benzo(k)fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Chrysene			<0.020		ug/L		0.02	28-FEB-14
Dibenzo(ah)anthracene			<0.020		ug/L		0.02	28-FEB-14
Fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Fluorene			<0.020		ug/L		0.02	28-FEB-14
Indeno(1,2,3-cd)pyrene			<0.020		ug/L		0.02	28-FEB-14
Naphthalene			<0.020		ug/L		0.02	28-FEB-14
Phenanthrene			<0.020		ug/L		0.02	28-FEB-14
Pyrene			<0.020		ug/L		0.02	28-FEB-14
Surrogate: 2-Fluorobiphenyl			86.9		%		50-150	28-FEB-14
Surrogate: d14-Terphenyl			95.4		%		50-150	28-FEB-14

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

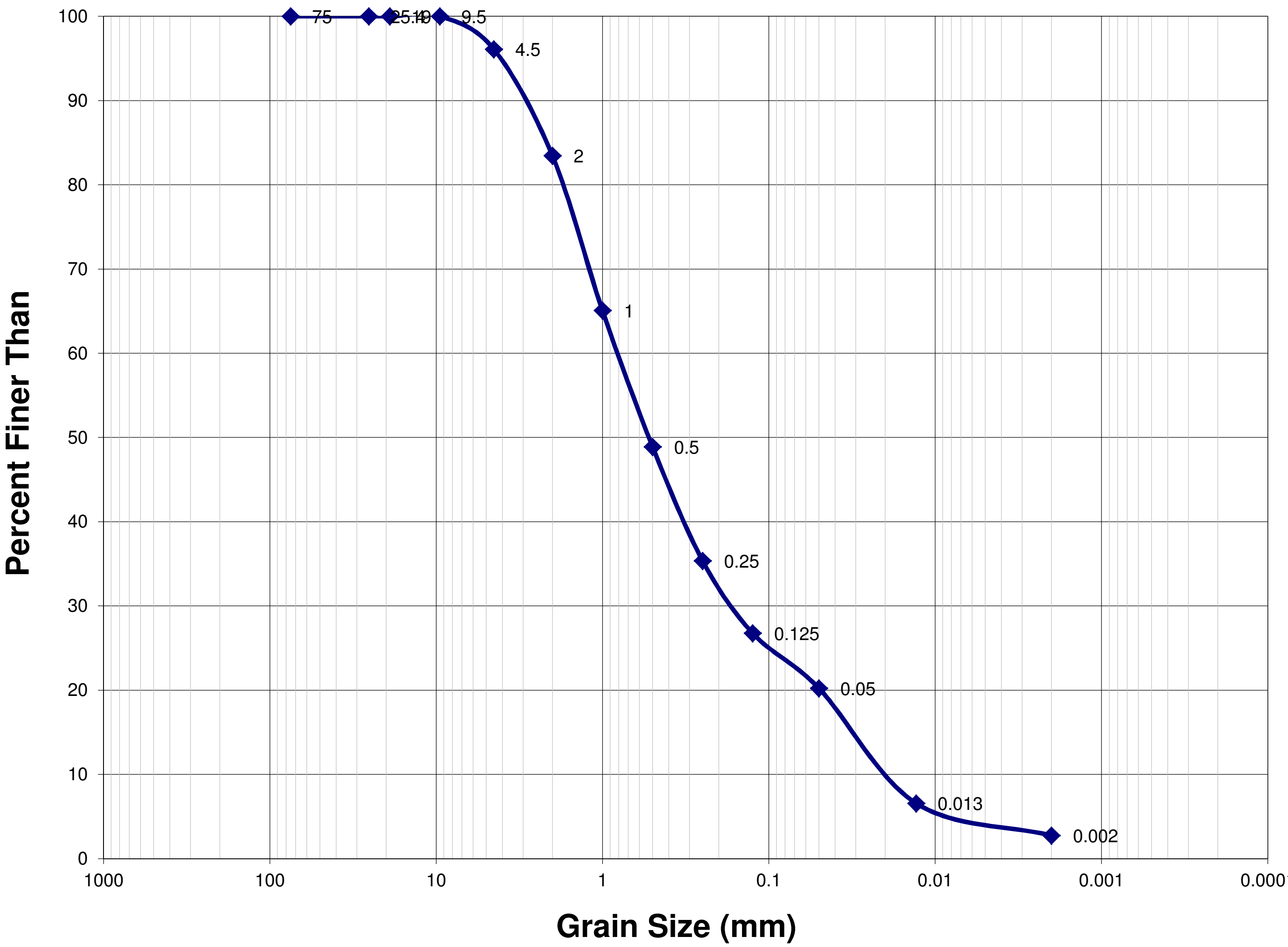
Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: COMPOSITE
Lab ID: L1424625-1

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	4
Coarse Sand	2.0mm - 4.75mm	13
Medium Sand	0.425mm - 2.0mm	35
Fine Sand	0.075mm - 0.425mm	26
Fines	< 0.075mm	22

Canadian Soil Survey Committee (CSSC)

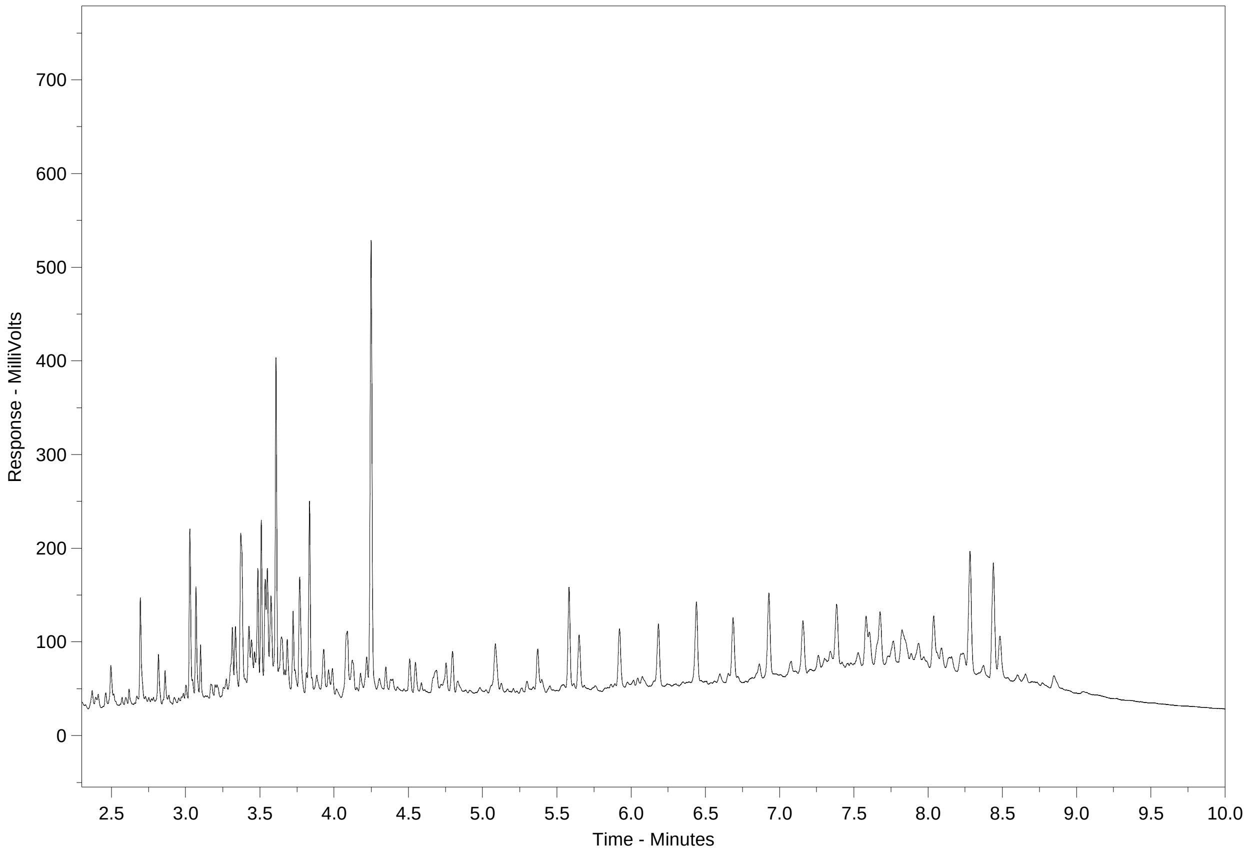
Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	17
Sand	0.05mm - 2mm	63
Silt	0.002mm - 0.05mm	17
Clay	< 0.002mm	3

Texture   Loamy sand

Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

Hydrocarbon Distribution Report

ALS Sample ID: L1424625-1
Client Sample ID: COMPOSITE



nC10	nC19	nC32
174°C	330°C	467°C
346°F	626°F	873°F

← Gasoline → ← Motor Oils / Lube Oils / Grease →
← Diesel / Jet Fuels →

The EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample. For further interpretation, a current library of reference products is available on www.alsglobal.com or upon request.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at the left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

APPENDIX D

Appendix D Environmental Investigation of Lower Dam

TECHNICAL MEMORANDUM

DATE April 28, 2014 **REFERENCE No.** 1314470516-005-TM-Rev0-7000

TO File: Lower Colliery Dam EvaluationNanaimo City Hall

FROM Jim Laidlaw, P.Eng. **EMAIL** jim_laidlaw@golder.com

INITIAL GEO-ENVIRONMENTAL ASSESSMENT OF SLAG FILL ENCOUNTERED AT THE LOWER COLLIERY DAM IN NANAIMO, BRITISH COLUMBIA

This technical memorandum presents the results of an initial geo-environmental assessment of suspect slag, ash and cinder fill (hereafter referred to as the slag fill) encountered during the investigation of the Lower Colliery Dam in Nanaimo, British Columbia.

1.0 BACKGROUND

The Lower Colliery Dam is the furthest downstream of a series of three dams on the Chase River system, is situated to the southeast of the City of Nanaimo, and is within a municipal park (Colliery Dam Park).

The Lower Colliery Dam was reported to have been constructed after 1904, to support the development and operation of local coal mines. The Lower Colliery Dam is a rock fill dam with a 1.2 metre thick, vertical, concrete core wall. The dam is approximately 24 metres high, and has a crest length and width of 77 metres and 10 metres, respectively. The concrete used to construct the core of the dam is thought to be one of the first industrial uses of concrete manufactured on Vancouver Island, following the establishment of the Todd Bay Portland Cement Quarry in 1904. The Todd Bay Quarry was located at the Butchart Gardens site, north of Victoria, BC[1].

Fill, consisting of mine and process waste, was placed on the downstream face of the dam sometime after the dam's construction. This fill was found (through previous investigations) to include zones of slag, cinder and ash material.

2.0 ISSUES WITH RESPECT TO THE LOWER DAM

A number of issues have been raised with respect to the Lower Dam, including the quality of fills placed to support the dam, the design and capacity of the dam and spillway structure, and the seismic and flood performance of the dam. An additional concern relates to the age of the dam, and the integrity of the concrete in the core wall.

To further assess the condition of the dam, and the fill comprising the downstream face of the dam, a geotechnical investigation was initiated by Golder Associates Ltd. (Golder) in 2014. The purpose of the geotechnical investigation was to address gaps and uncertainties in the existing information available for the Lower Dam. The investigation included a surface geophysical survey, the coring of holes in the concrete wall of the Lower Dam, and the drilling and sampling of three boreholes in the downstream shell of the Lower Dam.

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[1] Based on information contained in an EBA Engineering Consultants Ltd. report, dated April 14, 2010.

As part of the geotechnical and geophysical investigation of the dam, sampling and analysis of representative samples of the slag fill material was also undertaken, for the assessment of potential contamination issues. Coal slag has been reported, in the literature, to potentially contain concentrations of metals and hydrocarbon components.

3.0 GEOTECHNICAL INVESTIGATION AND SOIL SAMPLING

The geotechnical investigation of the Lower Dam was conducted February 11 to 14, 2014. As part of the geotechnical investigation of the dam, soil samples were collected from the suspect slag fill material for potential chemical analyses.

Three boreholes (SH14-04 to SH14-06) were drilled within the dam fill, and ten (10) sub-samples (plus one duplicate sample) of the soil containing visible slag fill, were collected from varying depth intervals, for environmental evaluation and testing.

Details on the geotechnical investigation including sample locations and soil conditions can be found in Section 6.0 of the Factual Report.

3.1 Observations

The slag fill was encountered below surficial fill and extended 3.6 to 5.4 m below ground surface. The slag fill was generally described as being black in colour, and containing cinder, slag and ash components. No odours, staining or other debris was noted to be associated with this material.

3.2 Potential Contaminants of Concern

The origin of the reported slag fill is currently unknown. However, assuming that it was a by-product of local coal mining and processing operations, the following potential contaminants of concern were inferred, based on the results of limited research on coal slag composition:

- Metals (in particular, lead and zinc);
- Polycyclic Aromatic Hydrocarbons (PAH);
- Extractable Petroleum Hydrocarbons (EPH); and
- Leachable metals and hydrocarbons.

3.3 Inferred Applicable Standards

The Lower Dam is located within the City of Nanaimo, and also within a City park. While a dam would typically be considered industrial land use, the location of the dam (*i.e.,* within a public park) would suggest that the most conservative applicable standards would be the British Columbia Ministry of Environment’s (BC MoE’s) Contaminated Sites Regulation (CSR) Park Land Use (PL) soil standards.

Residential developments are located in the vicinity of the park, but outside the area of the dam. Commercial and industrial operations are located to the northwest of the park, but again, at some distance from the dam. No agricultural lands have been identified in the immediate vicinity of the dam, to date. Therefore, the Agricultural Land Use (AL), Residential Land Use (RL), Commercial Land Use (CL) and Industrial Land Use (IL) soil standards were not considered relevant for the purposes of this initial assessment.

With respect to potentially applicable, site-specific factors under the CSR, the following site-specific factors were considered relevant, given the initial evaluation of conditions at and near the dam:

- Intake of Contaminated Soil (applicable at all sites);
- Toxicity to Soil Invertebrates and Plants (applicable at all sites);
- Groundwater Flow to Surface Water Used by Aquatic Life (freshwater); and
- Groundwater Used for Drinking Water.

In addition to the CSR standards, the standards presented in the BC MoE's Hazardous Waste Regulation (HWR) were also considered relevant. Leachate Quality Standards (LQS) used in the assessment of the leachability of the material, and other specific standards associated with composition (for example, PAH Toxicity Equivalence (TEQ) factor) were also referenced.

4.0 RESULTS OF ANALYSES

4.1 General

Soil samples collected during the geotechnical investigation of the Lower Dam were placed in clean, glass sample containers supplied by the analytical laboratory. Soil was placed in each jar such that there was minimal headspace remaining in the jar. The jars were then sealed, appropriately labeled, and placed in a cooler with ice packs, for storage and transport to the analytical laboratory.

Soil samples collected from the dam were shipped to ALS Laboratories (ALS) in Burnaby, British Columbia for selected chemical analyses and/or archiving. ALS is a Canadian Association for Laboratory Accreditation (CALA) certified, professional environmental testing laboratory. All sample submissions were accompanied by appropriately completed, Chain-of-Custody forms.

The results of chemical analyses were detailed in the Certificate of Analysis report prepared by ALS, and this report is attached following the text of this technical memorandum. The results of analyses have also been tabulated and compared with the inferred relevant environmental quality standards under the CSR and HWR. The tabulated results are presented in Tables 1 to 4, and are also attached following the text of this technical memorandum.

The environmental sampling and analysis program was split into two phases: an initial phase and a follow-up phase. The reasoning for this split was that it was considered important to obtain an indication of the chemical quality of the slag fill as soon as possible, so that if additional sampling was required, it could be conducted at the time of the geotechnical investigation. Therefore, samples of the slag fill obtained from the first borehole excavated at the Lower Dam (*i.e.,* SH14-05) were collected and overnight couriered to the laboratory for rush analysis of selected parameters. The results of these initial analyses would then determine the need for, and scope of, follow-up sampling and analysis.

4.2 Initial Analyses

To initially assess the chemical quality of the slag fill, three samples from the initial borehole (SH14-05) were submitted for selected chemical analyses, including: metals, Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH: basically a combination of EPH and PAH analyses) and Toxicity Characteristics Leaching Procedure (TCLP; for assessment of metals leachability).

The results of analyses were compared with the relevant CSR and HWR standards. The interpretation of these initial results was as follows:

- The slag fill contained metals concentrations that exceeded the CSR PL and CSR IL soil standards. Arsenic and barium were identified as the primary metals found in exceedance of the CSR soil standards (Table 1).
- Sodium concentrations detected in the slag fill were also reported to exceed the CSR PL soil standard (Table 1). However, the reported sodium concentration was based on an aggressive, Inductively Coupled Plasma – Mass Spectrometer (ICP-MS) testing method. The BC MoE recommends a less aggressive, Saturated Paste Method of analysis for determination of sodium and chloride concentrations in soil. In our experience, the ICP-MS testing method results in a significantly higher reported sodium concentration than the Saturated Paste Method. Therefore, the reported sodium concentrations are likely over-estimates of the actual sodium (ion) concentrations in soil. It is important to note that the CSR standard for sodium is also based on the sodium (ion) concentration resulting from the Saturated Paste Method of analysis.
- The slag fill contained hydrocarbon and certain PAH constituent concentrations exceeding the CSR PL soil standards (Table 1). The hydrocarbon concentrations reported between samples collected from the same borehole were observed to vary significantly, suggesting inhomogeneity within the slag fill.
- The TCLP results for metals indicated that the slag fill would not be classified as a Hazardous Waste, based on metals leachability (Table 2).
- The slag fill would also not be classified as a Hazardous Waste, based on hydrocarbon content. Total hydrocarbon concentrations reported in the slag fill were much less than 30,000 milligrams per kilogram (mg/kg) or 3% oil and grease (*i.e.,* the HWR Waste Oil standard) (Table 3).
- The slag fill would not be classified as a Hazardous Waste, based on PAH TEQ calculations (Table 3).

The results of the initial chemical analyses conducted on samples from the first borehole drilled at the dam indicated that the slag fill did contain metals and hydrocarbon concentrations exceeding the inferred applicable CSR soil standards.

To further assess the slag fill, additional, follow-up analyses of other representative samples from slag fill was considered warranted.

4.3 Follow-Up Analyses

Once the remaining two, geotechnical boreholes had been drilled and sampled, selected additional analyses were requested, as follows:

- A composite sample, generated from all borehole samples collected from the slag fill material, was prepared and submitted for analysis of:
  - Total metals;
  - EPH;
  - PAH; and
  - Synthetic Precipitation Leaching Procedure (SPLP; analysed for metals and PAH).
- TCLP analysis for benzo (a) pyrene was also requested for a previously submitted, discrete slag fill sample.

The intent of the composite sample analysis was to assess the general chemical characteristics of the slag fill, in light of the relatively inhomogeneous nature of the fill material noted from the analysis of the initial, three, discrete samples from the first borehole.

The intent of the SPLP test was to assess the leachate generated through simulated precipitation flow-through, to evaluate whether such leachate would contain chemical concentrations of concern with respect to the CSR Water standards and/or the British Columbia Water Quality Guidelines (BCWQG).

The intent of the TCLP analysis for benzo (a) pyrene was to provide information necessary to assess whether the material would be considered a Hazardous Waste, based on benzo (a) pyrene leachability.

The results of these follow-up analyses are summarized below:

- The composite slag fill sample (comprising equal portions of 10 discrete samples from the slag fill zone) contained an arsenic concentration exceeding both the CSR PL and CSR IL soil standards (with reference to the site-specific factors considered applicable) (Table 1).
- Reported sodium concentrations in the composite slag fill sample exceeded the CSR PL soil standard. However, this reported concentration is not considered valid for the purposes of chemical quality assessment, for the reasons outlined in the previous section (Table 1).
- The composite slag fill sample contained hydrocarbon (light and heavy extractable petroleum hydrocarbon; LEPH and HEPH) concentrations exceeding the CSR PL soil standards (Table 1).
- The composite slag fill sample contained a naphthalene concentration exceeding the CSR PL soil standard (Table 1).
- The composite slag fill sample did not contain concentrations that would classify it as a Hazardous Waste, based on:
  - Total hydrocarbon concentrations – composite sample (Table 3);
  - PAH TEQ – composite sample (Table 3); or
  - TCLP leachability (benzo (a) pyrene). [Note that this analysis was conducted on the discrete sample containing the highest reported benzo (a) pyrene concentration (SH14-05; Sample 3)] (Table 2).

- The SPLP testing of the composite slag fill sample indicated that, while certain metals and PAH constituents were detected in the leachate, none of the reported concentrations in the leachate exceeded either the CSR AW (freshwater) standards, or the BCWQ freshwater guidelines, including that of arsenic (Table 4)[2].

5.0 GENERAL SUMMARY

The results of investigations and analyses conducted, to date, by Golder at the Lower Dam site indicate the following:

- The Lower Colliery Dam contains cinder, ash and slag fill on its downstream face.
- The slag fill is estimated to be up to 6 metres, or more, in thickness on the downstream face.
- The slag fill contains metals concentrations (specifically barium and arsenic) that exceed both the CSR PL and CSR IL soil standards.
- The slag fill contains hydrocarbon concentrations (extractable petroleum hydrocarbon (LEPH and/or HEPH) and selected polycyclic aromatic hydrocarbon (PAH) constituents) that exceed the CSR PL soil standards.
- Testing results obtained, to date, do not indicate that the slag fill would be classified as a Hazardous Waste under the HWR.
- Synthetic Precipitation Leaching Procedure (SPLP) testing suggests that the leachate generated through contact between the slag fill and precipitation would likely not result in water concentrations exceeding either the CSR AW (freshwater) standards or the BCWQ guidelines for freshwater.

As exceedances of the inferred applicable CSR soil standards have been detected in the slag fill, future treatment, handling or dam remediation activities involving this fill will likely require regulatory notification and, possibly, permitting.

6.0 LIMITATIONS AND USE

This technical memorandum (report) was prepared for the exclusive use of The City of Nanaimo. The report, which specifically includes all tables, figures and attachments, is based on data and information collected during the site investigation conducted by Golder Associates Ltd., and is based solely on the conditions of the property at the time of the field investigation, supplemented by historical information and data obtained by Golder Associates Ltd., as described in this report.

Except where specifically stated to the contrary, the information contained in this report was provided to Golder Associates Ltd. by others, and has not been independently verified or otherwise examined by Golder Associates Ltd. to determine its accuracy of completeness. Golder Associates Ltd. has relied in good faith on this information and does not accept responsibility of any deficiency, misstatements or inaccuracies contained in the report as a result of omissions, misinterpretation and/or fraudulent acts of the persons interviewed or contacted, or errors or omissions in the reviewed documentation.

[2] Certain metal detection limits exceeded the standards and/or guidelines, making interpretation of these results impossible. However, for the primary contaminants of concern (*i.e.,* arsenic and barium), where detection limits were raised, a request was made to re-analyse the sample to obtain a lower detection limit.

The assessment of environmental conditions and possible hazards at this site has been made using the results of chemical analyses of discrete soil samples from a limited number of locations. The site conditions between sampling locations have been inferred based on conditions observed at the borehole locations. Subsurface conditions may vary from these sample locations. Additional study, including further subsurface investigation, can reduce inherent uncertainties associated with this type of study. However, it is never possible, even with exhaustive sampling and testing, to dismiss the possibility that part of a site may be contaminated and remains undetected.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

The content of this report is based on information collected during our investigation, our present understanding of the site conditions, and our professional judgment in light of such information available at the time of this report. This report provides a professional opinion, and therefore no warranty is either expressed, implied or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments, as required.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Jim Laidlaw, P.Eng.
Principal, Senior Project Engineer

JL/sn

Attachments: Table 1 – Results of Soil Analyses – Metals, Hydrocarbons
Table 2 – Results of Soil Leachate Analyses – TCLP (Metals, B[a]P)
Table 3 – Results of Soil Analyses – Other HWR Tests
Table 4 – Results of Soil Leachate Analyses – SPLP
Attachment 1 – Certificate of Analysis - ALS

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Table 1: Results of Soil Analyses - Metals, Hydrocarbons
Namaimo Colliery Dams
Nanaimo, BC

Sample Identification **Depth (metres, below ground surface)** **SCN** **Date Sampled** **QA/QC**	CSR Standards for Park Land Use (CSR PL)	**MCS**	**CSR Standards for Industrial Land Use (CSR IL)**	**MCS**	**SH14-05 SA E1** 0.76 - 1.15 10-368952 #1 11-Feb-14 Discrete	**SH14-05 SA E3** 3.69 - 4.00 10-368952 #3 11-Feb-14 Discrete	**SH14-05 SA E5** 6.77 - 7.08 10-368952 #5 11-Feb-14 Discrete	**SH14-04/05/06** Various L1424625-1 11 to 14-Feb-14 Composite
Physical Parameters								
moisture (%)					32.1	17.6	18.7	19.2
pH (pH units)					8.01	7.74	7.22	8.17
Total Metals								
aluminum					34500	12400	15300	15400
antimony	20	G	**40**	G	1.04	0.50	0.46	0.67
arsenic	15	DW	**15**	DW	5.15	**56.4**	**20.3**	**49.6**
barium	400	DW	**400**	DW	**623**	220	140	229
beryllium	4	G	**8**	G	1.31	0.39	0.37	0.51
bismuth					<0.20	<0.20	<0.20	<0.20
cadmium	1.5 - 35	D/I/pH	**1.5 - 500**	D/T/pH	<0.050	0.121	0.112	0.108
calcium					74200	26600	27800	34000
chromium	60 Total	DW	**60 Total**	DW	26.4	42.5	34.4	31.1
cobalt	50	G	**300**	G	12.9	9.95	10.6	10.1
copper	90 - 150	F/T/pH	**90-250**	F/T/pH	66.6	46.8	50.9	47.5
iron					23100	22800	17900	20200
lead	100 - 500	D/I/pH	**100 - 2,000**	D/T/pH	<5.0	13.9	<6.0	8.56
lithium	1,600	S	**20,000**	S	27.7	21.3	26.3	19.1
magnesium					2030	4490	3290	2920
manganese	1,800	S	**19,000**	S	335	339	305	294
mercury (inorganic)	15	I	**150**	T	0.0190	0.312	0.163	0.206
molybdenum	10	G	**40**	G	3.15	2.59	1.37	2.76
nickel	100	G	**500**	G	35.2	71.0	57.2	58.3
phosphorus					723	404	392	326
potassium					480	910	1020	740
selenium	3	G	**10**	G	<0.20	0.64	0.43	0.49
silver	20	G	**40**	G	0.11	0.12	0.12	<0.10
sodium (ion)	200	T	**1000**	T	*540*	*240*	*340*	*280*
strontium (stable)	47,000	S	**100,000**	S	444	286	221	215
thallium					<0.050	0.170	0.094	0.148
tin	50	G	**300**	G	<2.0	<2.0	<2.0	<2.0
titanium					1960	465	1100	731
uranium	16	S	**200**	S	1.34	0.539	0.541	0.610
vanadium	200	G			180	59.5	66.3	101
zinc	150 - 450	D/T/pH	**150 - 600**	D/T/pH	12.1	37.2	34.5	33.4
Extractable Hydrocarbons								
EPH_{C10-19}	*1,000*	G	***2,000***	G	<200	1,610	560	1,210
EPH_{C19-32}	*1,000*	G	***5,000***	G	<200	2,340	840	1,620
LEPHs	1,000	G	**2,000**	G	<200	1,590	550	1,200
HEPHs	1,000	G	**5,000**	G	<200	2,340	840	1,610
Polycyclic Aromatic Hydrocarbons								
acenaphthene					<0.050	<0.20	<0.050	<0.20
acenaphthylene					<0.050	<0.40	<0.090	<0.40
anthracene					<0.050	0.628	0.251	0.429
benzo(a)anthracene	1	G	**10**	G	0.077	1.04	0.275	0.438
benzo(a)pyrene	1	T	**10**	T	<0.050	0.242	0.168	0.163
benzo(b)fluoranthene	1	G	**10**	G	<0.050	0.495	0.279	0.364
benzo(g,h,i)perylene					<0.050	<0.20	0.088	0.088
benzo(k)fluoranthene	1	G	**10**	G	<0.050	<0.30	<0.070	<0.060
chrysene					0.063	0.774	0.236	0.384
dibenz(a,h)anthracene	1	G	**10**	G	<0.050	<0.050	<0.050	<0.050
fluoranthene					0.053	0.606	0.231	0.393
fluorene					<0.050	<0.30	<0.20	<0.30
indeno(1,2,3-c,d)pyrene	1	G	**10**	G	<0.050	0.098	<0.050	0.055
2-methylnaphthalene					1.25	17.6	5.70	14.5
naphthalene	5	G	**50**	G	0.891	12.3	3.78	10.9
phenanthrene	5	G	**50**	G	0.335	4.25	1.74	2.85
pyrene	10	G	**100**	G	0.067	0.747	0.330	0.497

Notes:

Results are expressed in micrograms per gram (ug/g), unless otherwise indicated.

Standards shown are from the Contaminated Sites Regulation (CSR), enacted in 1997, and updated to March 2013.

SCN = sample control number

Land Use abbreviations: PL (Urban Park Land); IL (Industrial Land)

MCS: most conservative standard based on applicable site-specific standards

Referenced site-specific factors include: I = Intake of Contaminated Soil; T = Toxicity to Invertebrates and Plants; AW = Groundwater Flow to Surface Water used by Aquatic Life;

F = Fresh Water Aquatic Life; DW = Drinking Water; G = Generic; S = Schedule 10; pH = standard is pH dependent

QA/QC = quality assurance/quality control

FDA = Field Duplicate Available; FD = Field Duplicate

< = less than

EPH_{C10-19} = extractable petroleum hydrocarbons, carbon range 10-19; used as an indicator for LEPH

EPH_{C19-32} = extractable petroleum hydrocarbons, carbon range 19-32; used as an indicator for HEPH

LEPHs = light extractable petroleum hydrocarbons

HEPHs = heavy extractable petroleum hydrocarbons

Sodium (ion) concentrations are highlighted, italicized and underlined as results based on ICP-MS analysis, which typically yields much higher concentrations than recommended Saturated Paste Method.

Table 2: Results of Soil Leachate Analyses - TCLP (Metals, B[a]P)
Nanaimo Colliery Dams
Nanaimo, BC

Sample Identification Depth (metres beloow ground surface) SCN Date Sampled	HWR Leachate Quality Standards	SH14-05 SA E1 0.76 - 1.15 10-368952 #1 11-Feb-14	SH14-05 SA E3 3.69 - 4.00 10-368952 #3 11-Feb-14	SH14-05 SA E5 6.77 - 7.08 10-368952 #5 11-Feb-14
Polycyclic Aromatic Hydrocarbons				
1st Preliminary pH (pH units)		-	9.18	-
2nd Preliminary pH (pH units)		-	1.73	-
Extractable Solution Initial pH (pH units)		-	4.91	-
Final pH (pH units)		-	5.52	-
benzo(a)pyrene	**0.001**	-	<0.00050	-
TCLP Metals				
1st Preliminary pH (pH units)		9.44	8.99	7.87
2nd Preliminary pH (pH units)		5.10	1.77	1.67
Extractable Solution Initial pH (pH units)		2.86	4.89	4.89
Final pH (pH units)		5.09	5.37	5.06
antimony		<1.0	<1.0	<1.0
arsenic	**2.5**	<1.0	<1.0	<1.0
barium	**100**	<2.5	<2.5	<2.5
beryllium		<0.025	<0.025	<0.025
boron	**500**	0.79	<0.50	<0.50
cadmium	**0.5**	<0.050	<0.050	<0.050
calcium		1480	372	293
chromium	**5**	<0.25	<0.25	<0.25
cobalt		<0.050	<0.050	<0.050
copper	**100**	<0.050	<0.050	<0.050
iron		<0.15	<0.15	0.33
lead	**5**	<0.25	<0.25	<0.25
magnesium		3.35	6.28	4.32
mercury	**0.1**	<0.0010	<0.0010	<0.0010
nickel		<0.25	<0.25	<0.25
selenium	**1**	<1.0	<1.0	<1.0
silver	**5**	<0.050	<0.050	<0.050
thallium		<1.0	<1.0	<1.0
vanadium		<0.15	<0.15	<0.15
zinc	**500**	<0.50	<0.50	<0.50

Notes:
Results are expressed in milligrams per liter (mg/L), unless otherwise indicated.
Standards shown are from the Hazardous Waste Regulation (HWR), enacted in 1988 and updated to April 2009.
SCN = sample control number
"<" = less than; "-" = not tested
TCLP = Toxicity Characteristic Leaching Procedure

Table 3: Results of Soil Analyses - Other HWR Tests
Nanaimo Colliery Dams
Nanaimo, BC

Sample Identification	SH14-05 SA E1	SH14-05 SA E3	SH14-05 SA E5	SH14-04/05/06
Depth (metres, below ground surface)	0.76 - 1.15	3.69 - 4.00	6.77 - 7.08	Various
SCN	10-368952 #1	10-368952 #3	10-368952 #5	L1424625-1
Date Sampled	11-Feb-14	11-Feb-14	11-Feb-14	11 to 14-Feb-14
QA/QC	Discrete	Discrete	Discrete	Composite
Polycyclic Aromatic Hydrocarbons				
acenaphthene	<0.050	<0.20	<0.050	<0.20
acenaphthylene	<0.050	<0.40	<0.090	<0.40
anthracene	<0.050	0.628	0.251	0.429
benzo(a)anthracene	0.077	1.04	0.275	0.438
benzo(a)pyrene	<0.050	0.242	0.168	0.163
benzo(b)fluoranthene	<0.050	0.495	0.279	0.364
benzo(g,h,i)perylene	<0.050	<0.20	0.088	0.088
benzo(k)fluoranthene	<0.050	<0.30	<0.070	<0.060
chrysene	0.063	0.774	0.236	0.384
dibenz(a,h)anthracene	<0.050	<0.050	<0.050	<0.050
fluoranthene	0.053	0.606	0.231	0.393
fluorene	<0.050	<0.30	<0.20	<0.30
indeno(1,2,3-c,d)pyrene	<0.050	0.098	<0.050	0.055
2-methylnaphthalene	1.25	17.6	5.70	14.5
naphthalene	0.891	12.3	3.78	10.9
phenanthrene	0.335	4.25	1.74	2.85
pyrene	0.067	0.747	0.330	0.497
Calculated PAH TEQ	0.133	0.500	0.295	0.315
HWR PAH TEQ	**100**	**100**	**100**	**100**
Extractable Hydrocarbons				
EPH_{C10-19}	<200	1610	560	1210
EPH_{C19-32}	<200	2340	840	1620
LEPHs	<200	1590	550	1200
HEPHs	<200	2340	840	1610
Sum (EPH)	<400	3950	1400	2830
HWR (Waste Oil)	**30,000**	**30,000**	**30,000**	**30,000**

Notes:

Results are expressed in micrograms per gram (ug/g), unless otherwise indicated.

Standards shown are from the Hazardous Waste Regulation (HWR), enacted in 1988, and updated to 2009.

SCN = sample control number

< = less than

TEQ = Toxicity Equivalence Factor

PAH TEQ = Sum (PAH Constituent Concentration * TEF for PAH Constituent)

PAH TEQ = Sum([BaA]*0.1+[BaP]*1+[BbF]*0.1+[BkF]*0.1+[D(a,h)A]*1.1+[I(1,2,3-cd)P]*0.2)

EPH_{C10-19} = extractable petroleum hydrocarbons, carbon range 10-19; used as an indicator for LEPH

EPH_{C19-32} = extractable petroleum hydrocarbons, carbon range 19-32; used as an indicator for HEPH

LEPHs = light extractable petroleum hydrocarbons

HEPHs = heavy extractable petroleum hydrocarbons

Sum (EPH) used as an indicator of oil and grease concentrations

HWR Waste Oil = 3 % or 30,000 micrograms per gram of oil

Table 4: Results of Soil Leachate Analyses - SPLP
Nanaimo Colliery Dams
Nanaimo, BC

Sample Identification Depth (metres, below ground surface) SCN Date Sampled QA/QC	CSR Aquatic Life (freshwater) (CSR AWf)	Notes	BC Water Quality Guidelines (BCWQG - fresh)	Notes	SH14-04/05/06 Various L1424625-1 11 to 14-Feb-14 Composite
SPLP Test Results					
Metals					
aluminum			20 - 100	pH	***<200***
antimony	**200**				<200
arsenic	**50**		5		3.09
barium	**10,000**				<500
beryllium	**53**				<5
bismuth					<200
boron	**50,000**		1,200		<100
cadmium	**0.1-1.3**	H			***<10***
calcium					134000
chromium	**10^{VI}, 90^{III}**	V			***<50***
cobalt	**40**		110		<10
copper	**20-90**	H	Calculation	H	***<10***
iron					<30
lead	**40-160**	H	3 - 330	H	***<50***
lithium					<10
magnesium					1470
manganese			800 - 3,800	H	<5
mercury	**1**		0.1		***<1***
molybdenum	**10,000**		2,000		<30
nickel	**250-1,500**	H			<50
phosphorus			5 - 15		***<300***
potassium					<2000
selenium	**10**		2		***<200***
silicon					3090
silver	**0.5-15**	H	0.1 - 3		***<50***
sodium					<2000
strontium					437
thallium	**3**				***<200***
tin					<30
titanium	**1,000**				14
uranium	**3,000**				-
vanadium					<30
zinc	**75-3,150**	H	33 - 265	H	***<100***
Polycyclic Aromatic Hydrocarbons					
acenaphthene	**60**		6		<0.020
acenaphthylene					<0.020
anthracene	**1**		0.1 - 4		<0.020
benzo(a)anthracene	**1**		0.1		<0.020
benzo(a)pyrene	**0.1**		0.01		<0.010
benzo(b)fluoranthene					<0.020
benzo(g,h,i)perylene					<0.020
benzo(k)fluoranthene					<0.020
chrysene	**1**				<0.020
dibenzo(a,h)anthracene					<0.020
fluoranthene	**2**		0.2 - 4		<0.020
fluorene	**120**		12		<0.020
indeno(1,2,3-c,d)pyrene					<0.020
1-methylnaphthalene					0.026
2-methylnaphthalene					0.031
naphthalene	**10**		1		0.046
phenanthrene	**3**		0.3		0.026
pyrene	**0.2**		0.02		<0.020

Results are expressed in micrograms per liter (ug/L), unless otherwise indicated.
Standards and guidelines shown are from the Contaminated Sites Regulation (CSR), enacted in 1997 and updated to 2013; and BC Water Quality Guidelines (Approved), updated to August 2006. (max value)
SCN = sample control number
"<" = less than; "-" = not tested
SPLP = Synthetic Precipitation Leaching Procedure
Bold and italicized results indicate detection limit exceeds standard/guideline therefore interpretation is not possible.

ATTACHMENT 1

Certificate of Analysis - ALS

GOLDER ASSOCIATES LTD.
ATTN: Jim Laidlaw
500 - 4260 Still Creek Drive
Burnaby BC V5C 6C6

Date Received: 20-FEB-14
Report Date: 18-MAR-14 14:15 (MT)
Version: FINAL REV. 3

Client Phone: 604-298-6623

Certificate of Analysis

Lab Work Order #: L1424625

Project P.O. #: NOT SUBMITTED
Job Reference: 13-1447-0516
C of C Numbers:
Legal Site Desc:

Comments: The composite sample in this report was created with equal volumes of the following samples:

L1421658 - 1, 2, 3, 4, 5
L1423043 - 1, 2, 3
L1423044 - 1, 2

11-MAR-2014 SPLP Arsenic has been re-processed to provide a lower detection limit.
18-MAR-2014 Grain Size Analysis added, see end of report.

Amber Springer
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
SOIL						
Physical Tests	Grain Size Curve	SEE ATTACHED				
	Moisture (%)	19.2				
	pH (1:2 soil:water) (pH)	8.17				
Metals	Aluminum (Al) (mg/kg)	15400				
	Antimony (Sb) (mg/kg)	0.67				
	Arsenic (As) (mg/kg)	49.6				
	Barium (Ba) (mg/kg)	229				
	Beryllium (Be) (mg/kg)	0.51				
	Bismuth (Bi) (mg/kg)	<0.20				
	Cadmium (Cd) (mg/kg)	0.108				
	Calcium (Ca) (mg/kg)	34000				
	Chromium (Cr) (mg/kg)	31.1				
	Cobalt (Co) (mg/kg)	10.1				
	Copper (Cu) (mg/kg)	47.5				
	Iron (Fe) (mg/kg)	20200				
	Lead (Pb) (mg/kg)	8.56				
	Lithium (Li) (mg/kg)	19.1				
	Magnesium (Mg) (mg/kg)	2920				
	Manganese (Mn) (mg/kg)	294				
	Mercury (Hg) (mg/kg)	0.206				
	Molybdenum (Mo) (mg/kg)	2.76				
	Nickel (Ni) (mg/kg)	58.3				
	Phosphorus (P) (mg/kg)	326				
	Potassium (K) (mg/kg)	740				
	Selenium (Se) (mg/kg)	0.49				
	Silver (Ag) (mg/kg)	<0.10				
	Sodium (Na) (mg/kg)	280				
	Strontium (Sr) (mg/kg)	215				
	Thallium (Tl) (mg/kg)	0.148				
	Tin (Sn) (mg/kg)	<2.0				
	Titanium (Ti) (mg/kg)	731				
	Uranium (U) (mg/kg)	0.610				
	Vanadium (V) (mg/kg)	101				
	Zinc (Zn) (mg/kg)	33.4				
SPLP Metals	Extraction Solution Initial pH (pH)	4.99				
	Final pH (pH)	7.67				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L1424625-1
	Sample ID	L1424625-1
	Description	Soil
	Sampled Date	
	Sampled Time	
	Client ID	COMPOSITE
SOIL		
SPLP Metals	Aluminum (Al)-Leachable (mg/L)	<0.20
	Antimony (Sb)-Leachable (mg/L)	<0.20
	Arsenic (As)-Leachable (mg/L)	0.00309
	Barium (Ba)-Leachable (mg/L)	<0.50
	Beryllium (Be)-Leachable (mg/L)	<0.0050
	Bismuth (Bi)-Leachable (mg/L)	<0.20
	Boron (B)-Leachable (mg/L)	<0.10
	Cadmium (Cd)-Leachable (mg/L)	<0.010
	Calcium (Ca)-Leachable (mg/L)	134
	Chromium (Cr)-Leachable (mg/L)	<0.050
	Cobalt (Co)-Leachable (mg/L)	<0.010
	Copper (Cu)-Leachable (mg/L)	<0.010
	Iron (Fe)-Leachable (mg/L)	<0.030
	Lead (Pb)-Leachable (mg/L)	<0.050
	Lithium (Li)-Leachable (mg/L)	<0.010
	Magnesium (Mg)-Leachable (mg/L)	1.47
	Manganese (Mn)-Leachable (mg/L)	<0.0050
	Mercury (Hg)-Leachable (mg/L)	<0.0010
	Molybdenum (Mo)-Leachable (mg/L)	<0.030
	Nickel (Ni)-Leachable (mg/L)	<0.050
	Phosphorus (P)-Leachable (mg/L)	<0.30
	Potassium (K)-Leachable (mg/L)	<2.0
	Selenium (Se)-Leachable (mg/L)	<0.20
	Silicon (Si)-Leachable (mg/L)	3.09
	Silver (Ag)-Leachable (mg/L)	<0.050
	Sodium (Na)-Leachable (mg/L)	<2.0
	Strontium (Sr)-Leachable (mg/L)	0.437
	Thallium (Tl)-Leachable (mg/L)	<0.20
	Tin (Sn)-Leachable (mg/L)	<0.030
	Titanium (Ti)-Leachable (mg/L)	0.014
	Vanadium (V)-Leachable (mg/L)	<0.030
	Zinc (Zn)-Leachable (mg/L)	<0.10
Hydrocarbons	EPH10-19 (mg/kg)	1210
	EPH19-32 (mg/kg)	1620
	LEPH (mg/kg)	1200
	HEPH (mg/kg)	1610

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
SOIL						
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.20 DLM				
	Acenaphthylene (mg/kg)	<0.40 DLM				
	Anthracene (mg/kg)	0.429				
	Benz(a)anthracene (mg/kg)	0.438				
	Benzo(a)pyrene (mg/kg)	0.163				
	Benzo(b)fluoranthene (mg/kg)	0.364				
	Benzo(g,h,i)perylene (mg/kg)	0.088				
	Benzo(k)fluoranthene (mg/kg)	<0.060 DLM				
	Chrysene (mg/kg)	0.384				
	Dibenz(a,h)anthracene (mg/kg)	<0.050				
	Fluoranthene (mg/kg)	0.393				
	Fluorene (mg/kg)	<0.30 DLM				
	Indeno(1,2,3-c,d)pyrene (mg/kg)	0.055				
	2-Methylnaphthalene (mg/kg)	14.5				
	Naphthalene (mg/kg)	10.9				
	Phenanthrene (mg/kg)	2.85				
	Pyrene (mg/kg)	0.497				
	Surrogate: Acenaphthene d10 (%)	109.5				
	Surrogate: Chrysene d12 (%)	71.8				
	Surrogate: Naphthalene d8 (%)	93.1				
	Surrogate: Phenanthrene d10 (%)	81.5				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1424625-1				
	Description	Soil				
	Sampled Date					
	Sampled Time					
	Client ID	COMPOSITE				
Grouping	**Analyte**					
WASTE						
Polycyclic Aromatic Hydrocarbons	Acenapthene (ug/L)	<0.020				
	Acenaphthylene (ug/L)	<0.020				
	Anthracene (ug/L)	<0.020				
	Benzo(a)anthracene (ug/L)	<0.020				
	Benzo(a)pyrene (ug/L)	<0.010				
	Benzo(b)fluoranthene (ug/L)	<0.020				
	Benzo(g,h,i)perylene (ug/L)	<0.020				
	Benzo(k)fluoranthene (ug/L)	<0.020				
	Chrysene (ug/L)	<0.020				
	Dibenzo(ah)anthracene (ug/L)	<0.020				
	Fluoranthene (ug/L)	<0.020				
	Fluorene (ug/L)	<0.020				
	Indeno(1,2,3-cd)pyrene (ug/L)	<0.020				
	1-Methylnaphthalene (ug/L)	0.026				
	2-Methylnaphthalene (ug/L)	0.031				
	Naphthalene (ug/L)	0.046				
	Phenanthrene (ug/L)	0.026				
	Pyrene (ug/L)	<0.020				
	Surrogate: 2-Fluorobiphenyl (%)	87.2				
	Surrogate: d14-Terphenyl (%)	98.0				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Calcium (Ca)-Leachable	MS-B	L1424625-1
Matrix Spike	Magnesium (Mg)-Leachable	MS-B	L1424625-1
Matrix Spike	Silicon (Si)-Leachable	MS-B	L1424625-1
Matrix Spike	Strontium (Sr)-Leachable	MS-B	L1424625-1

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
EPH-TUMB-FID-VA	Soil	EPH in Solids by Tumbler and GCFID	BC MOE EPH GCFID

Analysis is in accordance with BC MOE Lab Manual method "Extractable Petroleum Hydrocarbons in Solids by GC/FID", v2.1, July 1999. Soil samples are extracted with a 1:1 mixture of hexane and acetone using a rotary extraction technique modified from EPA 3570 prior to gas chromatography with flame ionization detection (GC-FID). EPH results include Polycyclic Aromatic Hydrocarbons (PAH) and are therefore not equivalent to Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH).

GRAIN SIZE-SK	Soil	Grain Size Analysis	SSIR-51 METHOD 3.2.1

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

HG-SPLP-CVAFS-VA	Soil	Mercury by CVAFS (SPLP)	EPA 1312/245.7

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

HG-WW-200.2-CVAF-VA	Soil	Hg in Soil by CVAFS	EPA 200.2/245.7

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, sieved (wet sample) through a 2 mm (10 mesh) sieve, and a representative subsample of the material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis is by atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

LEPH/HEPH-CALC-VA	Soil	LEPHs and HEPHs	BC MOE LABORATORY MANUAL (2005)

Light and Heavy Extractable Petroleum Hydrocarbons in Solids. These results are determined according to the British Columbia Ministry of Environment, Lands, and Parks Analytical Method for Contaminated Sites "Calculation of Light and Heavy Extractable Petroleum Hydrocarbons in Solids or Water". According to this method, LEPH and HEPH are calculated
by subtracting selected Polycyclic Aromatic Hydrocarbon results from Extractable Petroleum Hydrocarbon results. To calculate LEPH, the individual results for Naphthalene and Phenanthrene are subtracted from EPH(C10-19). To calculate HEPH, the individual results for Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenz(a,h)anthracene, Indeno(1,2,3-c,d)pyrene, and Pyrene
are subtracted from EPH(C19-32). Analysis of Extractable Petroleum Hydrocarbons adheres to all prescribed elements of the BCMELP method "Extractable Petroleum Hydrocarbons in Solids by GC/FID" (Version 2.1, July 20, 1999).

MET-SPLP-ICP-VA	Soil	Metals by ICPOES (SPLP)	EPA 1312/6010B

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fiber filter and analyzed using inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-SPLP-MS-VA	Soil	Metals by ICPMS (SPLP)	EPA 1312/6020A

Reference Information

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1312, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using water adjusted to pH 5.0 or pH 4.20 (Depending of the sampling location relative to the Mississippi river) by adding drops of 60/40 weight percent mixture of sulfuric and nitric acids. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using inductively coupled plasma - mass spectrometry (EPA Method 6020A).

MET-WW-200.2-CCMS-VA	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, sieved (wet sample) through a 2 mm (10 mesh) sieve, and a representative subsample of the material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

MOISTURE-SIEVE-VA	Soil	Moisture for CSR Metals Calculations	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

MOISTURE-VA	Soil	Moisture content	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

PAH-SPLP-WT	Waste	Leachable PAH for O.Reg 153/04	SW846 8270
PAH-TMB-H/A-MS-VA	Soil	PAH - Rotary Extraction (Hexane/Acetone)	EPA 3570/8270

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3570 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PH-WW-1:2-DI-MAN-VA	Soil	pH in Soil (1:2 Soil:Water Ext.) (WET)	BC WLAP METHOD: PH, ELECTROMETRIC, SOIL

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the wet sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water, where the samples moisture is accounted for. The pH of the solution is then measured using a standard pH probe.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: GOLDER ASSOCIATES LTD.
500 - 4260 Still Creek Drive
Burnaby BC V5C 6C6

Contact: Jim Laidlaw

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EPH-TUMB-FID-VA	**Soil**							
Batch R2796505								
WG1836681-3 IRM		**ALS PHC2 RM**						
EPH10-19			101.8		%		70-130	27-FEB-14
EPH19-32			102.9		%		70-130	27-FEB-14
WG1836681-1 MB								
EPH10-19			<200		mg/kg		200	27-FEB-14
EPH19-32			<200		mg/kg		200	27-FEB-14
HG-SPLP-CVAFS-VA	**Soil**							
Batch R2797307								
WG1835844-2 DUP		**L1424625-1**						
Mercury (Hg)-Leachable		<0.0010	<0.0010	RPD-NA	mg/L	N/A	30	26-FEB-14
WG1835844-1 MB								
Mercury (Hg)-Leachable			<0.0010		mg/L		0.001	26-FEB-14
WG1835844-3 MS		**L1424625-1**						
Mercury (Hg)-Leachable			100.3		%		70-130	26-FEB-14
HG-WW-200.2-CVAF-VA	**Soil**							
Batch R2797904								
WG1836549-14 CRM		**VA-CANMET-TILL1**						
Mercury (Hg)			96.4		%		70-130	27-FEB-14
WG1836549-15 CRM		**VA-NRC-STSD1**						
Mercury (Hg)			95.4		%		70-130	27-FEB-14
WG1836549-11 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	27-FEB-14
WG1836549-12 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	27-FEB-14
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-2 DUP		**L1424625-1**						
Aluminum (Al)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Antimony (Sb)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Barium (Ba)-Leachable		<0.50	<0.50	RPD-NA	mg/L	N/A	30	26-FEB-14
Beryllium (Be)-Leachable		<0.0050	<0.0050	RPD-NA	mg/L	N/A	30	26-FEB-14
Bismuth (Bi)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Boron (B)-Leachable		<0.10	<0.10	RPD-NA	mg/L	N/A	30	26-FEB-14
Cadmium (Cd)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Calcium (Ca)-Leachable		134	131		mg/L	2.2	30	26-FEB-14
Chromium (Cr)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Cobalt (Co)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-2 DUP		**L1424625-1**						
Copper (Cu)-Leachable		<0.010	<0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Iron (Fe)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Lead (Pb)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Lithium (Li)-Leachable		<0.010	0.010	RPD-NA	mg/L	N/A	30	26-FEB-14
Magnesium (Mg)-Leachable		1.47	1.47		mg/L	0.1	30	26-FEB-14
Manganese (Mn)-Leachable		<0.0050	<0.0050	RPD-NA	mg/L	N/A	30	26-FEB-14
Molybdenum (Mo)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Nickel (Ni)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Phosphorus (P)-Leachable		<0.30	<0.30	RPD-NA	mg/L	N/A	30	26-FEB-14
Potassium (K)-Leachable		<2.0	<2.0	RPD-NA	mg/L	N/A	30	26-FEB-14
Selenium (Se)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Silicon (Si)-Leachable		3.09	3.10		mg/L	0.2	30	26-FEB-14
Silver (Ag)-Leachable		<0.050	<0.050	RPD-NA	mg/L	N/A	30	26-FEB-14
Sodium (Na)-Leachable		<2.0	<2.0	RPD-NA	mg/L	N/A	30	26-FEB-14
Strontium (Sr)-Leachable		0.437	0.437		mg/L	0.1	30	26-FEB-14
Thallium (Tl)-Leachable		<0.20	<0.20	RPD-NA	mg/L	N/A	30	26-FEB-14
Tin (Sn)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Titanium (Ti)-Leachable		0.014	0.014		mg/L	4.4	30	26-FEB-14
Vanadium (V)-Leachable		<0.030	<0.030	RPD-NA	mg/L	N/A	30	26-FEB-14
Zinc (Zn)-Leachable		<0.10	<0.10	RPD-NA	mg/L	N/A	30	26-FEB-14
WG1835844-1 MB								
Aluminum (Al)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Antimony (Sb)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Barium (Ba)-Leachable			<0.50		mg/L		0.5	26-FEB-14
Beryllium (Be)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Bismuth (Bi)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Boron (B)-Leachable			<0.10		mg/L		0.1	26-FEB-14
Cadmium (Cd)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Calcium (Ca)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Chromium (Cr)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Cobalt (Co)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Copper (Cu)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Iron (Fe)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Lead (Pb)-Leachable			<0.050		mg/L		0.05	26-FEB-14

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-1 MB								
Lithium (Li)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Magnesium (Mg)-Leachable			<0.10		mg/L		0.1	26-FEB-14
Manganese (Mn)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Molybdenum (Mo)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Nickel (Ni)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Phosphorus (P)-Leachable			<0.30		mg/L		0.3	26-FEB-14
Potassium (K)-Leachable			<2.0		mg/L		2	26-FEB-14
Selenium (Se)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Silicon (Si)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Silver (Ag)-Leachable			<0.050		mg/L		0.05	26-FEB-14
Sodium (Na)-Leachable			<2.0		mg/L		2	26-FEB-14
Strontium (Sr)-Leachable			<0.0050		mg/L		0.005	26-FEB-14
Thallium (Tl)-Leachable			<0.20		mg/L		0.2	26-FEB-14
Tin (Sn)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Titanium (Ti)-Leachable			<0.010		mg/L		0.01	26-FEB-14
Vanadium (V)-Leachable			<0.030		mg/L		0.03	26-FEB-14
Zinc (Zn)-Leachable			<0.10		mg/L		0.1	26-FEB-14
WG1835844-3 MS		**L1424625-1**						
Aluminum (Al)-Leachable			106.9		%		70-130	26-FEB-14
Antimony (Sb)-Leachable			103.4		%		70-130	26-FEB-14
Beryllium (Be)-Leachable			101.4		%		70-130	26-FEB-14
Bismuth (Bi)-Leachable			104.2		%		70-130	26-FEB-14
Boron (B)-Leachable			106.8		%		70-130	26-FEB-14
Cadmium (Cd)-Leachable			101.8		%		70-130	26-FEB-14
Calcium (Ca)-Leachable			N/A	MS-B	%		-	26-FEB-14
Chromium (Cr)-Leachable			102.9		%		70-130	26-FEB-14
Cobalt (Co)-Leachable			102.9		%		70-130	26-FEB-14
Copper (Cu)-Leachable			105.8		%		70-130	26-FEB-14
Iron (Fe)-Leachable			112.8		%		70-130	26-FEB-14
Lead (Pb)-Leachable			100.5		%		70-130	26-FEB-14
Lithium (Li)-Leachable			112.6		%		70-130	26-FEB-14
Magnesium (Mg)-Leachable			N/A	MS-B	%		-	26-FEB-14
Manganese (Mn)-Leachable			102.3		%		70-130	26-FEB-14
Molybdenum (Mo)-Leachable			102.0		%		70-130	26-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-SPLP-ICP-VA	**Soil**							
Batch R2797349								
WG1835844-3 MS		**L1424625-1**						
Nickel (Ni)-Leachable			102.1		%		70-130	26-FEB-14
Phosphorus (P)-Leachable			104.1		%		70-130	26-FEB-14
Potassium (K)-Leachable			112.6		%		70-130	26-FEB-14
Selenium (Se)-Leachable			105.3		%		70-130	26-FEB-14
Silicon (Si)-Leachable			N/A	MS-B	%		-	26-FEB-14
Silver (Ag)-Leachable			101.6		%		70-130	26-FEB-14
Sodium (Na)-Leachable			102.8		%		70-130	26-FEB-14
Strontium (Sr)-Leachable			N/A	MS-B	%		-	26-FEB-14
Thallium (Tl)-Leachable			101.6		%		70-130	26-FEB-14
Tin (Sn)-Leachable			93.5		%		70-130	26-FEB-14
Titanium (Ti)-Leachable			102.3		%		70-130	26-FEB-14
Vanadium (V)-Leachable			103.7		%		70-130	26-FEB-14
Zinc (Zn)-Leachable			102.3		%		70-130	26-FEB-14
MET-SPLP-MS-VA	**Soil**							
Batch R2802885								
WG1835844-2 DUP		**L1424625-1**						
Arsenic (As)-Leachable		0.00309	0.00301		mg/L	2.7	30	10-MAR-14
WG1835844-1 MB								
Arsenic (As)-Leachable			<0.00010		mg/L		0.0001	10-MAR-14
WG1835844-3 MS		**L1424625-1**						
Arsenic (As)-Leachable			106.5		%		70-130	10-MAR-14
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-4 CRM		**VA-CANMET-TILL1**						
Aluminum (Al)			99.3		%		70-130	28-FEB-14
Antimony (Sb)			87.3		%		70-130	28-FEB-14
Arsenic (As)			102.9		%		70-130	28-FEB-14
Barium (Ba)			101.4		%		70-130	28-FEB-14
Beryllium (Be)			0.43		mg/kg		0.34-0.74	28-FEB-14
Bismuth (Bi)			89.2		%		70-130	28-FEB-14
Cadmium (Cd)			88.9		%		70-130	28-FEB-14
Calcium (Ca)			91.4		%		70-130	28-FEB-14
Chromium (Cr)			103.3		%		70-130	28-FEB-14
Cobalt (Co)			98.6		%		70-130	28-FEB-14
Copper (Cu)			94.5		%		70-130	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-4 CRM		**VA-CANMET-TILL1**						
Iron (Fe)			95.6		%		70-130	28-FEB-14
Lead (Pb)			80.9		%		70-130	28-FEB-14
Lithium (Li)			77.8		%		70-130	28-FEB-14
Magnesium (Mg)			98.5		%		70-130	28-FEB-14
Manganese (Mn)			98.8		%		70-130	28-FEB-14
Molybdenum (Mo)			0.59		mg/kg		0.24-1.24	28-FEB-14
Nickel (Ni)			99.4		%		70-130	28-FEB-14
Phosphorus (P)			96.5		%		70-130	28-FEB-14
Potassium (K)			105.8		%		70-130	28-FEB-14
Selenium (Se)			0.31		mg/kg		0.12-0.52	28-FEB-14
Silver (Ag)			0.19		mg/kg		0.12-0.32	28-FEB-14
Sodium (Na)			113.0		%		70-130	28-FEB-14
Strontium (Sr)			88.2		%		70-130	28-FEB-14
Thallium (Tl)			0.104		mg/kg		0.075-0.175	28-FEB-14
Tin (Sn)			0.9		mg/kg		0-3	28-FEB-14
Titanium (Ti)			103.4		%		70-130	28-FEB-14
Uranium (U)			92.8		%		70-130	28-FEB-14
Vanadium (V)			103.5		%		70-130	28-FEB-14
Zinc (Zn)			100.1		%		70-130	28-FEB-14
WG1837121-5 CRM		**VA-NRC-STSD1**						
Aluminum (Al)			105.9		%		70-130	28-FEB-14
Antimony (Sb)			99.1		%		70-130	28-FEB-14
Arsenic (As)			102.0		%		70-130	28-FEB-14
Barium (Ba)			100.3		%		70-130	28-FEB-14
Beryllium (Be)			111.9		%		70-130	28-FEB-14
Cadmium (Cd)			100.7		%		70-130	28-FEB-14
Calcium (Ca)			105.5		%		70-130	28-FEB-14
Chromium (Cr)			102.6		%		70-130	28-FEB-14
Cobalt (Co)			100.2		%		70-130	28-FEB-14
Copper (Cu)			102.3		%		70-130	28-FEB-14
Iron (Fe)			102.1		%		70-130	28-FEB-14
Lead (Pb)			99.9		%		70-130	28-FEB-14
Lithium (Li)			106.9		%		70-130	28-FEB-14
Magnesium (Mg)			100.0		%		70-130	28-FEB-14

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-5 CRM		**VA-NRC-STSD1**						
Manganese (Mn)			100.1		%		70-130	28-FEB-14
Molybdenum (Mo)			100.8		%		70-130	28-FEB-14
Nickel (Ni)			102.5		%		70-130	28-FEB-14
Phosphorus (P)			102.2		%		70-130	28-FEB-14
Potassium (K)			105.5		%		70-130	28-FEB-14
Selenium (Se)			100.1		%		70-130	28-FEB-14
Silver (Ag)			104.0		%		70-130	28-FEB-14
Sodium (Na)			104.7		%		70-130	28-FEB-14
Strontium (Sr)			104.1		%		70-130	28-FEB-14
Thallium (Tl)			100.5		%		70-130	28-FEB-14
Tin (Sn)			99.8		%		70-130	28-FEB-14
Titanium (Ti)			112.3		%		70-130	28-FEB-14
Vanadium (V)			104.5		%		70-130	28-FEB-14
Zinc (Zn)			103.2		%		70-130	28-FEB-14
WG1837121-3 DUP		**L1424625-1**						
Aluminum (Al)		15400	15700		mg/kg	1.9	40	28-FEB-14
Antimony (Sb)		0.67	0.79		mg/kg	17	30	28-FEB-14
Arsenic (As)		49.6	40.4		mg/kg	21	30	28-FEB-14
Barium (Ba)		229	238		mg/kg	4.0	40	28-FEB-14
Beryllium (Be)		0.51	0.51		mg/kg	0.8	30	28-FEB-14
Bismuth (Bi)		<0.20	<0.20	RPD-NA	mg/kg	N/A	30	28-FEB-14
Cadmium (Cd)		0.108	0.113		mg/kg	4.8	30	28-FEB-14
Calcium (Ca)		34000	33200		mg/kg	2.4	30	28-FEB-14
Chromium (Cr)		31.1	32.5		mg/kg	4.1	30	28-FEB-14
Cobalt (Co)		10.1	9.81		mg/kg	3.3	30	28-FEB-14
Copper (Cu)		47.5	56.4		mg/kg	17	30	28-FEB-14
Iron (Fe)		20200	21700		mg/kg	6.8	30	28-FEB-14
Lead (Pb)		8.56	11.5		mg/kg	29	40	28-FEB-14
Lithium (Li)		19.1	19.9		mg/kg	4.0	30	28-FEB-14
Magnesium (Mg)		2920	3110		mg/kg	6.2	30	28-FEB-14
Manganese (Mn)		294	327		mg/kg	10	30	28-FEB-14
Molybdenum (Mo)		2.76	3.14		mg/kg	13	40	28-FEB-14
Nickel (Ni)		58.3	61.0		mg/kg	4.6	30	28-FEB-14
Phosphorus (P)		326	428		mg/kg	27	30	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-3 DUP		**L1424625-1**						
Potassium (K)		740	790		mg/kg	6.7	40	28-FEB-14
Selenium (Se)		0.49	0.65		mg/kg	30	30	28-FEB-14
Silver (Ag)		<0.10	0.11	RPD-NA	mg/kg	N/A	40	28-FEB-14
Sodium (Na)		280	270		mg/kg	6.3	40	28-FEB-14
Strontium (Sr)		215	248		mg/kg	14	40	28-FEB-14
Thallium (Tl)		0.148	0.176		mg/kg	17	30	28-FEB-14
Tin (Sn)		<2.0	<2.0	RPD-NA	mg/kg	N/A	40	28-FEB-14
Titanium (Ti)		731	674		mg/kg	8.2	40	28-FEB-14
Uranium (U)		0.610	0.706		mg/kg	15	30	28-FEB-14
Vanadium (V)		101	97.7		mg/kg	3.0	30	28-FEB-14
Zinc (Zn)		33.4	36.3		mg/kg	8.1	30	28-FEB-14
WG1837121-1 MB								
Aluminum (Al)			<50		mg/kg		50	28-FEB-14
Antimony (Sb)			<0.10		mg/kg		0.1	28-FEB-14
Arsenic (As)			<0.050		mg/kg		0.05	28-FEB-14
Barium (Ba)			<0.50		mg/kg		0.5	28-FEB-14
Beryllium (Be)			<0.20		mg/kg		0.2	28-FEB-14
Bismuth (Bi)			<0.20		mg/kg		0.2	28-FEB-14
Cadmium (Cd)			<0.050		mg/kg		0.05	28-FEB-14
Calcium (Ca)			<50		mg/kg		50	28-FEB-14
Chromium (Cr)			<0.50		mg/kg		0.5	28-FEB-14
Cobalt (Co)			<0.10		mg/kg		0.1	28-FEB-14
Copper (Cu)			<0.50		mg/kg		0.5	28-FEB-14
Iron (Fe)			<50		mg/kg		50	28-FEB-14
Lead (Pb)			<0.50		mg/kg		0.5	28-FEB-14
Lithium (Li)			<5.0		mg/kg		5	28-FEB-14
Magnesium (Mg)			<20		mg/kg		20	28-FEB-14
Manganese (Mn)			<1.0		mg/kg		1	28-FEB-14
Molybdenum (Mo)			<0.50		mg/kg		0.5	28-FEB-14
Nickel (Ni)			<0.50		mg/kg		0.5	28-FEB-14
Phosphorus (P)			<50		mg/kg		50	28-FEB-14
Potassium (K)			<100		mg/kg		100	28-FEB-14
Selenium (Se)			<0.20		mg/kg		0.2	28-FEB-14
Silver (Ag)			<0.10		mg/kg		0.1	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-1 MB								
Sodium (Na)			<100		mg/kg		100	28-FEB-14
Strontium (Sr)			<0.50		mg/kg		0.5	28-FEB-14
Thallium (Tl)			<0.050		mg/kg		0.05	28-FEB-14
Tin (Sn)			<2.0		mg/kg		2	28-FEB-14
Titanium (Ti)			<1.0		mg/kg		1	28-FEB-14
Uranium (U)			<0.050		mg/kg		0.05	28-FEB-14
Vanadium (V)			<0.20		mg/kg		0.2	28-FEB-14
Zinc (Zn)			<1.0		mg/kg		1	28-FEB-14
WG1837121-2 MB								
Aluminum (Al)			<50		mg/kg		50	28-FEB-14
Antimony (Sb)			<0.10		mg/kg		0.1	28-FEB-14
Arsenic (As)			<0.050		mg/kg		0.05	28-FEB-14
Barium (Ba)			<0.50		mg/kg		0.5	28-FEB-14
Beryllium (Be)			<0.20		mg/kg		0.2	28-FEB-14
Bismuth (Bi)			<0.20		mg/kg		0.2	28-FEB-14
Cadmium (Cd)			<0.050		mg/kg		0.05	28-FEB-14
Calcium (Ca)			<50		mg/kg		50	28-FEB-14
Chromium (Cr)			<0.50		mg/kg		0.5	28-FEB-14
Cobalt (Co)			<0.10		mg/kg		0.1	28-FEB-14
Copper (Cu)			<0.50		mg/kg		0.5	28-FEB-14
Iron (Fe)			<50		mg/kg		50	28-FEB-14
Lead (Pb)			<0.50		mg/kg		0.5	28-FEB-14
Lithium (Li)			<5.0		mg/kg		5	28-FEB-14
Magnesium (Mg)			<20		mg/kg		20	28-FEB-14
Manganese (Mn)			<1.0		mg/kg		1	28-FEB-14
Molybdenum (Mo)			<0.50		mg/kg		0.5	28-FEB-14
Nickel (Ni)			<0.50		mg/kg		0.5	28-FEB-14
Phosphorus (P)			<50		mg/kg		50	28-FEB-14
Potassium (K)			<100		mg/kg		100	28-FEB-14
Selenium (Se)			<0.20		mg/kg		0.2	28-FEB-14
Silver (Ag)			<0.10		mg/kg		0.1	28-FEB-14
Sodium (Na)			<100		mg/kg		100	28-FEB-14
Strontium (Sr)			<0.50		mg/kg		0.5	28-FEB-14
Thallium (Tl)			<0.050		mg/kg		0.05	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-WW-200.2-CCMS-VA	**Soil**							
Batch R2798489								
WG1837121-2 MB								
Tin (Sn)			<2.0		mg/kg		2	28-FEB-14
Titanium (Ti)			<1.0		mg/kg		1	28-FEB-14
Uranium (U)			<0.050		mg/kg		0.05	28-FEB-14
Vanadium (V)			<0.20		mg/kg		0.2	28-FEB-14
Zinc (Zn)			<1.0		mg/kg		1	28-FEB-14
MOISTURE-VA	**Soil**							
Batch R2797649								
WG1836679-2 LCS								
Moisture			99.8		%		70-130	26-FEB-14
WG1836679-1 MB								
Moisture			<0.25		%		0.25	26-FEB-14
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2797995								
WG1836681-4 IRM		**ALS PAH1 RM**						
Acenaphthene			70.7		%		60-130	27-FEB-14
Acenaphthylene			126.6		%		60-130	27-FEB-14
Anthracene			125.0		%		60-130	27-FEB-14
Benz(a)anthracene			116.8		%		60-130	27-FEB-14
Benzo(a)pyrene			99.1		%		60-130	27-FEB-14
Benzo(b)fluoranthene			129.3		%		60-130	27-FEB-14
Benzo(g,h,i)perylene			94.5		%		60-130	27-FEB-14
Benzo(k)fluoranthene			107.4		%		60-130	27-FEB-14
Chrysene			118.7		%		60-130	27-FEB-14
Dibenz(a,h)anthracene			109.5		%		60-130	27-FEB-14
Fluoranthene			123.8		%		60-130	27-FEB-14
Fluorene			77.7		%		60-130	27-FEB-14
Indeno(1,2,3-c,d)pyrene			100.0		%		60-130	27-FEB-14
2-Methylnaphthalene			97.2		%		60-130	27-FEB-14
Naphthalene			99.0		%		50-130	27-FEB-14
Phenanthrene			118.4		%		60-130	27-FEB-14
Pyrene			123.5		%		60-130	27-FEB-14
WG1836681-1 MB								
Acenaphthene			<0.0050		mg/kg		0.005	27-FEB-14
Acenaphthylene			<0.0050		mg/kg		0.005	27-FEB-14
Anthracene			<0.0040		mg/kg		0.004	27-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-TMB-H/A-MS-VA	**Soil**							
Batch R2797995								
WG1836681-1 MB								
Benz(a)anthracene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(a)pyrene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(b)fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	27-FEB-14
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Chrysene			<0.010		mg/kg		0.01	27-FEB-14
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	27-FEB-14
Fluoranthene			<0.010		mg/kg		0.01	27-FEB-14
Fluorene			<0.010		mg/kg		0.01	27-FEB-14
Indeno(1,2,3-c,d)pyrene			<0.010		mg/kg		0.01	27-FEB-14
2-Methylnaphthalene			<0.010		mg/kg		0.01	27-FEB-14
Naphthalene			<0.010		mg/kg		0.01	27-FEB-14
Phenanthrene			<0.010		mg/kg		0.01	27-FEB-14
Pyrene			<0.010		mg/kg		0.01	27-FEB-14
Surrogate: Naphthalene d8			74.8		%		50-130	27-FEB-14
Surrogate: Acenaphthene d10			76.7		%		60-130	27-FEB-14
Surrogate: Phenanthrene d10			77.6		%		60-130	27-FEB-14
Surrogate: Chrysene d12			88.0		%		60-130	27-FEB-14
PH-WW-1:2-DI-MAN-VA	**Soil**							
Batch R2797958								
WG1836549-13 DUP		**L1424625-1**						
pH (1:2 soil:water)		8.17	8.09	J	pH	0.08	0.3	27-FEB-14
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1837346-1 CVS								
1-Methylnaphthalene			99.2		%		50-150	28-FEB-14
2-Methylnaphthalene			102.2		%		50-150	28-FEB-14
Acenapthene			103.8		%		50-150	28-FEB-14
Acenaphthylene			104.9		%		50-150	28-FEB-14
Anthracene			107.8		%		50-150	28-FEB-14
Benzo(a)anthracene			105.1		%		50-150	28-FEB-14
Benzo(a)pyrene			104.6		%		50-150	28-FEB-14
Benzo(b)fluoranthene			105.2		%		50-150	28-FEB-14
Benzo(g,h,i)perylene			92.9		%		50-150	28-FEB-14

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1837346-1 CVS								
Benzo(k)fluoranthene			99.2		%		50-150	28-FEB-14
Chrysene			109.7		%		50-150	28-FEB-14
Dibenzo(ah)anthracene			106.2		%		50-150	28-FEB-14
Fluoranthene			103.9		%		50-150	28-FEB-14
Fluorene			104.8		%		50-150	28-FEB-14
Indeno(1,2,3-cd)pyrene			100.6		%		50-150	28-FEB-14
Naphthalene			107.9		%		50-150	28-FEB-14
Phenanthrene			102.6		%		50-150	28-FEB-14
Pyrene			112.4		%		50-150	28-FEB-14
WG1836846-2 LCS								
1-Methylnaphthalene			78.5		%		50-150	28-FEB-14
2-Methylnaphthalene			79.2		%		50-150	28-FEB-14
Acenapthene			85.9		%		50-150	28-FEB-14
Acenaphthylene			86.9		%		50-150	28-FEB-14
Anthracene			89.6		%		50-150	28-FEB-14
Benzo(a)anthracene			86.7		%		50-150	28-FEB-14
Benzo(a)pyrene			86.2		%		50-150	28-FEB-14
Benzo(b)fluoranthene			75.5		%		50-150	28-FEB-14
Benzo(g,h,i)perylene			80.1		%		50-150	28-FEB-14
Benzo(k)fluoranthene			81.1		%		50-150	28-FEB-14
Chrysene			91.1		%		50-150	28-FEB-14
Dibenzo(ah)anthracene			88.1		%		50-150	28-FEB-14
Fluoranthene			90.1		%		50-150	28-FEB-14
Fluorene			88.8		%		50-150	28-FEB-14
Indeno(1,2,3-cd)pyrene			84.8		%		50-150	28-FEB-14
Naphthalene			84.0		%		50-150	28-FEB-14
Phenanthrene			88.7		%		50-150	28-FEB-14
Pyrene			97.6		%		50-150	28-FEB-14
WG1836846-1 MB								
1-Methylnaphthalene			<0.020		ug/L		0.02	28-FEB-14
2-Methylnaphthalene			<0.020		ug/L		0.02	28-FEB-14
Acenapthene			<0.020		ug/L		0.02	28-FEB-14
Acenaphthylene			<0.020		ug/L		0.02	28-FEB-14
Anthracene			<0.020		ug/L		0.02	28-FEB-14
Benzo(a)anthracene			<0.020		ug/L		0.02	28-FEB-14

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-SPLP-WT	**Waste**							
Batch R2798085								
WG1836846-1 MB								
Benzo(a)pyrene			<0.010		ug/L		0.01	28-FEB-14
Benzo(b)fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Benzo(g,h,i)perylene			<0.020		ug/L		0.02	28-FEB-14
Benzo(k)fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Chrysene			<0.020		ug/L		0.02	28-FEB-14
Dibenzo(ah)anthracene			<0.020		ug/L		0.02	28-FEB-14
Fluoranthene			<0.020		ug/L		0.02	28-FEB-14
Fluorene			<0.020		ug/L		0.02	28-FEB-14
Indeno(1,2,3-cd)pyrene			<0.020		ug/L		0.02	28-FEB-14
Naphthalene			<0.020		ug/L		0.02	28-FEB-14
Phenanthrene			<0.020		ug/L		0.02	28-FEB-14
Pyrene			<0.020		ug/L		0.02	28-FEB-14
Surrogate: 2-Fluorobiphenyl			86.9		%		50-150	28-FEB-14
Surrogate: d14-Terphenyl			95.4		%		50-150	28-FEB-14

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

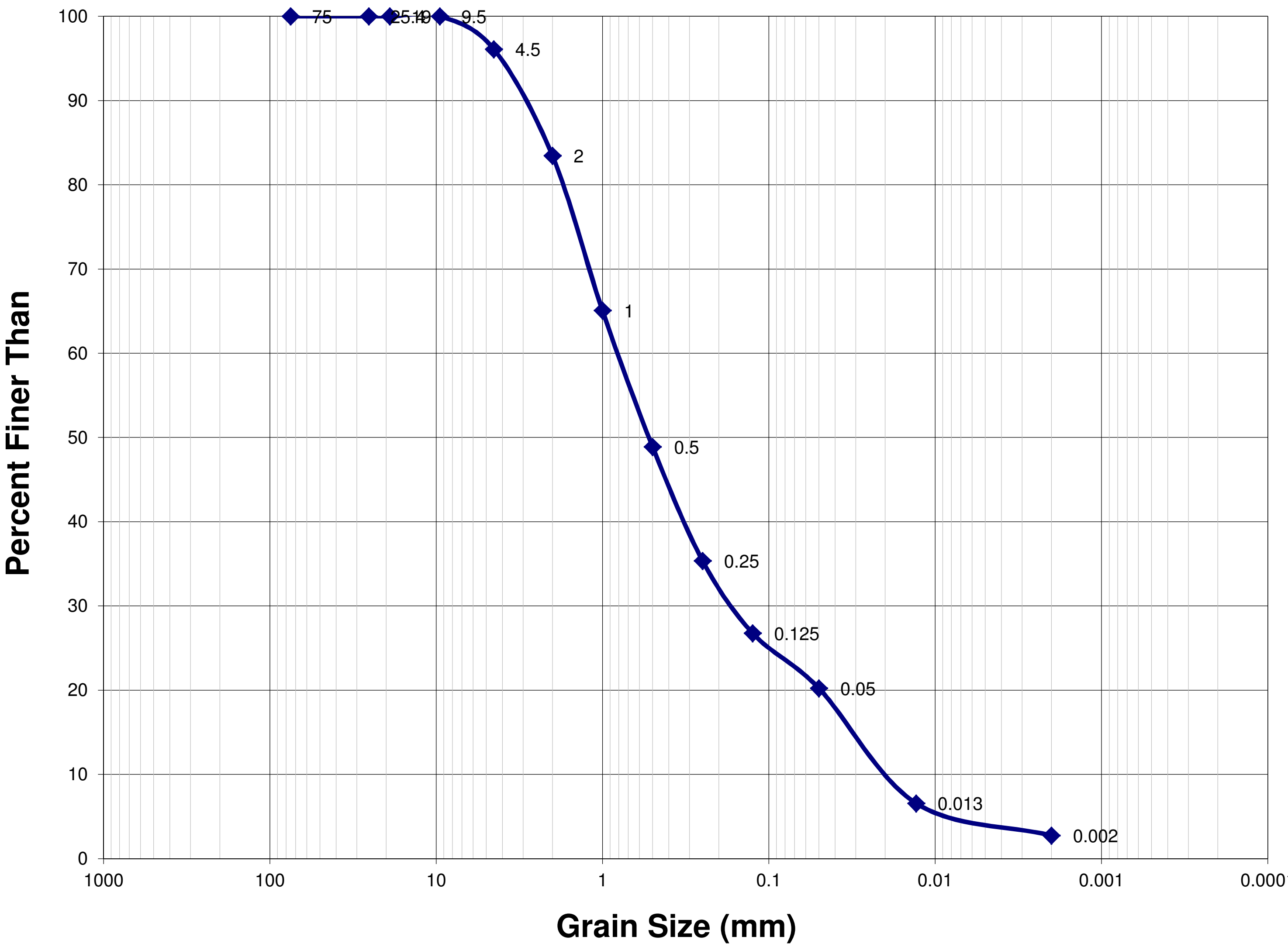
Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES
Environmental Division

819-58th Street, Saskatoon, SK S7K 6X5

Client Name: GOLDER ASSOCIATES LTD
Project:
Sample ID: COMPOSITE
Lab ID: L1424625-1

Particle Size Distribution Curve



Summary of Results

Unified Soil Classification System (USCS)

Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	4.75mm - 3"	4
Coarse Sand	2.0mm - 4.75mm	13
Medium Sand	0.425mm - 2.0mm	35
Fine Sand	0.075mm - 0.425mm	26
Fines	< 0.075mm	22

Canadian Soil Survey Committee (CSSC)

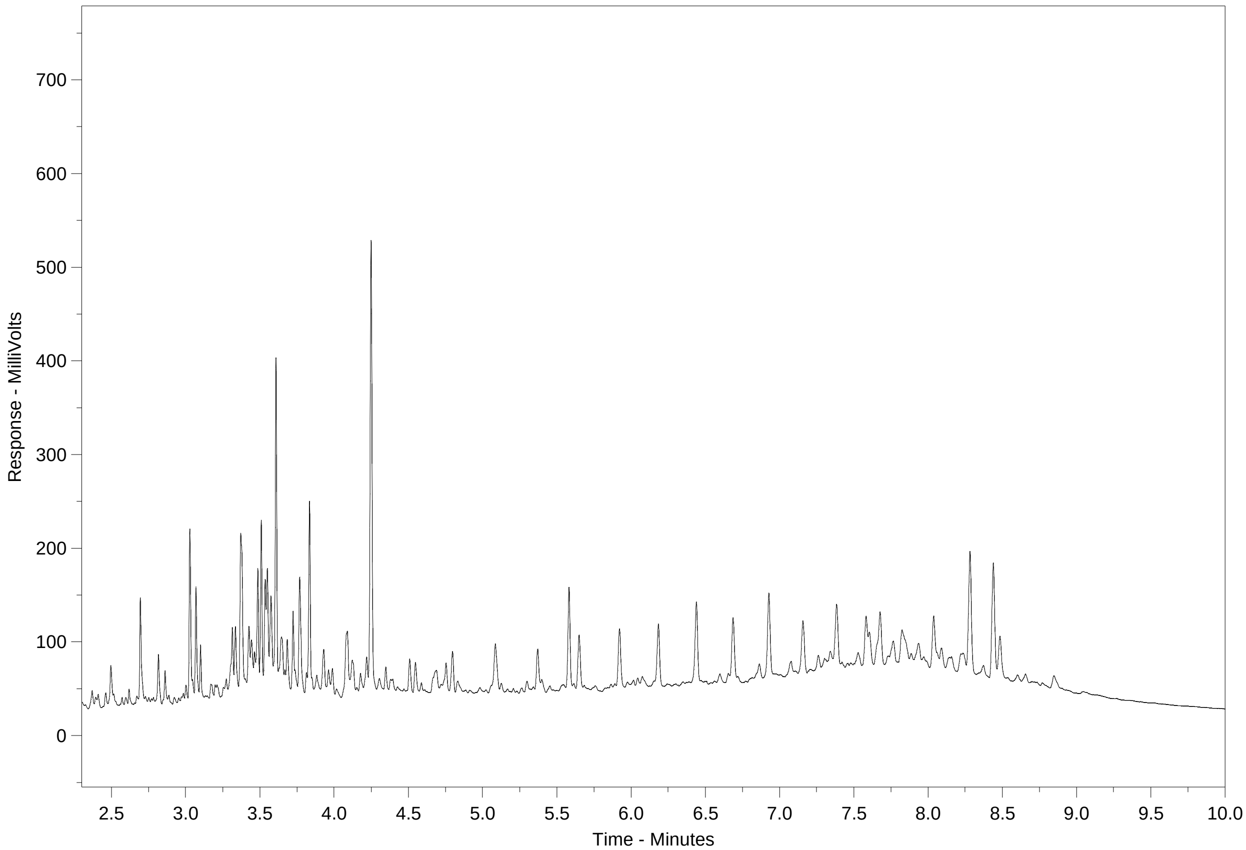
Size Class	Size Range	Wt. (%)
Cobbles	> 3"	0
Gravel	2mm - 3"	17
Sand	0.05mm - 2mm	63
Silt	0.002mm - 0.05mm	17
Clay	< 0.002mm	3

Texture   Loamy sand

Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

Hydrocarbon Distribution Report

ALS Sample ID: L1424625-1
Client Sample ID: COMPOSITE



nC10	nC19	nC32
174°C 346°F	330°C 626°F	467°C 873°F
← Gasoline →	← Motor Oils / Lube Oils / Grease →	
← Diesel / Jet Fuels →		

The EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample. For further interpretation, a current library of reference products is available on www.alsglobal.com or upon request.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at the left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

APPENDIX E

Appendix E Concrete Investigation of Lower Dam

Annex A Record of Coreholes

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446452.09 E: 430000.53

RECORD OF BOREHOLE: CH14-02

DRILLING DATE: 02/11/2014 - 02/12/2014

DATUM: NAD 83

DEPTH SCALE METRES	BORING RECORD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE (mm) TYPE	BLOWS/0.3m	CORE RUN No.	RECOVERY %	GRAVEL	SAND	FINES	HYDRAULIC CONDUCTIVITY, k, cm/s	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Top of Concrete		72.90											
0	Track Mounted Diamond Drill Rig / Diamond Drilling	CONCRETE		0.00	C1										
		- pour joint													
		- 0.61 m of cinder and slag fill above concrete core excavated by hand.													
		- pour joint						1							
1															
		- pour joint													
		- pour joint													
2															
		- pour joint						2							
		- pour joint													
3															
		- pour joint													
		- pour joint													
4								3							
5															
		- pour joint						4							
6															
7								5							
8		- pour joint													
		- pour joint			C2										
								6							
9															
		- pour joint													
		- pour joint						7							
10															

Hydraulic conductivity scale: 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}. Recovery % scale: 80, 60, 40, 20.

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446452.09 E: 430000.53

RECORD OF BOREHOLE: CH14-02

DRILLING DATE: 02/11/2014 - 02/12/2014

DATUM: NAD 83

BORING RECORD: Track Mounted Diamond Drill Rig; Diamond Drilling

DEPTH SCALE METRES	SOIL PROFILE — DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	CORE RUN No.
10	CONCRETE *(continued)*			
11	- pour joint			
	- pour joint		C6	7
12	- pour joint			
13	- break at large size aggregate location. - pour joint - broken pieces encountered from 13.1 m to 13.2 m depth. - 50-100 mm diameter pieces of concrete were encountered from 13.6 m to 15.3 m.			
14	- pour joint			8
	- pour joint - pour joint			
15			C3 C8	
	- break at large size aggregate location. - rebar encountered at 15.7 m, 16.2 m, 16.8 m, 17.1 m, and 17.4 m depth.			
16				9
17		55.15 17.75		
18	fresh, massive; grey to dark grey; pebbles and granules, medium strong (R3), CONGLOMERATE, clast supported, clasts typically sub-rounded. - pour joint			10
19				11
20				

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446452.09 E: 430000.53

RECORD OF BOREHOLE: CH14-02

DRILLING DATE: 02/11/2014 - 02/12/2014

DATUM: NAD 83

DEPTH SCALE METRES	BORING RECORD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE (mm) / TYPE	BLOWS/0.3m	CORE: RUN No.	RECOVERY % (80 60 40 20)	GRADATION %: GRAVEL	SAND	FINES	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3})	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
20				52.78				11							
		End of Borehole. **Note -** Concrete pieces may be the result of fracture during coring and retrieval process.		20.12											
21															
22															
23															
24															
25															
26															
27															
28															
29															
30															

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: AC

RECORD OF BOREHOLE: CH14-03

PROJECT No.: 13-1447-0516 / 7000
CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446440.67 E: 430007.37

DRILLING DATE: 02/13/2014 - 02/14/2014

DATUM: NAD 83

BORING RECORD: Track Mounted Diamong Drill; Diamond Drilling

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	CORE RUN No.
	Top of Concrete	72.90		
0	CONCRETE	0.00		
	- 0.7 m of cinder and slag fill above concrete core excavated by hand.			
	- rebar encountered at 0.8 m.			1
1	- core was dropped and broken between 0 m and 1.8 m depth. - joints and rebar encountered within the core, relative locations unknown.			
2	- 100-200 mm diameter pieces of concrete were encountered from 1.8 m to 2.8 m depth. - pour joint		C9 C4	
	- pour joint			2
3	- pour joint		C7	
4	- 100-250 mm diameter pieces of concrete were encountered from 4.0 m to 5.4 m depth. - pour joint			3
5	- pour joint - pour joint			
	- 50-100 mm diameter pieces of concrete encountered from 5.4 m to 8.8 m.			4
6				
7	- pour joint		C5	5
	- pour joint			
8	- pour joint - pour joint			6
9		63.65		
	fresh, massive; grey to dark grey; pebbles and granules, medium strong (R3), CONGLOMERATE, clast supported; clasts typically sub-rounded.			7
10				

CONTINUED NEXT PAGE

Column headings also printed: STRATA PLOT; SAMPLES TYPE (mm) TYPE; BLOWS/0.3m; CORE RECOVERY % (80, 60, 40, 20); GRADATION % (GRAVEL, SAND, FINES); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); ADDITIONAL LAB. TESTING; PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: AC

PROJECT No.: 13-1447-0516 / 7000

CLIENT: City of Nanaimo
PROJECT: Colliery Dams
LOCATION: Nanaimo, B.C.
N: 5446440.67 E: 430007.37

RECORD OF BOREHOLE: CH14-03

DRILLING DATE: 02/13/2014 - 02/14/2014

SHEET 2 OF 2
DATUM: NAD 83

DEPTH SCALE METRES	BORING RECORD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE (mm) / TYPE	BLOWS/0.3m	CORE: RUN No.	RECOVERY % (80 60 40 20)	GRADATION %: GRAVEL	SAND	FINES	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3})	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
10	Track Mounted Diamong Drill / Diamond Drilling	fresh, massive; grey to dark grey; pebbles and granules, medium strong (R3), CONGLOMERATE, clast supported; clasts typically sub-rounded. *(continued)*						7							
11								8							
12				60.40 / 12.50											
13		End of Borehole. **Note -** Concrete pieces may be the result of fracture during coring and retrieval process.													
14															
15															
16															
17															
18															
19															
20															

DEPTH SCALE
1 : 50

Golder Associates

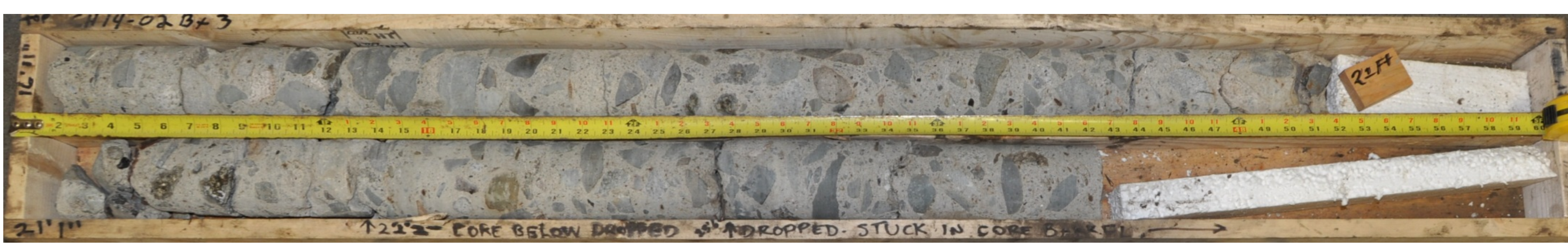
SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: AC

Annex B Diamond Drilling Core Photos

O:\Active_2013\1447\13-1447-0516 Nanaimo Colliery Dams Nanaimo\5.0 Work in Progress\Phase 7000 FIELD INVESTIGATION\7300 Geotechnical Drilling\Photos\Core Photos

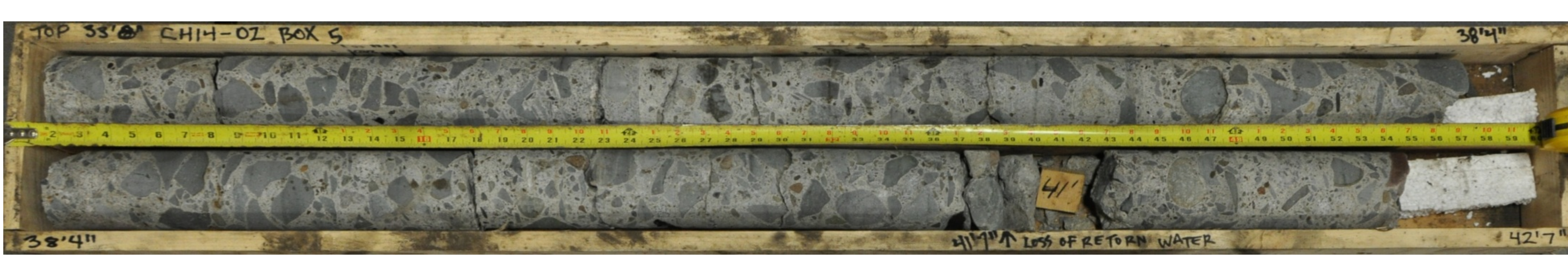
Box 1 of 8: 0.00 m to 2.3 m (0 ft to 7.5 ft)

Box 2 of 8: 2.3 m to 4.9 m (7.5 ft to 16.0 ft)



Box 3 of 8: 4.9 m to 7.2 m (16.0 ft to 23.5 ft)

Box 4 of 8: 7.2 m to 10.1 m (23.5 ft to 33.0 ft)



Box 5 of 8: 10.1 m to 12.9 m (33.0 ft to 42.5 ft)

PROJECT

CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE

CH14-02
DIAMOND DRILL CORE PHOTOGRAPHS - DRY
BOXES 1 TO 5 OF 8, 0 m to 12.9 m (0 ft to 42.5 ft)

Golder Associates

PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
DESIGN	TM	18MAR14	SCALE NTS	REV.
CADD	TM	24MAR14	
CHECK			**FIGURE C-1**
REVIEW			

Box 6 of 8: 12.9 m to 15.4 m (42.5 ft to 50.5 ft)

Box 7 of 8: 15.4 m to 18.1 m (50.5 ft to 59.5 ft)

Box 8 of 8: 18.1 m to 20.1 m (59.5 ft to 66.0 ft)

PROJECT

CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE

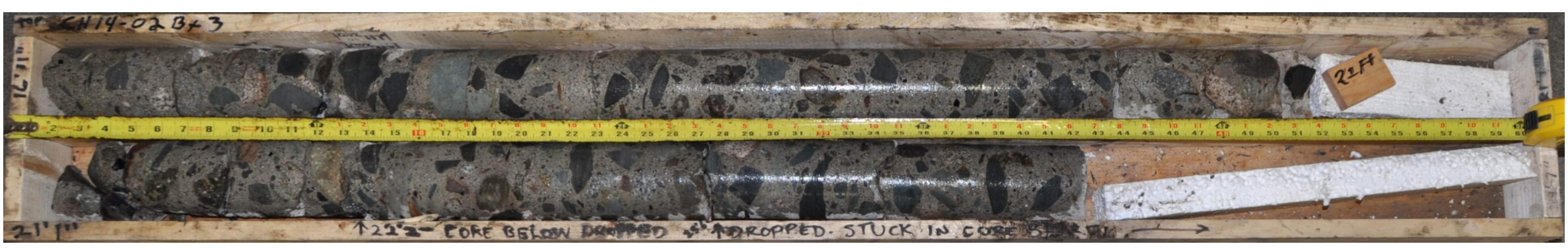
CH14-02
DIAMOND DRILL CORE PHOTOGRAPHS - DRY
BOXES 6 TO 8 OF 8, 12.9 m to 20.1 m (42.5 ft to 66.0 ft)

Golder Associates

PROJECT No.	13-1447-0516		Phase / Task No. 7000/7300
DESIGN	TM	18MAR14	SCALE NTS REV.
CADD	TM	24MAR14	**FIGURE C-2**
CHECK			
REVIEW			

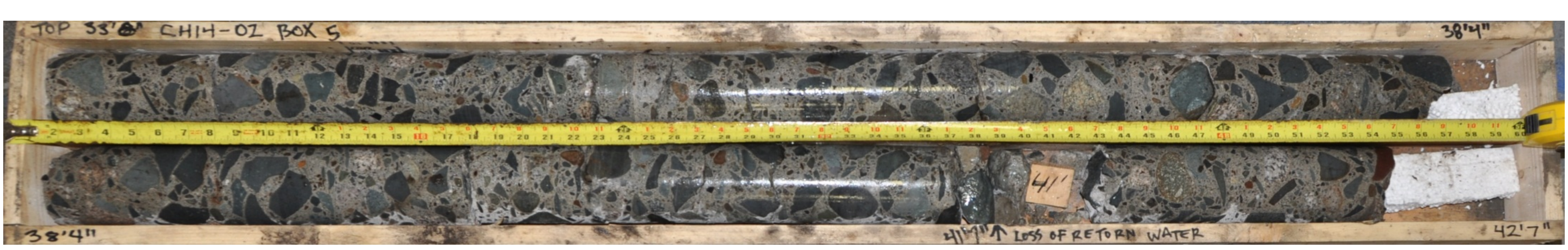
Box 1 of 8: 0.00 m to 2.3 m (0 ft to 7.5 ft)

Box 2 of 8: 2.3 m to 4.9 m (7.5 ft to 16.0 ft)



Box 3 of 8: 4.9 m to 7.2 m (16.0 ft to 23.5 ft)

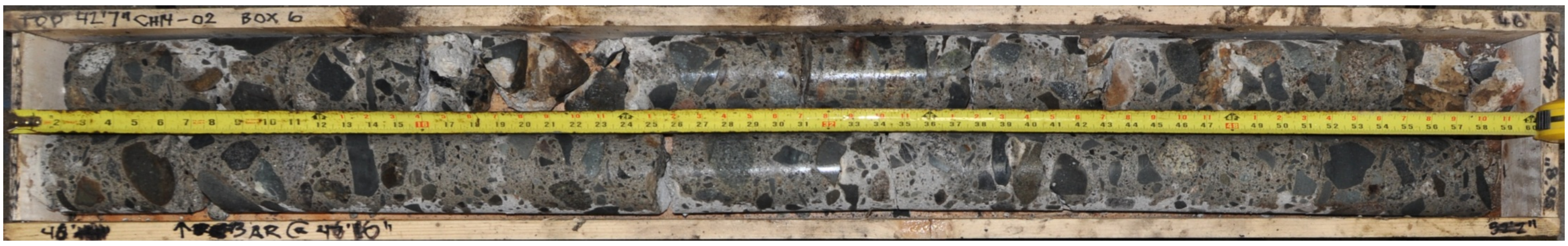
Box 4 of 8: 7.2 m to 10.1 m (23.5 ft to 33.0 ft)



Box 5 of 8: 10.1 m to 12.9 m (33.0 ft to 42.5 ft)

PROJECT	CITY OF NANAIMO COLLIERY DAMS PARK – LOWER DAM NANAIMO, B.C.			
TITLE	**CH14-02** **DIAMOND DRILL CORE PHOTOGRAPHS - WET** **BOXES 1 TO 5 OF 8, 0 m to 12.9 m (0 ft to 42.5 ft)**			
Golder Associates	PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
	DESIGN	TM 18MAR14	SCALE NTS	REV.
	CADD	TM 24MAR14	**FIGURE C-3**	
	CHECK			
	REVIEW			

O:\Active_2013\1447\13-1447-0516 Nanaimo Colliery Dams Nanaimo\5.0 Work in Progress\Phase 7000 FIELD INVESTIGATION\7300 Geotechnical Drilling\Photos\Core Photos



Box 6 of 8: 12.9 m to 15.4 m (42.5 ft to 50.5 ft)

Box 7 of 8: 15.4 m to 18.1 m (50.5 ft to 59.5 ft)

Box 8 of 8: 18.1 m to 20.1 m (59.5 ft to 66.0 ft)

PROJECT

CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

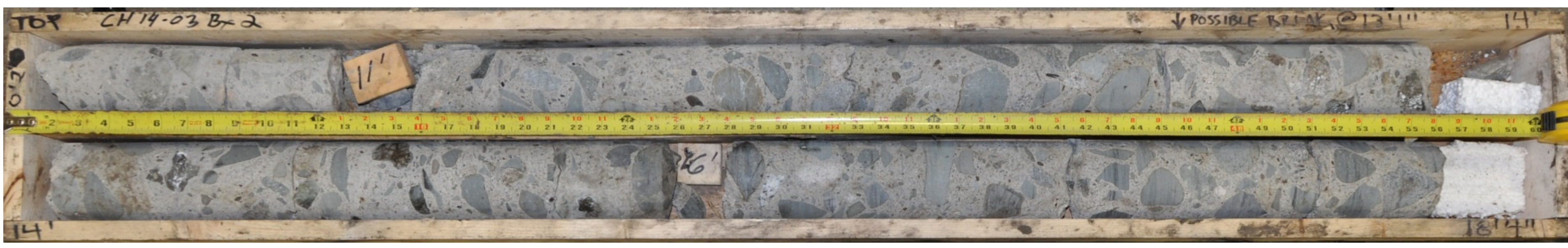
TITLE

CH14-02
DIAMOND DRILL CORE PHOTOGRAPHS - WET
BOXES 6 TO 8 OF 8, 12.9 m to 20.1 m (42.5 ft to 66.0 ft)

Golder Associates

PROJECT No.	13-1447-0516		Phase / Task No. 7000/7300
DESIGN	TM	18MAR14	SCALE NTS REV.
CADD	TM	24MAR14	
CHECK			**FIGURE C-4**
REVIEW			

Box 1 of 5: 0.00 m to 2.4 m (0 ft to 8.0 ft)



Box 2 of 5: 2.4 m to 5.2 m (8.0 ft to 17.0 ft)

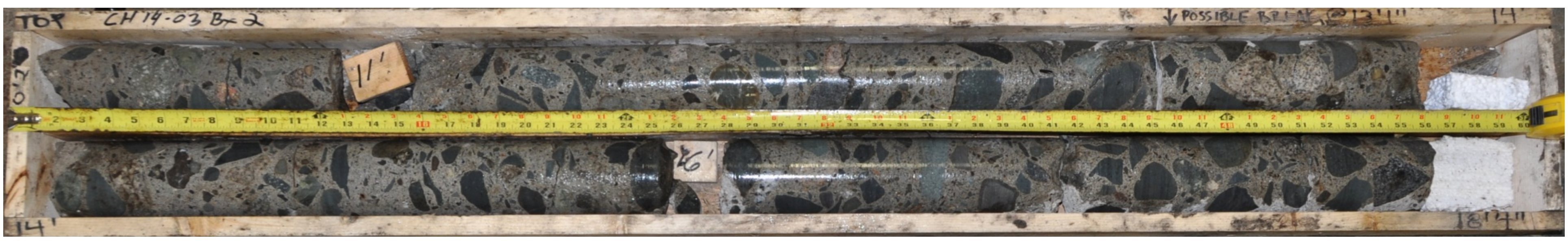
Box 3 of 5: 5.2 m to 8.1 m (17.0 ft to 26.5 ft)

Box 4 of 5: 8.1 m to 10.8 m (26.5 ft to 35.5 ft)

Box 5 of 5: 10.8 m to 12.3 m (35.5 ft to 40.5 ft)

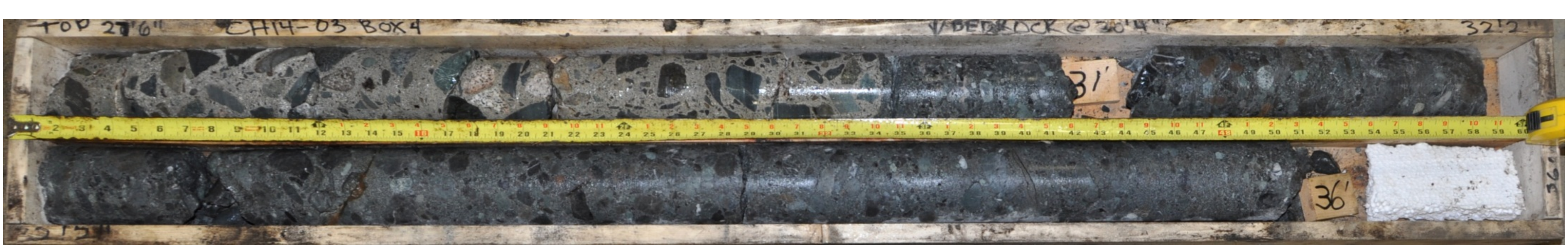
PROJECT	CITY OF NANAIMO COLLIERY DAMS PARK – LOWER DAM NANAIMO, B.C.			
TITLE	**CH14-03** **DIAMOND DRILL CORE PHOTOGRAPHS - DRY** **BOXES 1 TO 5 OF 5, 0 m to 12.3 m (0 ft to 40.5 ft)**			
Golder Associates	PROJECT No. 13-1447-0516		Phase / Task No. 7000/7300	
	DESIGN	TM	18MAR14	SCALE NTS	REV.
	CADD	TM	24MAR14	**FIGURE C-5**
	CHECK			
	REVIEW			

Box 1 of 5: 0.00 m to 2.4 m (0 ft to 8.0 ft)



Box 2 of 5: 2.4 m to 5.2 m (8.0 ft to 17.0 ft)

Box 3 of 5: 5.2 m to 8.1 m (17.0 ft to 26.5 ft)



Box 4 of 5: 8.1 m to 10.8 m (26.5 ft to 35.5 ft)

Box 5 of 5: 10.8 m to 12.3 m (35.5 ft to 40.5 ft)

PROJECT
CITY OF NANAIMO
COLLIERY DAMS PARK – LOWER DAM
NANAIMO, B.C.

TITLE
CH14-03
DIAMOND DRILL CORE PHOTOGRAPHS - WET
BOXES 1 TO 5 OF 5, 0 m to 12.3 m (0 ft to 40.5 ft)

Golder Associates

PROJECT No.	13-1447-0516		Phase / Task No. 7000/7300
DESIGN	TM	18MAR14	SCALE NTS / REV.
CADD	TM	24MAR14	
CHECK			**FIGURE C-6**
REVIEW			

Annex C Laboratory Testing Results

OBTAINING AND TESTING DRILLED CORES FOR COMPRESSIVE STRENGTH TESTING

CSA A23.2-14C

March 31, 2014

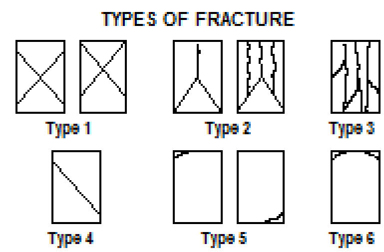
Project Number: 13-1447-0516

City of Nanaimo
445 Wallace Street
Nanaimo, BC
V9R 5J6

PROJECT: Colliery Dam, Nanaimo, BC

Concrete Supplier:	Unknown		Mix #:	Unknown
Date Cored:	February 11 to 14, 2014		Cored By:	Client
Date Tested:	March 28, 2014		Tested By:	Golder-GP

Core No.	Core Location	Test Age	Core Parameters				Maximum Load (kN)	Compressive Strength (MPa)		Failure Type	Unit Mass (kg/m^3)
			Diameter, D (mm)	Core Length L, (mm)	L/D	Correction factor		Tested	Corrected		
C1	CH14-02 (0.00' - 0.42')	n/a	81.13	117.49	1.45	0.95	306.00	59.2	**56.3**	3	2316
C2	CH14-02 (27.00'-27.42')	n/a	81.89	167.89	2.05	1.00	172.30	32.7	**32.7**	3	2478
C3	CH14-02 (49.67'-50.17')	n/a	82.06	167.89	2.05	1.00	161.40	30.5	**30.5**	3	2439
C4	CH14-03 (7.08'-7.42')	n/a	82.34	167.10	2.03	1.00	168.40	31.6	**31.6**	3	2423
C5	CH14-03 (23.25'- 23.67')	n/a	81.03	167.57	2.07	1.00	127.70	24.8	**24.8**	3	2419



Comments:
Concrete cores were tested in saturated condition
Core diameter less than three times the nominal aggregate size.

Reported By: L. Hu, M.Sc.E.

Reviewed by: ____________________________
Oon-Soo Ooi, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

OBTAINING AND TESTING DRILLED CORES FOR DIRECT TENSILE STRENGTH OF BOND TESTING

CSA A23.2-6B

April 11, 2014

Project Number: 13-1447-0516

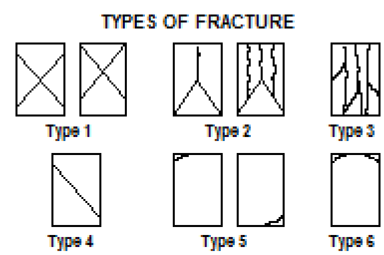
City of Nanaimo
445 Wallace Street
Nanaimo, BC
V9R 5J6

PROJECT: Colliery Dam, Nanaimo, BC

Concrete Supplier: Unknown
Date Cored: February 11 to 14, 2014
Date Tested: March 28, 2014

Mix #: Unknown
Cored By: Client
Tested By: Golder-GP

Core No.	Test Date	Core Location	Test Age	Core Parameters			Maximum Load (kN)	Tensile Strength (MPa)	Failure Notes
				Diameter (mm)	Length (mm)	Area (mm^2)			
C6	April 11, 2014	CH14-02 (36.67' – 37.5')	n/a	82.0	57.5	5281	4.89	0.95	Failure partially at the pour joint and partially in the overlying concrete
C7	April 07, 2014	CH14-03 (9.67' – 10.17')					-	-	Invalid test. Sample failed premature due to poor bond between two pours



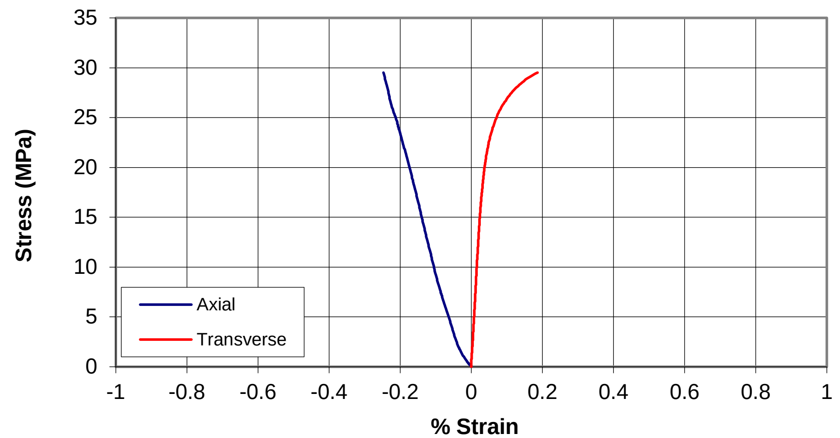
Comments:
Concrete cores were tested in saturated condition
Core diameter less than three times the nominal aggregate size.

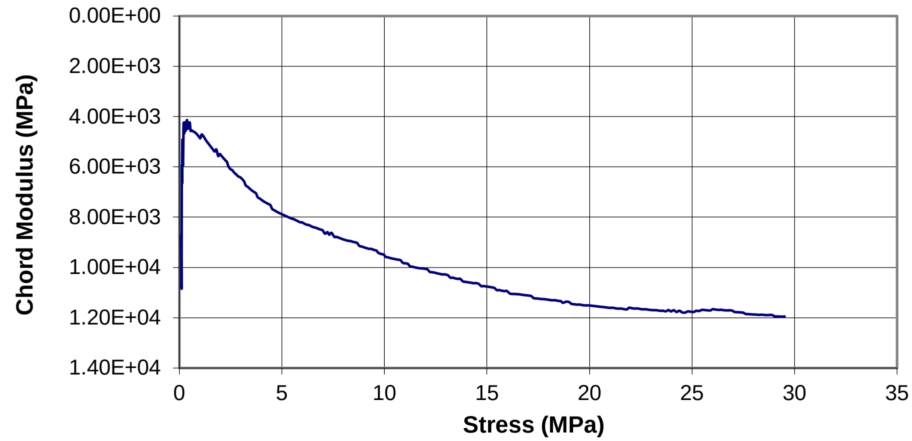
Reported By: L. Hu, M.Sc.E.

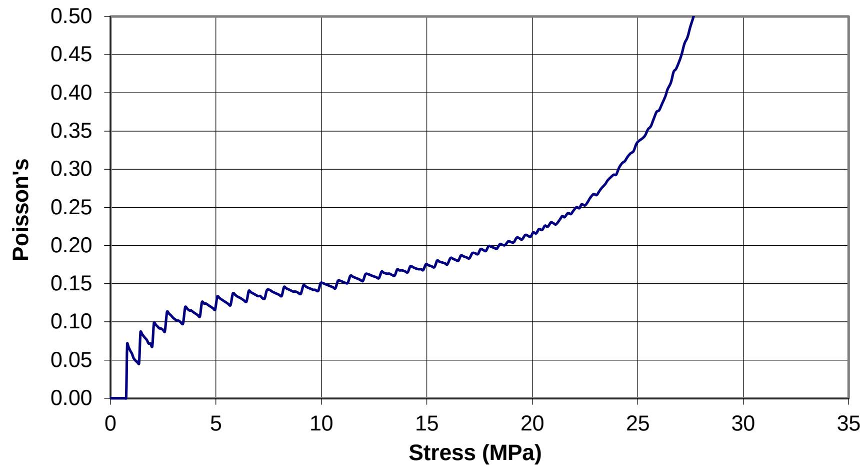
Reviewed by: ____________________________
Oon-Soo Ooi, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

Golder Associates Ltd. - Burnaby Lab
#300 - 3811 North Fraser Way
Burnaby, B.C. Canada V5J 5J2







Before Test

After Test

Test Summary		
Peak Stress σ_{peak}	32.10	MPa
Chord Modulus ε_{40}	10.26	GPa
Poisson's Ratio ε_{40}	0.16	

Sample soaked in lab for not less than 48hrs prior to testing

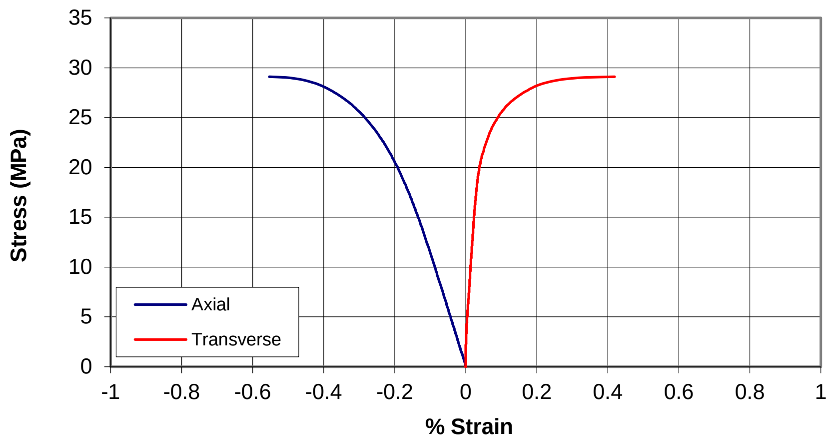
ASTM C469/C469M – 10
Modulus in Uniaxial Compression

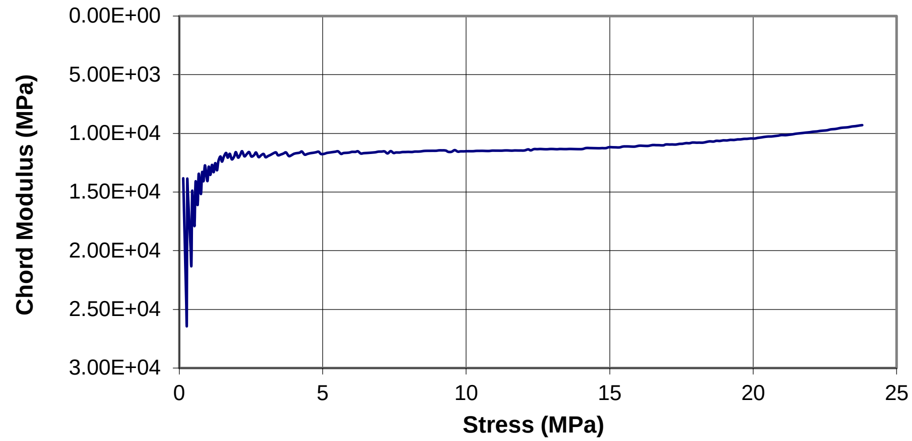
Sample:	**CH14-02 C8**
Depth (ft):	**50.17-50.83**

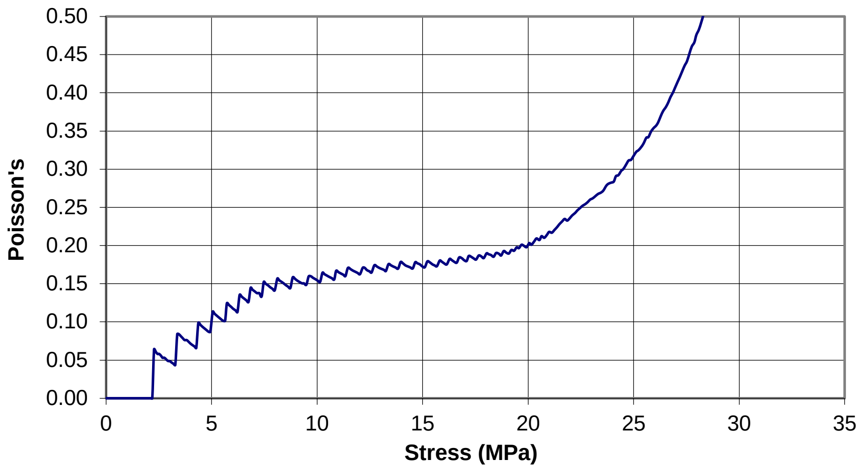
Project Details

Project No.:	13-1447-0516
Project:	Nanaimo Dam-Concrete Core Testing
Client:	City of Nanaimo
Test Date:	April 10, 2014
Tech:	G. Patton
Checked:	E. Kostyukov

Golder Associates Ltd. - Burnaby Lab
#300 - 3811 North Fraser Way
Burnaby, B.C. Canada V5J 5J2







Before Test

After Test

Test Summary

Peak Stress σ_{peak}	29.10	MPa
Chord Modulus ε_{40}	11.47	GPa
Poisson's Ratio ε_{40}	0.17	

Sample soaked in lab for not less than 48hrs prior to testing

ASTM C469/C469M – 10
Modulus in Uniaxial Compression

Sample:	**CH14-03 C9**
Depth (ft):	**6.42-7.00**

Project Details

Project No.:	13-1447-0516
Project:	Nanaimo Dam-Concrete Core Testing
Client:	City of Nanaimo
Test Date:	April 10, 2014
Tech:	G. Patton
Checked:	E. Kostyukov

Golder Associates Ltd. - Burnaby Lab
#300 - 3811 North Fraser Way
Burnaby, B.C. Canada V5J 5J2

Unconfined Compressive Strength of Intact Rock Core Specimens

Reference
ASTM D7012-10 Method C

Project No.:	13-1447-0516
Project:	Nanaimo Dam-Concrete Core Testing
Client:	City of Nanaimo
Location:	Nanaimo Chase Creek
Lab ID	98

Failure Mode

(1) Diagonal shear plane(s)
(2) Vertical fracture(s)
(3) Vertical splitting
(4) Shear along foliation / discontinuity
(5) Conical
(6) Spalling
(7) Other
Note: (deg) measured from core axis

									Wet		Dry	Maximum	Stress			
No.	**Borehole**	**Sample**	**Depth**	**Dia**	**Ht**	**A**	**V**	**Mass**	**Density**	**W**	**Density**	**Load**	**σ**	**Rock Type**	**Failure Mode**	
	#	#	(ft)	(mm)	(mm)	(cm^2)	(cm^3)	(g)	(Kg/m^3)	(%)	(Kg/m^3)	(kN)	(MPa)		Type	(deg)
1	CH14-03	N/A	31.00-32.50	81.88	160.88	52.66	847.11	2199.60	2597	1.39	2561	196.00	37.2	Conglomerate	7	N/A

G. Patton	April 1, 2014	LP	APRIL 2,2014
TESTED BY	DATE	CHECKED BY	DATE

Golder Associates

Golder Associates Ltd. - Burnaby Lab
#300 - 3811 North Fraser Way
Burnaby, B.C. Canada V5J 5J2

Unconfined Compressive Strength of Intact Rock Core Specimens

Reference
ASTM D7012-10 Method C

Project No.:	13-1447-0516	**Borehole:**	**CH14-03**
Project:	Nanaimo Dam-Concrete Core Testing	**Sample Number:**	N/A
Location:	Nanaimo Chase Creek	**Depth (ft):**	31.00-32.50
Client:	City of Nanaimo	**Lab ID No:**	98

Testing Results

Max Load (kN)	**196.00**
Stress σ (MPa)	**37.2**
Pace Rate (kN/s)	1.25
Lithology	Conglomerate

Sample Measurements

Diameter (mm)	81.88
Height (mm)	160.88
Area (cm^2)	52.66
Volume (cm^3)	847.11
Mass (g)	2199.60
Moisture Content (%)	1.39
Wet Density (Kg/m^3)	2596.60
Dry Density (Kg/m^3)	2561.13

Failure Mode

Type: **7**

Degrees:* **N/A**

* Degrees measured with respect to core axis.

Notes

- Water content as received

Mode:
(1) Diagonal shear plane(s)
(2) Vertical fracture(s)
(3) Vertical splitting
(4) Shear along foliation /discontinuity
(5) Conical
(6) Spalling
(7) Other

Comments

Failed around clasts, through matrix material

** The test data given herein pertain to the sample provided only. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.*

BEFORE TEST

AFTER TEST

G. Patton	April 1, 2014	LP	APRIL 2,2014
TESTED BY	DATE	CHECKED BY	DATE

Annex D Risk Management Plan

TECHNICAL MEMORANDUM

DATE February 6, 2014 **DOCUMENT NO.** 13 1447 0516
No.

TO Thomas Madden

CC Vafa Rombough, Jenna Girdner

FROM Bruce Downing, Robert Chu, Grant Bonin **EMAIL** rchu@golder.com

INTERIM RISK MANAGEMENT PLAN, COLLIERY DAM, NANAIMO
LOWER DAM DRILLING INVESTIGATION

PURPOSE OF WORK

A preliminary geotechnical investigation program of the Lower Colliery Dam in Nanaimo is planned to further address gaps and uncertainties in the existing information available for the Lower Dam. A sketch of the plan and section of the proposed borehole locations is attached. The objectives of the investigation program have been broken out into boreholes planned for the concrete core wall and boreholes planned for the downstream shell.

Concrete Core Wall

Purpose of the investigation is to

- To observe the condition of the concrete core and confirm the possible presence and condition of reinforcement.
- To collect concrete core samples for evaluation of concrete conditions and possible further laboratory strength testing as a basis for assessing the core wall condition and response to earthquake induced deformations.
- To delineate the variation in thickness of the concrete core wall at depth and possibly detect reinforcement near the core holes (this will be done as a separate (later) geophysical survey).

Downstream Shell

Purpose of the investigation is to

- To observe the soil/fill material in the downstream shell and develop a profile of internal layering.
- To collect soil samples for laboratory testing of properties including grain size distribution, moisture content, etc.
- Profile underlying foundation (bedrock or till interface).
- Identify “water table,” and other possible variations in water saturation.
- If necessary (dependant on results of surface MASW survey) estimate the p and s wave velocities in the fill material (at one borehole location) – (if needed, this will be done as a separate (later) geophysical survey).

In order to execute the above objective, the scope of the drilling program includes coring three holes in the concrete wall of the lower dam and drilling three boreholes in the downstream shell (see attached sketches for approximate proposed locations). The drilling of both areas will be carried out concurrently by different drilling methods and are discussed further below.

Concrete Core Wall (3-4 field days)

- Drill three core holes to approximately 15 m depth using a diamond drill rig, the hole will be collared in the center of the wall, and the hole will be surveyed during drilling to monitor that it does not deviate out of the interior of the core.
- A geotechnical engineer will be onsite to observe the drilling and carry out in-situ measurements (e.g. core permeability). A structural engineer will carry out visits in order to assess the condition of the core and possible rebar.
- The concrete core will be collected in core boxes and transferred to the Golder warehouse for potential further laboratory testing of strength properties.
- The core holes will be capped and left open for testing at a later date.
- A radar survey will be carried out in one of the core holes to attempt to delineate the thickness of the concrete core wall at depth and possibly detect the presence of reinforcement (this will be done as a separate (later) geophysical survey).
- Upon completion of all testing, the core holes will be sealed with grout with properties as specified by the structural engineer. This will be completed separately at a later date.

Downstream Shell (3-4 field days)

- Drill three boreholes to bedrock (approximately 15 m depth) using a sonic drill rig,
- A geotechnical representative of Golder will be onsite to sample (geotechnical and limited geo-environmental) and observe and log the condition of the soil.
- The soil samples will be transferred to the Golder warehouse for potential further laboratory testing.
- The boreholes will be completed as follows,
    - Two of the boreholes will be completed with piezometer installations as directed by the Golder field personnel onsite.
    - One of the boreholes will be completed with a 3inch PVC Casing, for a down hole seismic survey (if needed, this will be done as a separate (later) survey).

RISK MANAGEMENT MEASURES

The key dam safety related risks that have been identified are presented below. Prior to implementing any of the Mitigation recommendations, the key personnel listed below shall be consulted.

Identified Risks and Mitigation

Concrete Core Wall

The principal dam safety concerns that will need to be considered in the drilling of these boreholes relates to minimizing damage to the core, which could lead to increase seepage through the core of the dam.

1. Risk. The borehole may deviate and not stay within the concrete core
   a. Mitigation. Survey the borehole, at minimum 5 m intervals to verify that the holes is within the central half of the core (ie a minimum of 0.3 m from the face of the core). If the borehole deviates more than this amount, re-orient the hole, or abandon the hole and re-drill.
2. Risk. Borehole instability. If very poor quality concrete is encountered, to such a degree that the stability of the borehole cannot be maintained, borehole collapse may occur which could lead to increased seepage through the core.
   a. Mitigation. Maintain drilling fluid pressures within the hole to increase stability. Advance casing to stabilize the hole, or grout the borehole is accordance with the procedures below (see Appendix).
3. Risk. Loss of drilling fluids – excessive loss of fluids may have an adverse impact on the core and on the environment (although losses would be expected to be to the downstream side of the dam, rather than into the reservoir).
   a. Mitigation. Use lost circulation materials, or grout the hole (in accordance with the procedure in the Appendix) and re-drill the hole.
4. Risk. Long term borehole stability in question – if, at the end of drilling, it appears that the borehole is not sufficiently stable to remain open until the additional down-hole testing is completed at a later date, there is a risk that the borehole may collapse in the intervening period..
   a. Mitigation. Provide support to the borehole by means of a standpipe or casing, or grout the borehole is accordance with the procedures below (see Appendix).
5. Risk. Concrete damage due to vibrations.
   a. Mitigation. Use diamond drilling methods, which have minimal vibrations that could cause damage.

Downstream Shell

The principal dam safety concerns that will need to be considered in the drilling of these boreholes relates to minimizing damage to the shell.

1. Risk. Borehole instability – excess excavation (sand production) results in loosening the dam fills and creation of voids.
   a. Mitigation. These potential effects will be mitigated by using sonic drilling (a proven method to put down boreholes in coarse granular soils), by advancing casing where needed and by monitoring penetration rates and cuttings production.
2. Risk Loss of tooling downhole.
   a. Mitigation. Where possible, tooling shall be recovered by the use of appropriate retrieval tools. If unsuccessful the hole shall be grouted in accordance with procedures that will be developed specific to the situation.

DISTRIBUTION AND CONTACT INFORMATION		**Land Line**	**Cell Phone**
Project Manager – Golder	Bruce Downing	604 296 4350	604 992 2958
Project Engineer – Golder	Jenna Girdner	604 297 2045	778 878 7598
Project Engineer – Golder	Anne Crowley	604 296 2891	604 313 8804
Project Director – Golder	Herb Hawson	604 296 4333	604 240 7923
Golder Site Engineer	Thomas Madden		604 346 5762
Environmental Manager	Mark Johannes		604 376 1737
Environmental Biologist	Steven Henstra		778 269 2482
City of Nanaimo	Dale Lindsey		250 750 4493
City of Nanaimo	Bill Sims		250 714 3568 250 756 5302
Storm Drainage City of Nanaimo	Dean Robinson		250 758 5222
Dam Safety Section	Scott Morgan	250 387 3263	250 356 0605

APPENDIX

This Appendix provides a procedure for mixing a balanced, stable grout to be used for borehole backfilling operations at the Lower Dam, if necessary.

1.0 BENTONITE HYDRATION

The following procedure will produce a bentonite slurry at 10% solution by weight of water (BWOW), yielding approximately 100 Litres, enough for five batches of grout.

Materials Required:

- 1 x 200 L metal drum (clean);
- 1 x 40 kg bag of dry, powdered bentonite (Baroid Aquagel Gold Seal, see attached);
- Supply of clean water, free of deleterious substances;
- 1 x hydraulic mud mixer;
- 3 x clean and dry plastic or metal bowls (5 L capacity each);
- 2 x 20 L calibrated plastic buckets;
- 1 x electric, variable speed, hand held drill;
- 1 x metal paint mixing paddle, adaptable to hand held drill;
- 1 x electronic scale (5 kg capacity); and
- 1 x mud balance.

Procedure:

1. Using the electronic scale, weigh out 10 kg of dry powdered bentonite into the dry bowls and set aside in a dry, protected area. Place the left over bentonite into a plastic bag and seal.
2. Using 20 L calibrated buckets, measure out 100 L of water and pour into the drum.
3. Place the hydraulic mud mixer to the bottom of the metal drum and run at a high speed setting. The maximum speed should be set such that minimal cavitation is visible through the impeller blades of the mixer. Establish a good flow around the bottom of the drum.
4. Slowly add the 10 kg of dry powdered bentonite to the water. It should take a minimum of 2 minutes to add the dry bentonite to the water.
5. After all of the bentonite has been added, mix at high speed for 10 minutes.
6. Remove hydraulic mud mixer from the drum and clean.
7. Measure density of the bentonite slurry using the mud balance (theoretical is 1.055 g/cc).
8. Cover drum and move it to a protected area.
9. Allow the bentonite to hydrate at least 12 hours before use.

10. Agitate the bentonite slurry for a minimum of 1 minute using the handheld drill and metal paint mixer prior to measuring out for grout mix batching.

2.0 GROUT MIXING PROCEDURE

The following grout mixing procedure will yield approximately 110 L of grout. All percentages are listed by weight of cement (BWOC):

Grout Mix Design: 0.57:1 Water to cement ratio + 1% Super Plasticizer + 1.6% Bentonite Slurry

Materials Required:

- 1 x 200 L metal drum (clean);
- 3 x bags (40 kg each) of Type 10 (GU) cement (see attached);
- Supply of clean water;
- 1 x hydraulic mud mixer;
- 2 x 1 L plastic graduated cylinder;
- 3 x 20 L calibrated plastic buckets;
- 3 x 2 L calibrated plastic buckets;
- 1 x mud balance;
- 1 x Marsh funnel;
- 1 x handheld digital thermometer;
- Supply of pre-hydrated bentonite slurry (as per above); and
- Supply of superplasticizer (BASF Rheobuild 1000, see attached).

Procedure:

1. Measure out 1 L of superplasticizer and set aside.
2. Thoroughly agitate the pre-hydrated bentonite slurry for a minimum of 1 minute; measure out 20 L and set aside.
3. Measure out 50 L of clean water and add it to the metal drum.
4. Place the hydraulic mud mixer to the bottom of the drum and run at its highest speed setting.
5. Begin slowly adding cement to the water, noting the viscosity (thickness) of the mixture. As the viscosity begins to increase, add approximately 250 mL of superplasticizer.
    a. Superplasticizer will have to be added before all the cement is added. Continue adding cement and superplasticizer at the same time until all bags of cement have been added to the mixture. Save approximately 500 mL of super plasticizer and set aside.
    b. After all 3 bags of cement have been added to the, mix for 2 minutes.

6. Begin adding 20 L of bentonite slurry, noting the viscosity of the mixture. As the viscosity increases, add a portion of the remaining superplasticizer to the mixture. Continue adding bentonite slurry to the grout mixture. Add any remaining superplasticizer to the mixture.
    a. After all 20 L of bentonite slurry and super plasticizer have been added to the grout mixture, mix for an additional 2 minutes.

3.0 BACKFILLING PROCEDURE

1) Determine the volume of the borehole based on the current depth drilled. Calculate required amount of grout to fill the hole plus an additional 300 L.

2) Establish a grout reservoir using a spare water tub or tank. Mark the grout reservoir in 5 to 10 L increments and note the starting level before pumping begins.

3) Plumb a hose line from the grout reservoir to the triplex pump located on the drill.

4) Install grout header system between the triplex pump on the drill and the water swivel on the rod string. The grout header system consists of:

    a. A “tee”;

    b. Three sections of hose connecting:

        i. Triplex pump to tee

        ii. Tee to water swivel

        iii. Tee to return line (goes into the grout reservoir); and,

    c. Two valves:

        i. One at the water swivel to control grout flow into the rod string

        ii. One at the return line to control return speed, which controls the grout injection rate.

    d. Pressure gauge (reading in Bar or psi) installed at or near the water swivel and at the output of the triplex pump.

5) Install grout pressure plug (Van Ruth Type) onto rod string, and lower to required depth.

6) Batch an appropriate volume of grout using the procedures described in Sections 1.0 and 2.0 above, and fill the grout reservoir.

7) Before pumping of grout can begin, quality control measurements must be taken to ensure the suitability and quality of the grout mixture. These measurements consist of:

    a. Marsh Funnel Viscosity – Measured in seconds. The acceptable range for this is 150 sec ± 20 seconds (to be determined in the field, post-batching).

    b. Density – Measured in grams per cubic centimeter. The acceptable value for the grout described in Section 2.0 is 1.77 g/cc ± 0.02 g/cc.

c. Bleed – Settlement of grout in a 1000 mL graduated cylinder, measured in percent volume. The acceptable value for the grout described in Section 2.0 is < 2.0% after 2 hours.

8) Calculate the appropriate pressurization level using the formula 0.2 Bar / meter depth to mid-point of open hole.

9) Backfill the hole and pressurize to the value calculated above. During injection, flow rates should not exceed 20 L/min.

   a. During grout injection, and if multiple batches are required, note the level on the grout reservoir before and after the addition of additional batches of grout to keep track of volumes during injection.

   b. Consideration should be given to halting backfilling after a total of three well volumes worth of the backfill grout has been injected. Allow the grout to set up overnight and repeat as many times as is necessary to backfill (and pressurize) the interval. It may be necessary to drill out and re-install a Van Ruth plug on each subsequent attempt.

10) After grout has been pressurized to the required level, set the grout pressure plug by twisting on the rod string. Note the level on the grout reservoir to obtain the volume grouted.

11) Remove the rod string and flush the borehole over the grout pressure plug.

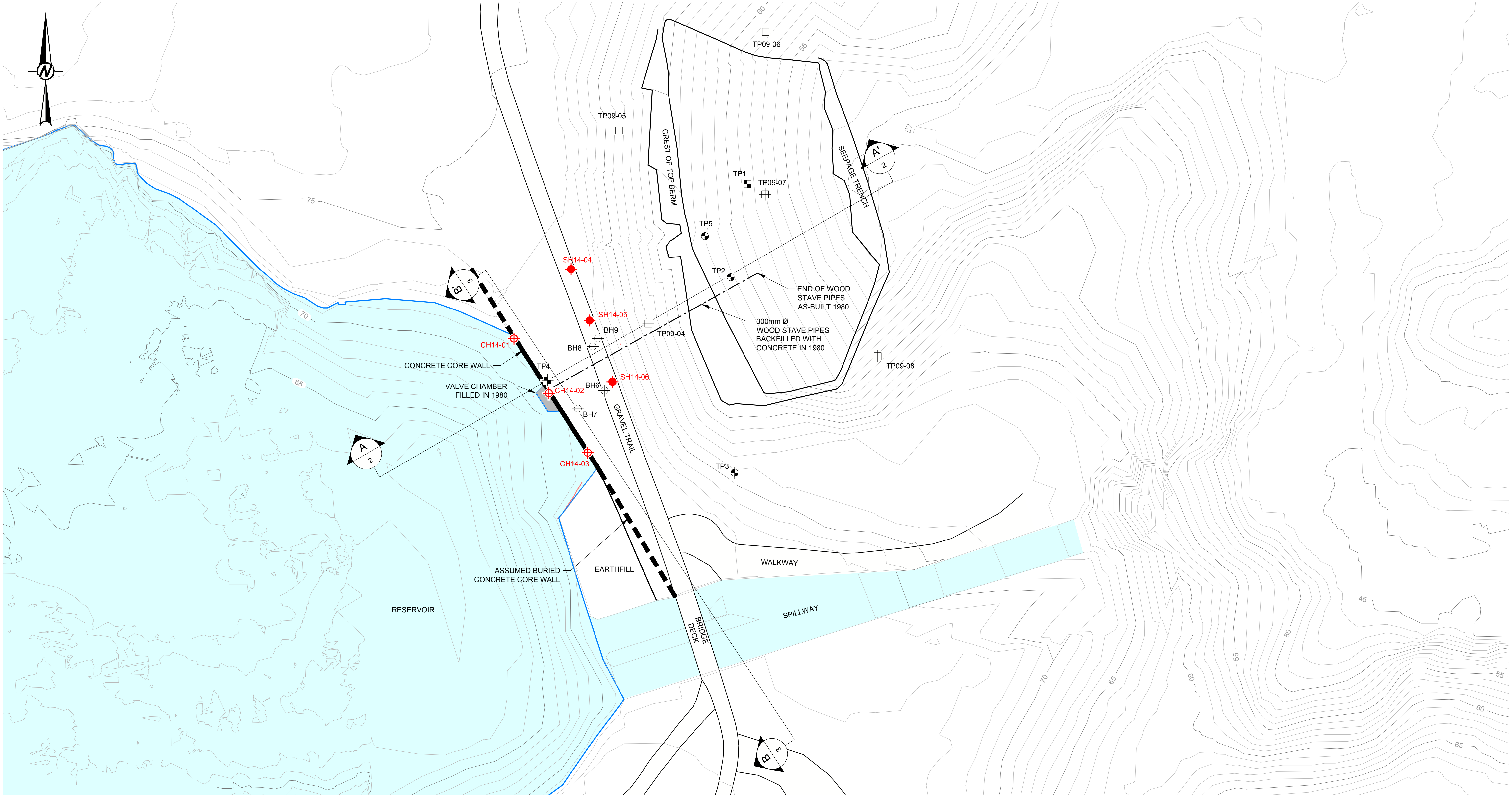
12) Allow the grout to set 24 hrs before any drilling operations are to be reinitiated.

Bruce Downing, P.Eng.
Principal

Grant Bonin, P.Eng.
Associate, Mining Geotechnical Engineer

RCC/GRB/rcc/vtr/grb

c:\users\bdowning\appdata\local\microsoft\windows\temporary internet files\content.outlook\wwer7d38\emergency grouting procedure_vtr_grb.docx



LEGEND

NORMAL OPERATING LEVEL OF RESERVOIR	OUTLINE OF WALL, 1.2m IN THICKNESS, AT 0.6m BELOW GROUND SURFACE
1978 BOREHOLE (GOLDER)	PROPOSED BOREHOLE (SONIC)
1978 TEST PIT PUT DOWN BY HAND (GOLDER)	PROPOSED BOREHOLE (DIAMOND)
1978 TEST PIT PUT DOWN BY EXCAVATOR (GOLDER)	
2009 TEST PIT (EBA)	

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
2. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, N 13101249, APRIL 14, 2014. (EBA 2010)

FOR DISCUSSION PURPOSES ONLY

DRAFT

SCALE 0 12 24 36

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-01-31	DRAFT - ISSUED FOR REVIEW	A.C.	M.R.	-	-

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

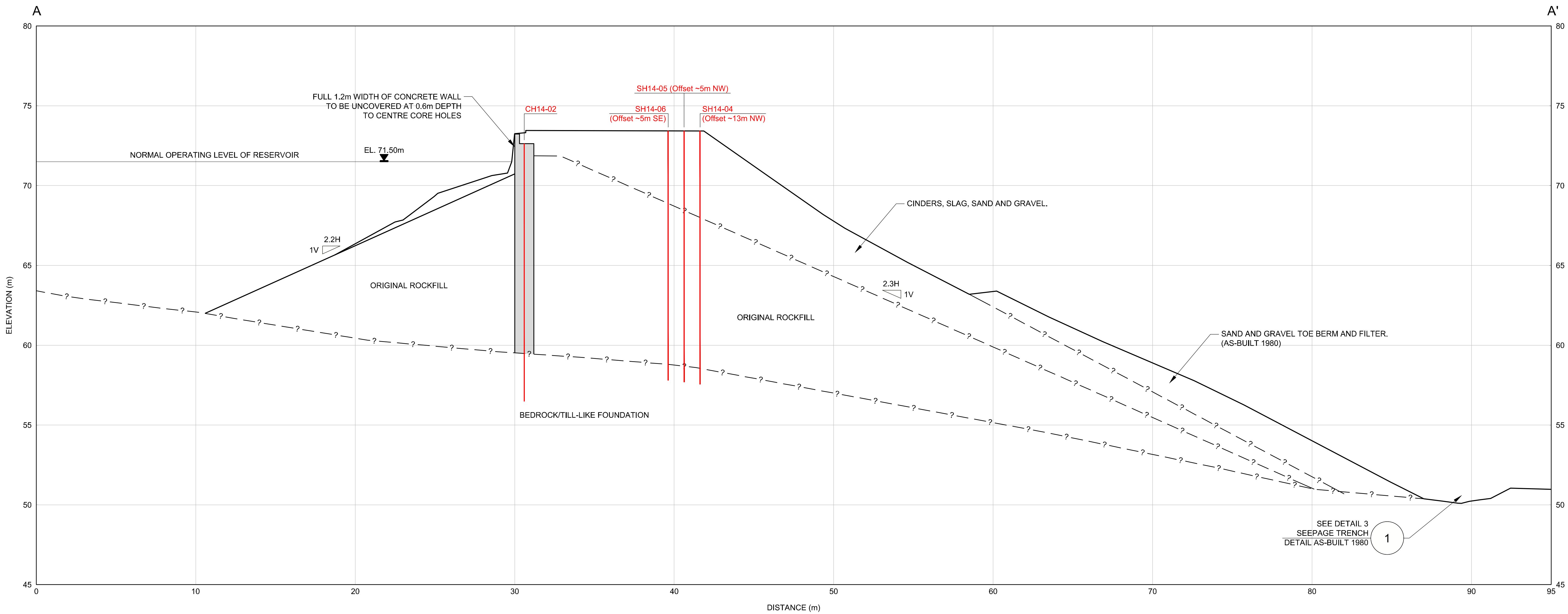
TITLE

PROPOSED BOREHOLE LOCATIONS LOWER DAM

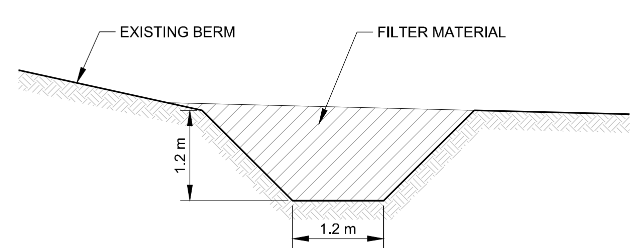
PROJECT No.	13-1447-0516.7000	FILE No.	1314470516_7000-01
DESIGN	A.C. 2014-01-29	SCALE	AS SHOWN
CADD	M.R. 2014-01-30	FIGURE	1
CHECK	- -		
REVIEW	- -		

Golder Associates

M:\Active\Year 2013\1447\13-1447-0516 (Chase Dams - City Of Nanaimo)\DRAFTING\7000\PRODUCTION\1314470516_7000-01.dwg | Layout: Layout1-ANSI_B_FIGURE_LANDSCAPE | Modified: matrobertson 01/30/2014 3:08 PM | Plotted: matrobertson 02/03/2014



SCALE A (A/1) CROSS-SECTION A-A'



SCALE B (1) SEEPAGE TRENCH DETAIL AS-BUILT 1980

LEGEND

— —?— INFERRED BOUNDARY BETWEEN DEPOSITS

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
3. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, N 13101249, APRIL 14, 2014. (EBA 2010)

FOR DISCUSSION PURPOSES ONLY

DRAFT

SCALE B: 0 2 4 6 METRES

SCALE A: 0 5 10 15 METRES

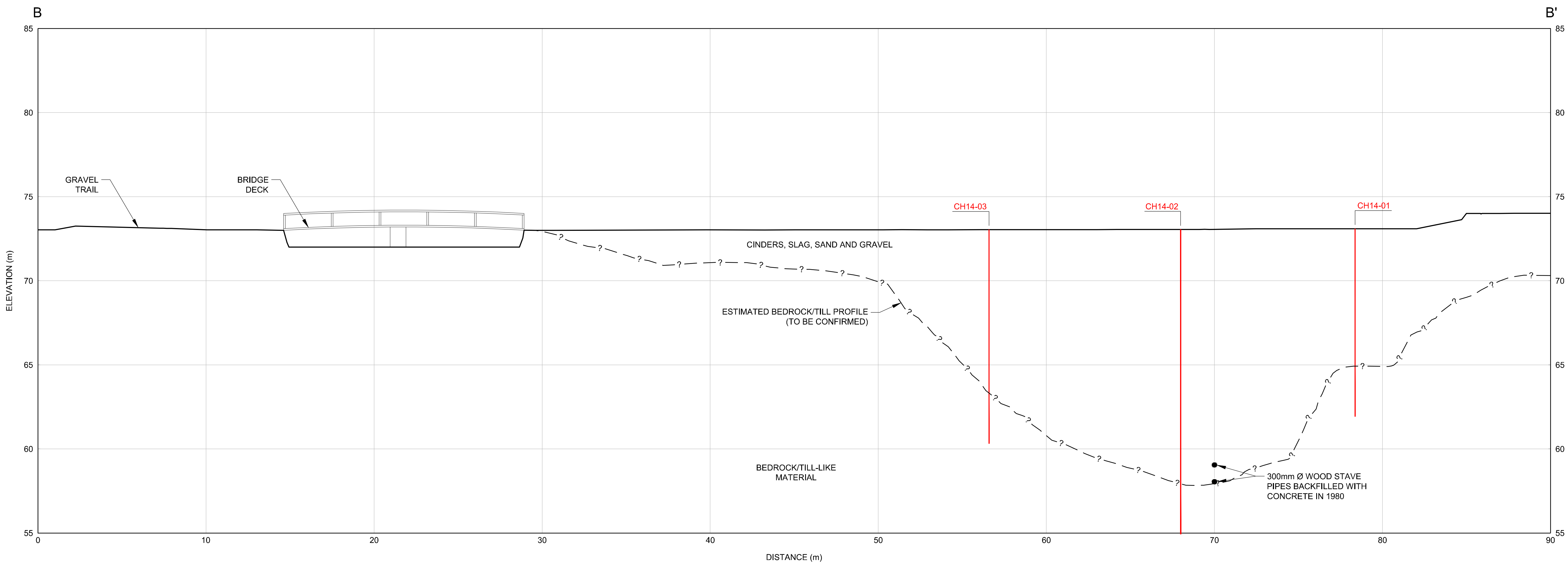
REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-01-31	DRAFT - ISSUED FOR REVIEW	A.C.	M.R.	-	-

PROJECT: CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE: **LOWER DAM CROSS-SECTION A-A'**

Golder Associates

PROJECT No.	13-1447-0516.7000		FILE No.	1314470516_7000-02
DESIGN	A.C.	2014-01-29	SCALE	AS SHOWN
CADD	M.R.	2014-01-30	FIGURE	2
CHECK	-	-		
REVIEW	-	-		



SCALE A B 1 CROSS-SECTION B-B'

LEGEND

— —?— INFERRED BOUNDARY BETWEEN DEPOSITS

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC DATA FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. WILLIS CUNLIFFE TAIT & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-builts.pdf, DATED: JULY 1978.
3. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, N 13101249, APRIL 14, 2014. (EBA 2010)

FOR DISCUSSION PURPOSES ONLY

DRAFT

0 5 10 15

SCALE A METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
A	2014-01-31	DRAFT - ISSUED FOR REVIEW	A.C.	M.R.	-	-

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

LOWER DAM
CROSS-SECTION B-B'

Golder Associates

PROJECT No.	13-1447-0516.7000		FILE No.	1314470516_7000-03
DESIGN	A.C.	2014-01-29	SCALE	AS SHOWN
CADD	M.R.	2014-01-30	FIGURE	3
CHECK	-	-		
REVIEW	-	-		

APPENDIX F

Appendix F Hydrogeological Investigation of Lower Dam

TECHNICAL MEMORANDUM

DATE March 27, 2014 **PROJECT No.** 1314470516 / 7000 / 7200

TO City of Nanaimo

CC

FROM Robert Chu, Denis Vachon, Michal Dobr **EMAIL** Robert_Chu@golder.com; Denis_Vachon@golder.com

2014 HYDROGEOLOGICAL TESTING PROGRAM – COLLIERY DAMS, CITY OF NANAIMO

1.0 INTRODUCTION

Hydrogeological testing program was carried out as part of the 2014 geotechnical field investigations in the area of the Nanaimo Colliery Dam.

This technical memorandum provides a summary and interpretation of the hydrogeological data collected during the program.

2.0 HYDROGEOLOGICAL FIELD INVESTIGATIONS

Hydrogeological testing was undertaken on March 24, 2014 in two boreholes drilled by Cabo Drilling Corp. The boreholes were cored with a nominal diameter of 122.6 mm (PQ). Detailed information on the selected test boreholes such as collar coordinates, borehole inclination, and depth, is presented in Table 1 below.

Table 1: Test Borehole Details

Borehole Number	Northing [m][a]	Easting [m][a]	Ground Surface Elevation [masl][b]	Borehole Depth [mab][c]	Borehole Azimuth [Degrees°]	Borehole Inclination [Degrees°]
CH14-02	5446452.1	430000.5	72.9	20.0	0	90
CH14-03	5446440.7	430007.4	72.9	12.4	0	90

Notes:

a = NAD 83

b = metres above sea level.

c = metres along borehole below ground surface.

.

2.1 Testing Approach

Single-well pressure response tests were carried out in the selected boreholes to obtain information on the hydraulic conductivity of a concrete wall and the underlying bedrock. Testing was conducted with PQ size pneumatic packer on dedicated 1 ¼” diameter test rods. Schematic diagram of the tool assembly is shown in Figure 1. To perform a test the tool was lowered, and once the packer reached the target depth it was inflated with water isolating the section of the borehole between the packer and the bottom of the borehole at that time. After the test was completed, the packer was deflated and removed from the borehole.

To monitor the progress of the individual test sequences a LevelTROLL 700 memory gauges was placed in a carrier attached below the packer to monitor the pressure response directly in the test interval. The transducer was programmed to collect data in 1 second, interval.

Prior to testing, the water level was measured in each borehole to select the depth for placement of the testing equipment to provide hydraulic conductivity for the saturated portion of each borehole. Based on the water level elevations the test intervals varied in length from 2.4 to 13.9 metres. Table 2 below presents a summary of the tests carried out in the two boreholes.

Table 2: Summary of Hydrogeological Tests

Borehole ID	Interval Tested [mbgs][a]	Number of Tests Conducted	Material Tested	Water level [mbgs][a]
CH14-02	6.1 – 20.0	1	Concrete/Bedrock	2.6
CH14-03	10.1 – 12.4	1	Bedrock	8.8

Notes:

a =metres below ground surface.

2.2 Testing Methodology

The following methodology was used for the hydrogeological testing at the Nanaimo Colliey dams project:

- Pressure Static Recovery Sequence – PSR;
- Slug Injection Sequence (SI) ;

The following provides detailed description of the individual test sequences.

2.2.1 Pressure Static Recovery

After the testing tool was placed to the desired depth the packer was inflated with water. Following packer inflation, the water table inside the test rods was measured with a water level tape to monitor the response of the aquifer in real time. The pressure static recovery sequence (PSR) was carried out to allow the aquifer within the isolated interval to reach static conditions after packer inflation. This sequence lasted approximately 1 hour. After this time, the next test sequence was initiated, even if full hydrostatic conditions were not achieved in the test interval.

2.2.2 Slug Injection Test

After the PSR sequence, a slug injection (SI) test was carried out. This test sequence consists of adding an instantaneous slug of water into the test rods. After the slug displacement, the water level inside the test rods was monitored until it recovered to the pre-test level. Slug recovery monitoring continued for a period of time lasting between 30 minutes and approximately 1 hour. After this time the test was terminated even if full recovery was not reached.

2.3 Test Analysis

2.3.1 Software

The test analyses were carried out with *HydroBench®* (Version 3.6.4.3), a Golder internally developed software package designed to analyze different types of hydrogeological tests. *HydroBench®* is a pressure transient interpretation package using the methodology of the Bourdet Derivative (e.g., Gringarten 2008), coupled with a library of analytical reservoir models. Further information on the *HydroBench®* software including a detailed documentation of the verification of the software is available on request.

2.3.2 Results

A summary of the transmissivity and hydraulic conductivity values calculated for the tested intervals is presented in Table 3 below. The hydraulic conductivity values were calculated by dividing the transmissivity value by the length of the corresponding test interval. The table shows the test sequences carried out in each interval such as pressure static recovery (PSR),and slug injection (SI).

Table 3: Summary of Single Well Test Results

Borehole ID	Test	Interval			Test Sequences		T [m^2/s]	K [m/s]
		Top [mbgs][a]	Bottom [mbgs][a]	Length [m][a]	Conducted	Analysed		
CH14-02	Test 1	6.1	20.0	13.9	PSR, SI	SI	9×10^{-6}	7×10^{-7}
CH14-03	Test 1	10.1	12.4	2.4	PSR, SI	SI	3×10^{-8}	1×10^{-8}

Notes: a = metres below ground surface

Based on the information presented in Table 2, the results of the test conducted in borehole CH14-02 (7×10^{-7} m/s) represent combined hydraulic conductivity of a concrete and bedrock, while the hydraulic conductivity derived from the test in borehole CH14-03 (1×10^{-8} m/s) represents bedrock only.

Detailed analytical test reports are presented in Attachment A. These reports are computer generated protocols, and some values in these documents might differ from values discussed within the text section of this document.

3.0 RECOMMENDATION

Because of the significant difference between the water levels recorded in borehole CH14-03 and the borehole CH13-02, it is recommended to carry out additional testing in borehole CH14-03 to locate the zone of potential breach in the wall causing the depressed water table at this location.

4.0 CONCLUSION

We trust that the information provided above satisfies your current project requirements. If you have any questions or concerns, please do not hesitate to contact us at your convenience.

5.0 REFERENCES

Horner, D.R. 1951. Pressure Build-Ups in Wells. Proc., Third World Petroleum Congress, The Hague, Section II, 503-523, 28 May – 6 June.

Gringarten AC., 2008. From Straight Lines to Deconvolution: The Evolution of the State of the Art in Well Test Analysis. SPE Reservoir Evaluation & Engineering 11: 41-62.

ORIGINAL SIGNED

ORIGINAL SIGNED

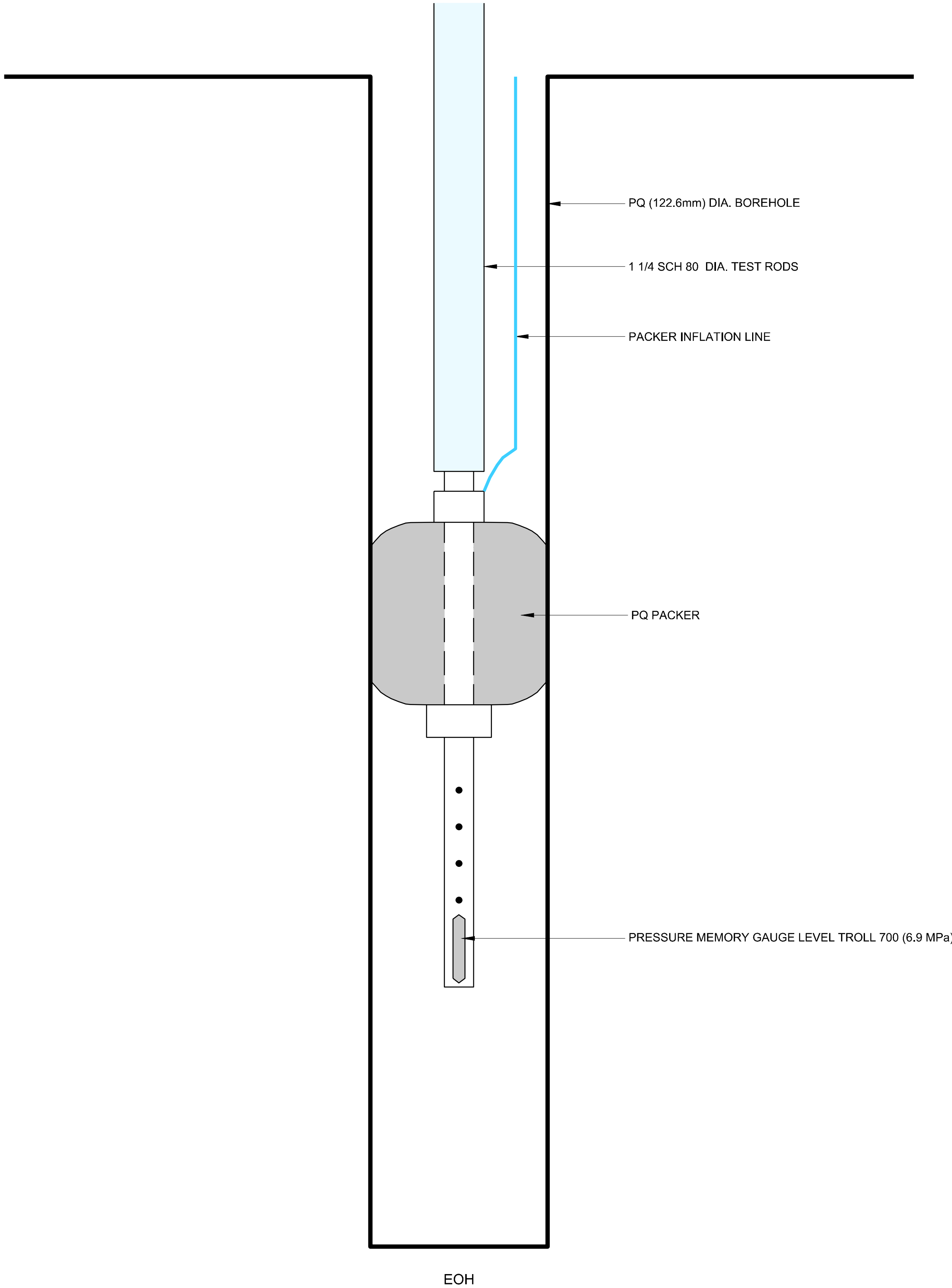
Robert Chu, BaSc., EIT
Mining Engineer

Mike Dobr, RNDr. P.Geo.
Principal, Senior Hydrogeologist

RC/MD

\\golder.gds\gal\burnaby\active_2013\1447\13-1447-0516 nanaimo colliery dams nanaimo\6.0 deliverables\factual report\appendix f hydrogeology investigation\1314470516-nanaimo colliery dams_april2.docx

Attachments: Figure 1: Downhole Testing Equipment – Single Packer Tool
Attachment A: *HydroBench*® Analysis Reports



SCHEMATIC ONLY

DRAFT

PROJECT

CITY OF NANAIMO
COLLIERY DAMS
NANAIMO, B.C.

TITLE

DOWNHOLE TESTING EQUIPMENT
SINGLE PACKER SETUP

Golder Associates

PROJECT No. 13-1447-0516.7000.7200			FILE No. 1314470516_7000_7200-01
DESIGN	A.C.	2014-01-09	SCALE NOT TO SCALE
CADD	T.A.K.	2014-04-03	FIGURE
CHECK	-	-	F- 1
REVIEW	-	-	

ATTACHMENT A

HydroBench® Analysis Reports

<u>Note:</u> These reports are computer generated protocols, and some values might differ from values discussed within the text section of this document.

HYDROBENCH REPORT

Project	CITY OF NANAIMO
Site	NANAIMO COLLIERY DAMS
Source Well	CH14-03
Test Name	Test 1
Test Date/Time	
Interval	top: 10.10 m bottom: 12.40 m
Description	

Basic Data

Test Interval	2.30 m		
Porosity	0.10		
Well Radius	0.061 m	Tubing Radius	0.016 m
Inclination	0.0 deg		
Test Volume	27.152 l		
Well Type	Source		

Fluid Properties

Viscosity	0.001 Pa*s
Density	1000.0 kg/m³
Compressibility	2.0e-09 1/Pa

Sequence Definition

Name	Category	t(o) [hrs]	P(o) [kPa]	P(i) [kPa]	Rate [l/min]	C [m³/Pa]
INF	Variable Pressure	0.00000	23.06			8.2e-08
PSR	Recovery	0.07722	26.68			8.2e-08
SI_Init	dP-Event	0.82333	23.44	-93.6 *		8.2e-08
SI	Slug	0.84556	117.05	23.4		8.2e-08

Analysis Results

Analysis "SI"

Static Pressure: 22.63 kPa

Shell Parameters:

Name	Transmissivity [m²/s]	Storativity [-]	Radius [m]	Flow Dimension [-]
Shell 1	2.8e-08	4.5e-06	- -	2.0

Sequence Parameters:

Name	Wellbore Storage [m³/Pa]	Skin [-]
INF	5.2e-05	0.0
PSR	5.2e-05	0.0
SI_Init	8.2e-08	0.0
SI	8.2e-08	0.0

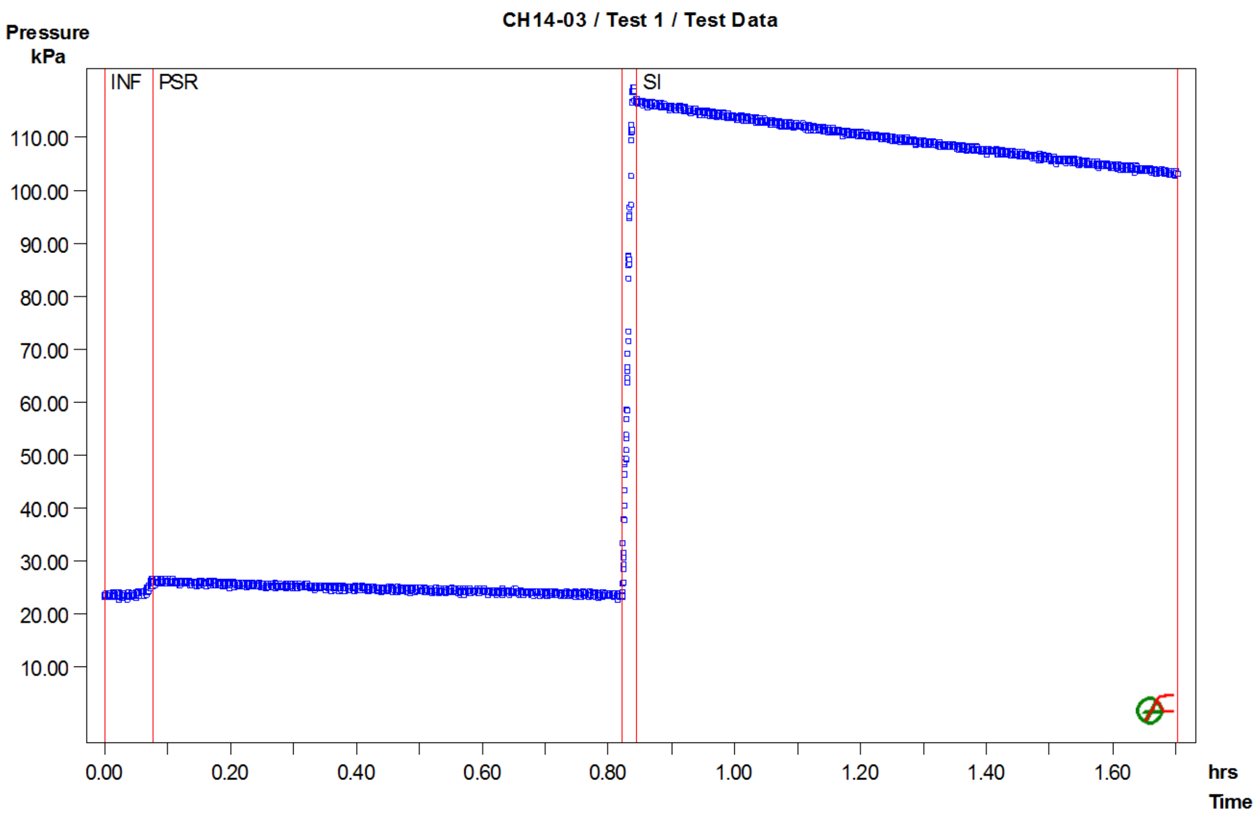


Figure 1: Pressure response and sequence definition

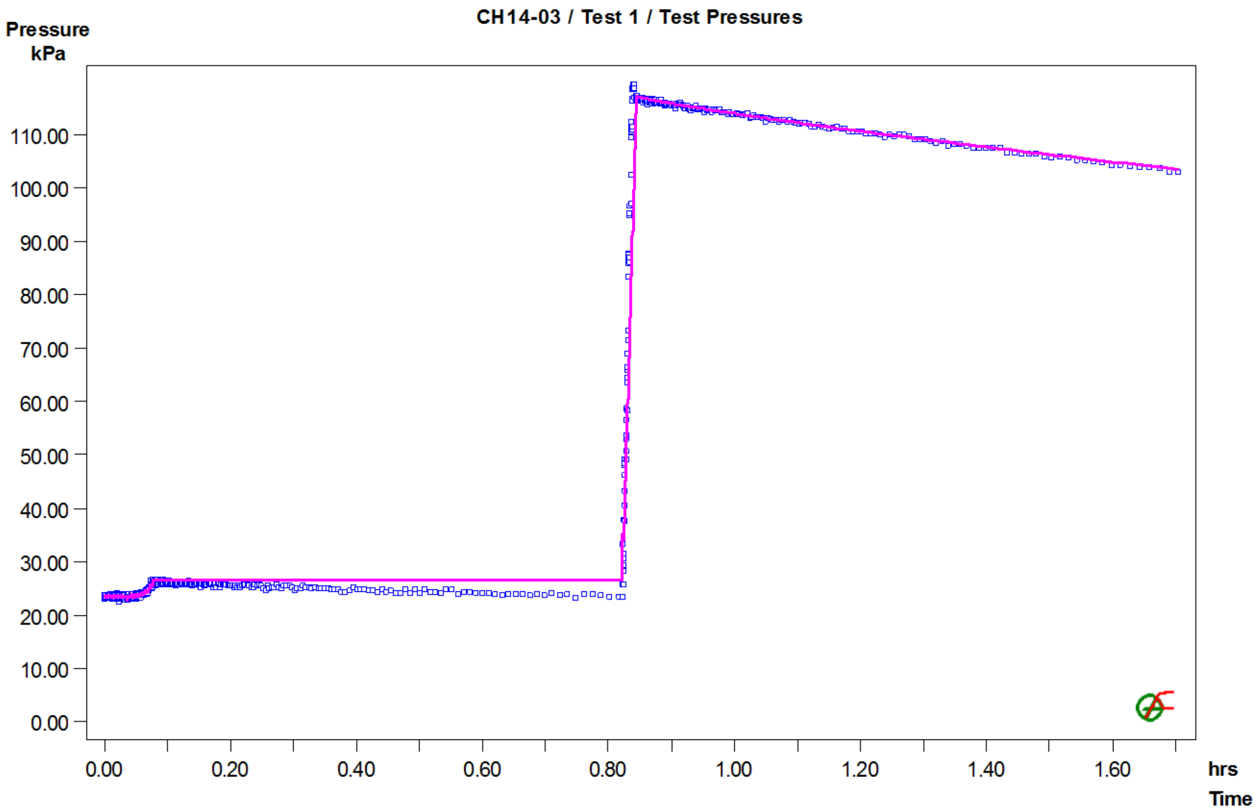


Figure 2: Pressure response (blue) and simulation (pink) cartesian plot

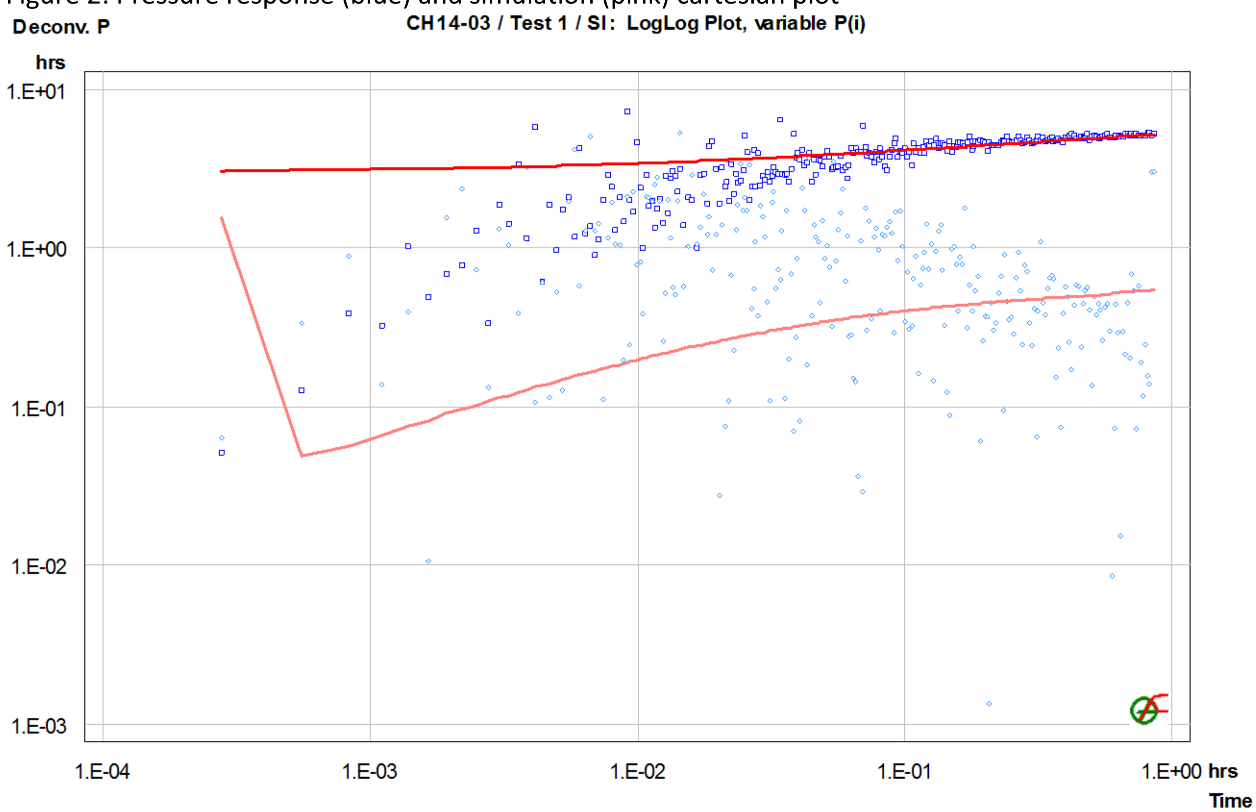


Figure 3: Deconvolved pressure response (dark blue), derivative (light blue) and simulation (red): Log-Log diagnostic plot, SI sequence

HYDROBENCH REPORT

Project	CITY OF NANAIMO
Site	NANAIMO COLLIERY DAMS
Source Well	CH14-02
Test Name	Test 1
Test Date/Time	
Interval	top: 6.10 m bottom: 20.00 m
Description	

Basic Data

Test Interval	13.90 m		
Porosity	0.10		
Well Radius	0.061 m	Tubing Radius	0.016 m
Inclination	0.0 deg		
Test Volume	162.489 l		
Well Type	Source		

Fluid Properties

Viscosity	0.001 Pa*s
Density	1000.0 kg/m³
Compressibility	2.0e-09 1/Pa

Sequence Definition

Name	Category	t(o) [hrs]	P(o) [kPa]	P(i) [kPa]	Rate [l/min]	C [m³/Pa]
INF	Variable Pressure	0.00000	41.91			8.2e-08
SI-Init-1	dP-Event	0.71583	41.21	-32.9 *		8.2e-08
SI-1	Slug	0.76194	74.11	41.2		8.2e-08
PSR-2	Recovery	0.96639	45.36			8.2e-08
SW-Init-2	dP-Event	1.04889	44.23	-29.2 *		8.2e-08
SI-2	Slug	1.06667	73.40	44.2		8.2e-08

Analysis Results

Analysis "SI-2 2 shell Final"

Static Pressure: 40.92 kPa

Shell Parameters:

Name	Transmissivity [m²/s]	Storativity [-]	Radius [m]	Flow Dimension [-]
Shell 1	8.8e-06	2.7e-05	4.64	2.0
Shell 2	1.5e-06	2.7e-05	- -	2.0

Sequence Parameters:

Name	Wellbore Storage [m³/Pa]	Skin [-]
INF	6.6e-12	0.0
SI-Init-1	8.2e-08	0.0
SI-1	8.2e-08	0.0
PSR-2	6.6e-12	0.0
SW-Init-2	8.2e-08	0.0
SI-2	8.2e-08	0.0

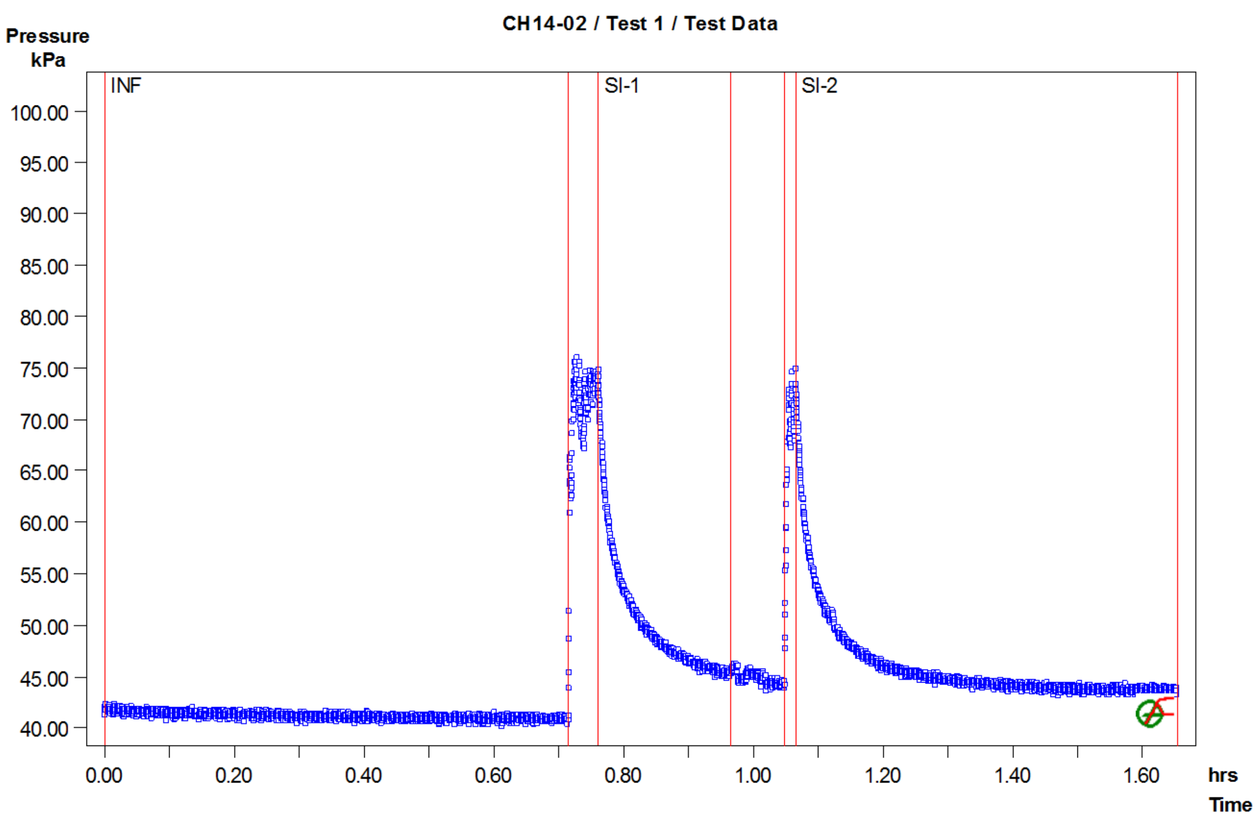


Figure 1: Pressure response and sequence definition

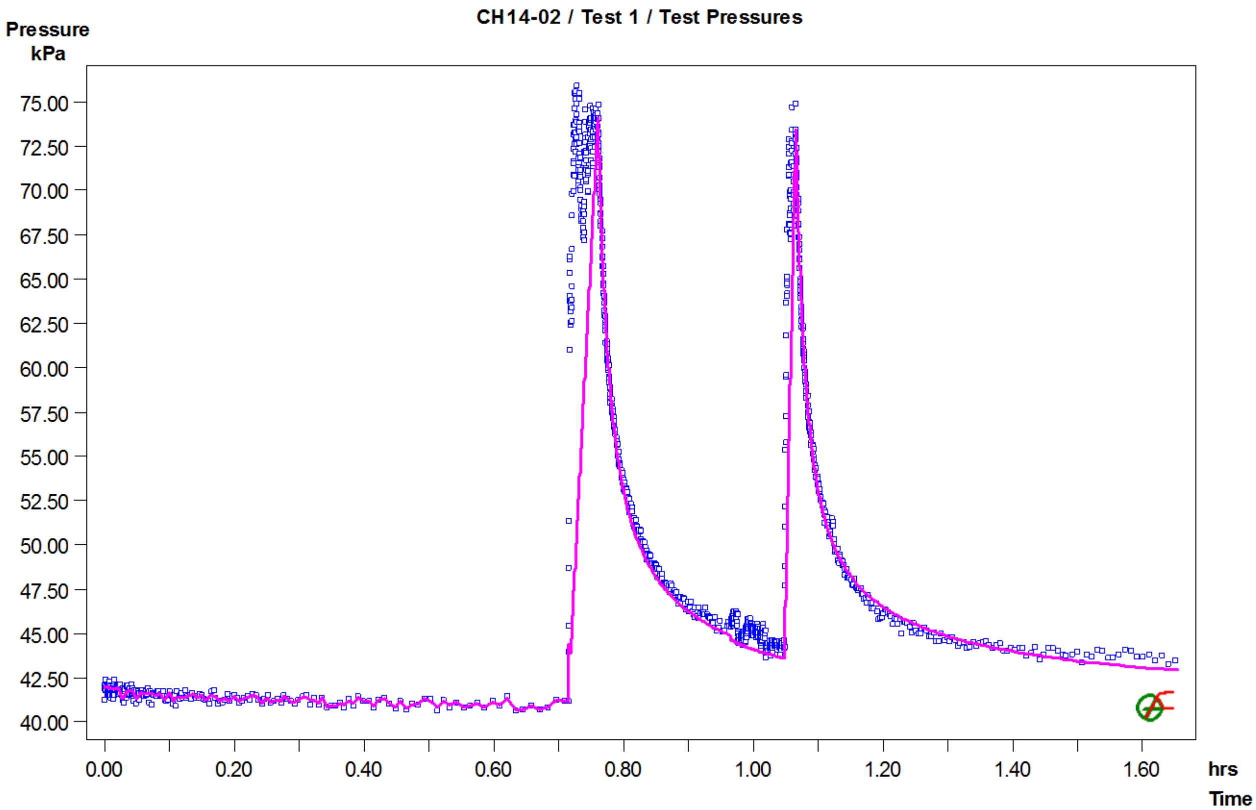


Figure 2: Pressure response (blue) and simulation (pink) cartesian plot

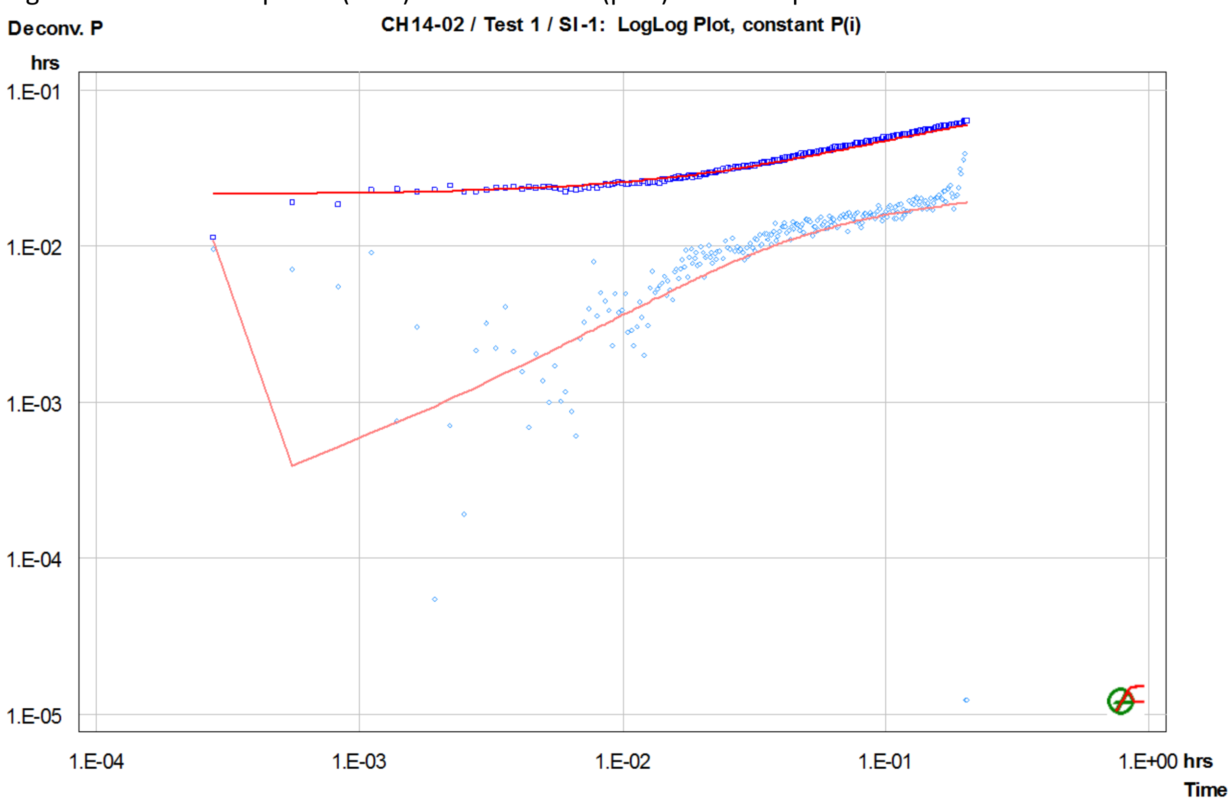


Figure 3: Deconvolved pressure response (dark blue), derivative (light blue) and simulation (red): Log-Log diagnostic plot, SI sequence

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