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LYALL HARBOUR BOOT COVE WATER LOCAL SERVICE COMMITTEE

Notice of Meeting on **Friday, November 18, 2016 at 1:30 pm**
Capital Regional District Headquarters
625 Fisgard Street, Room 107

Dan Thachuk (Chair)
John Money
Director Dave Howe
Ian Rowe
Ron Lewis
Michael Fry

AGENDA

1. Approval of Agenda
2. Adoption of Minutes of September 25, 2015
3. 2017 Operating and Capital Budget (staff report)
4. Draft Strategic Asset Management Plan for Lyall Harbour Boot Cove Water System (staff report)
5. Money Lake Dam No. 1 – Soil Investigation and Seismic Stability Assessment (staff report)
6. New Business
7. Adjournment

To ensure quorum, advise Lorrie Siemens 250.360.3087 if you cannot attend.

Minutes of a Meeting of the Lyall Harbour/Boot Cove Water Local Service Committee Held September 25, 2015 at Capital Regional District Headquarters, 625 Fisgard Street, Victoria, BC

PRESENT: **Committee Members**: D. Thachuk (Chair), R. Lewis, I Rowe, J. Money, D. Howe, Souther Gulf Islands Regional Director
Staff: M. Cowley, Senior Manager, Infrastructure Engineering and Operations; D. Robson, Manager Saanich Peninsula and Gulf Islands Operations, S. Mason, Manager, Water Engineering and Planning, P. Dayton, Senior Financial Analyst, L. Siemens (recorder)

ABSENT: M. Fry

The meeting was called to order at 10:30 am.

1. Approval of Agenda

MOVED by J. Money, **SECONDED** by I. Rowe,
That the agenda be approved as distributed.

CARRIED

2. Adoption of Minutes of November 7, 2014

MOVED by R. Lewis, **SECONDED** by J. Money,
That the minutes of November 7, 2014 be adopted as distributed.

CARRIED

3. Draft Operation, Maintenance and Survellance Plan and Emergency Preparedness Plan Document Update

S. Mason provided a verbal report and distributed draft copies of the Lyall Harbour Money Lake No. 1 Operations, Maintenance and Survellance Plan and Emergency Preparedness Plan. Initial comments from the committee included adding emergency notification procedures to key on-island stakeholders (i.e. Fire Department). The committee was requested to review the document and provide comments and any information to staff.

MOVED by J. Money, **SECONDED** by R. Lewis,
That the Lyall Harbour Boot Cove Water Local Service Committee receive the Lyall Harbour Money Lake No. 1 Operations and Survellance Plan and Emergency Preparedness Plan for information and that the committee provide comments and any information to staff by November 15, 2015.

CARRIED

4. 2016 Operating and Capital Budget

M. Cowley presented a written report and the 2016 Operating and Capital budget documents.

Chair Thachuk was provided with a copy of the October 15, 2014 Electoral Area Services Committee (EASC) meeting staff report entitled "Community Works Fund (CWF) Allocation: Lyall Harbour Boot Cove Water System – Capital Works"

The staff report was approved by the EASC and committed contributions up to $112,000 from the SGI-CWF to cover 50% of water system improvements. The current list of capital projects (from 2015 to 2019) as presented in the 2015 budget totalled $202,500 of which $101,250 is funded from the CWF.

Therefore, since only $101,250 of the $112,000 is committed from the community works fund, the committee requested that $10,000 of surplus CWF be allocated towards the 2016 capital project "Dam Safety Improvements".

MOVED by D. Thachuk, **SECONDED** by R. Lewis,
That the Lyall Harbour Boot Cove Water Local Service Committee:

1. Approve the 2016 operating and capital budget for the Lyall Harbour Boot Cove Water Service subject to CRD Finance approval that the 2016 capital project "Dam Safety Improvements" can be funded by $10,000 from the capital reserve fund and $30,000 from the SGI Community Works Fund;
2. Approve the 2016 Parcel Tax of $654.18 and User Charge of $528.24 for the Lyall Harbour Boot Cove Water Service; and
3. Balance the 2015 actual revenue and expense on the 2015 transfer to capital reserve fund.

CARRIED

5. New Business

Staff updated the committee on 2015 projects.

It was noted that scope for "Re-caulk Spillway Joint" had more than doubled from 24 lineal feet to 54 lineal feet once it had been cleaned and assessed. Therefore, the budget for this work needs to increase from $2,000 to $4,000. However, it was noted that two other projects (Filter Building Roof Replacement and draft OMS/EPP Manual) will be under budget by about $2,000.

The committee approved increasing the budget for Re-Caulk spillway Joint as long as the overall budget for all projects remains the same.

6. Adjournment

The meeting was adjourned at 12:20 pm.

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REPORT TO LYALL HARBOUR / BOOT COVE WATER LOCAL SERVICE COMMITTEE
MEETING OF FRIDAY, NOVEMBER 18, 2016

SUBJECT **2017 OPERATING AND CAPITAL BUDGET**

ISSUE

This report provides a synopsis of the 2017 operating and capital budget, highlighting significant proposed changes related to operational expenditures, debt charges, capital expenditures and revenue for the Lyall Harbour/Boot Cove Water Service.

In accordance with the establishment Bylaw No. 1875, the Lyall Harbour / Boot Cove Water Local Services Committee shall: *"Upon its establishment, and on or before December of each year, the Committee shall approve an annual budget for the services provided in the local service area which shall include estimates for the administrative, development, maintenance, operational and other expenses, including debt charges, and shall submit such expenditure estimates, together with estimates for expected revenue, to the Treasurer of the Regional Board for the approval of the Regional Board and for inclusion in the Regional Board's provisional and annual budgets."*

BACKGROUND

2016 Estimated Actual Revenue and Expense

The estimated actual operating expense is projected to be **$2,050** over budget as a result of:

- Lower than budgeted expenditures for:
  - Repairs and maintenance ($1,800)
- Higher than budgeted expenditures for:
  - Supplies ($1,730)
  - Labour charges ($1,460)
  - Other operating expenses ($660).

The estimated actual revenue is project to be $50 below budget as a result of lower than expected interest income.

This results in a projected net expense (deficit) of $2,100. Therefore, it is proposed that the planned 2016 transfer of $14,990 to the Capital Reserve Fund be reduced by this amount to $12,890 in order to balance the budget.

2017 Operating Expense

An increase in the 2017 operating expense of $2,700 (2.0%) is proposed.
This is the result of:

- Increase in:
    - Repairs & maintenance ($60)
    - Allocations ($6900)
        - Overhead charges related to vehicles were previously accounted for in the labour charge-out rate. Vehicle costs are now removed from the labour rate and are now tracked and charged under a vehicle allocation
    - Water Testing ($140)
    - Electricity ($70)
    - Supplies ($30)
    - Other Operating Expenses ($100)
- Decrease in:
    - Labour Charges ($4,600)
        - The labour charge-out rate in previous budgets included overhead charges related to vehicles. Vehicle overhead costs are now removed from the labour charge-out rate and are now tracked separately as a "vehicle allocation"

2017 Debt/Reserves

Maintenance Reserve:

The maintenance reserve is to be used for the purchase of equipment and supplies that are typically not replaced annually such as filter media, ultraviolet lamps and sensors and ozone system maintenance activities. Additionally, the reserve could be used for unplanned significant repairs.

It is proposed that transfers to the maintenance reserve of $1,500 remain at the 2016 amount. The maintenance reserve balance at the end of 2016 is projected to be $5,000.

Capital Funds on Hand (WSV185101)

There is a net amount of $70,509 in funding and interest for capital projects in progress, as shown in Table 1 below. After the projects are closed there may be funds remaining which could be transferred to the Capital Reserve Fund (CRF). This will be outlined in a future years' budget report following project closure.

Table 1: Summary of Capital Projects History

	Budget	Funding	Spent	Remaining	Tsfr to CRF
Dam Safety Improvements	56,000	56,000	(12,805)	43,195	-
SAMP Study	20,000	20,000	(1,339)	18,661	-
Equipment Infrastructure	18,000	18,000	(13,469)	4,531	-
Safety Equipment	2,000	2,000	(955)	1,045	-
Relocate shed to Upper TP	1,000	1,000	(103)	897	-
Interest	-	-	-	2,180	-
Total WSV185101	**97,000**	**97,000**	**(28,671)**	**70,509**	**-**

Capital Reserve Fund (1025):

It is proposed that $19,650 be transferred to the Capital Reserve Fund for anticipated future capital replacement projects.

The capital reserve fund balance at the end of 2016 is projected to be $82,350.

Municipal Finance Authority (MFA) Debt:

MFA debt servicing costs are incurred on debt of $250,000 issued in 2009 at 4.13% interest and $180,000 issued in 2010 at 4.50% interest. The annual debt servicing cost of $39,900 will remain unchanged in 2017.

2017 Revenue (User Charge and Parcel Tax)

It is proposed that:

- The user charge revenue be increased from $83,990 to $85,670; based on 160 Single Family Equivalents (SFE) this equates to $535.34/SFE or $7.20 over the 2016 amount.
- Other revenue (e.g. late payment penalties) remains at $190.
- The parcel tax be increased to $110,310 or $2,160 over the 2016 amount of $108,150 based on 173 taxable folios and including the 5.25% surveyor of taxes' fee (a handling fee charged by the Province for collecting taxes) this equates to $671.11/taxable folio, an increase of $16.92.

Capital Project Plan

Previous Capital Project Status:

As noted above, several capital projects were approved for 2016, which are indicated as follows with a summary of project status:

1. Dam Safety Improvements ($40,000) – the simple seismic stability assessment was conducted by Tetra Tech EBA consulting in the late summer and early fall and the findings were presented to the Committee (separate staff report).
2. Equipment Infrastructure Replacement ($5,000) - Phase 1 of the air release valve replacement was completed.
3. Safety Equipment ($2,000) – the additional eye wash safety equipment was installed.
4. Relocate Shed to Upper Plant ($1,000) – Schedule revised to be completed by the end of November 2017. Final location to be reviewed with property owner and work to be coordinated with other projects.
5. Re-Caulking Spillway Joints – the re-caulking of the spillway joints at Money Lake Dam #1 was completed.

It is proposed to complete the previously identified projects and include new projects for future years as noted (a brief description of each project is included in the budget documents).

2017 Capital Budget (totaling $99,000)

17-01 Dam Safety Improvements – Toe Drain Phase 1 ($45,000)
17-02 Paint Recirculation Pipe and Ancillary Work ($2,000)

17-03 NEW - Gillilan Lane Isolation Valve ($7,000)
17-04 NEW – Money Lake Dam #1 Remediation Preliminary Design ($40,000)
17-05 NEW – Pre-Treatment Assessment (Ozone) ($5,000)

2018 Capital Budget (totaling $47,000)

18-01 Dam Safety Improvements – Toe Drain Phase 2 ($45,000)
18-02 Cover Recirculation Pipe ($2,000)

2019 Capital Budget (totaling $36,000)

Equipment Infrastructure Replacement:
19-01 i) Phase 2 - Air valve replacement - The air valves are 35 years old and are corroded, giving rise to safety concerns ($20,000).
19-02 ii) Phase 2 - Isolation Valve/Bypasses for PRV Stations ($8,000).
19-03 iii) Standpipe & valve replacement ($8,000).

2020 Capital Budget (totaling $7,000)

20-01 Chlorine Injection Pump ($7,000)
Install an additional chlorine injection pump and related control equipment to address dosing requirements related to fluctuating water demands.

2021 Capital Budget (totaling $15,000)

21-01 Source water reliability study ($15,000)

RECOMMENDATION

That the Lyall Harbour / Boot Cove Water Local Service Committee recommend that the Capital Regional District Board:

1. Approve the 2017 operating and capital budget for the Lyall Harbour / Boot Cove Water Service as presented;

2. Approve the 2017 Parcel Tax of $671.11 and User Charge of $535.34 for the Lyall Harbour / Boot Cove Water Service; and

3. Balance the 2016 actual revenue and expense on the 2016 transfer to capital reserve fund.

M. Jesney

Ian Jesney, P.Eng.
Sr. Manager, Infrastructure Engineering
Integrated Water Services

Matthew McCrank, MSc., P.Eng.
Sr. Manager, Infrastructure Operations
Integrated Water Services

Amber Genero, MA, CPA, CMA
A/Manager Financial Planning & Analysis

Ted Robbins, B.Sc., C. Tech
General Manager, Integrated Water Services
Concurrence

PD/DR/SM:ls
Attachment: 1

CAPITAL REGIONAL DISTRICT

2017 Budget

Lyall Harbour Boot Cove Water (Saturna)

Committee Review

Compiled and Presented by CRD Finance

Oct 2016

Service: **2.640 Lyall Harbour Boot Cove Water (Saturna)** **Committee: Electoral Area Services**

DEFINITION:

To provide and operate and maintain a domestic water supply and distribution system for the Saturna Island Water Supply and Distribution System Specified Area in the Lyall Harbour/Boot Cove district on Saturna Island. Bylaw No. 513 (November 22, 1978).

PARTICIPATION:

Specified Area #14 - G(764)

MAXIMUM LEVY: Greater of $150,000 or $6.90 / $1,000 of actual assessed value of land and improvements, to a maximum of $337,010.

MAXIMUM CAPITAL DEBT:

AUTHORIZED:	LA Bylaw No. 3587 (Jan 14, 2009)	$430,000
BORROWED:	SI Bylaw 3634 (Aug 12, 2009)	$250,000
BORROWED:	SI Bylaw 3677 (Feb 10, 2010)	$180,000
REMAINING:		$0

COMMITTEE:

Lyall Harbour/Boot Cove Water Committee established by Resolution - September 29, 1982
Lyall Harbour/Boot Cove Water Local Services Committee established by Bylaw No. 1875 (December 12, 1990)

FUNDING:

Any deficiencies after user charge and/or frontage tax or parcel tax to be levied on taxable school assessments, excluding property that is taxable for school purposes by Special Act.

User Charge:	Annual charge per single family equivalency unit connected to the system.
Parcel Tax:	Annual charge levied only on properties capable of being connected to the system.
Connection Charges:	Actual Cost + 15% Admin Fee (Minimum Connection $400 Bylaw No. 2137, April 28, 1993).

RESERVE FUND:

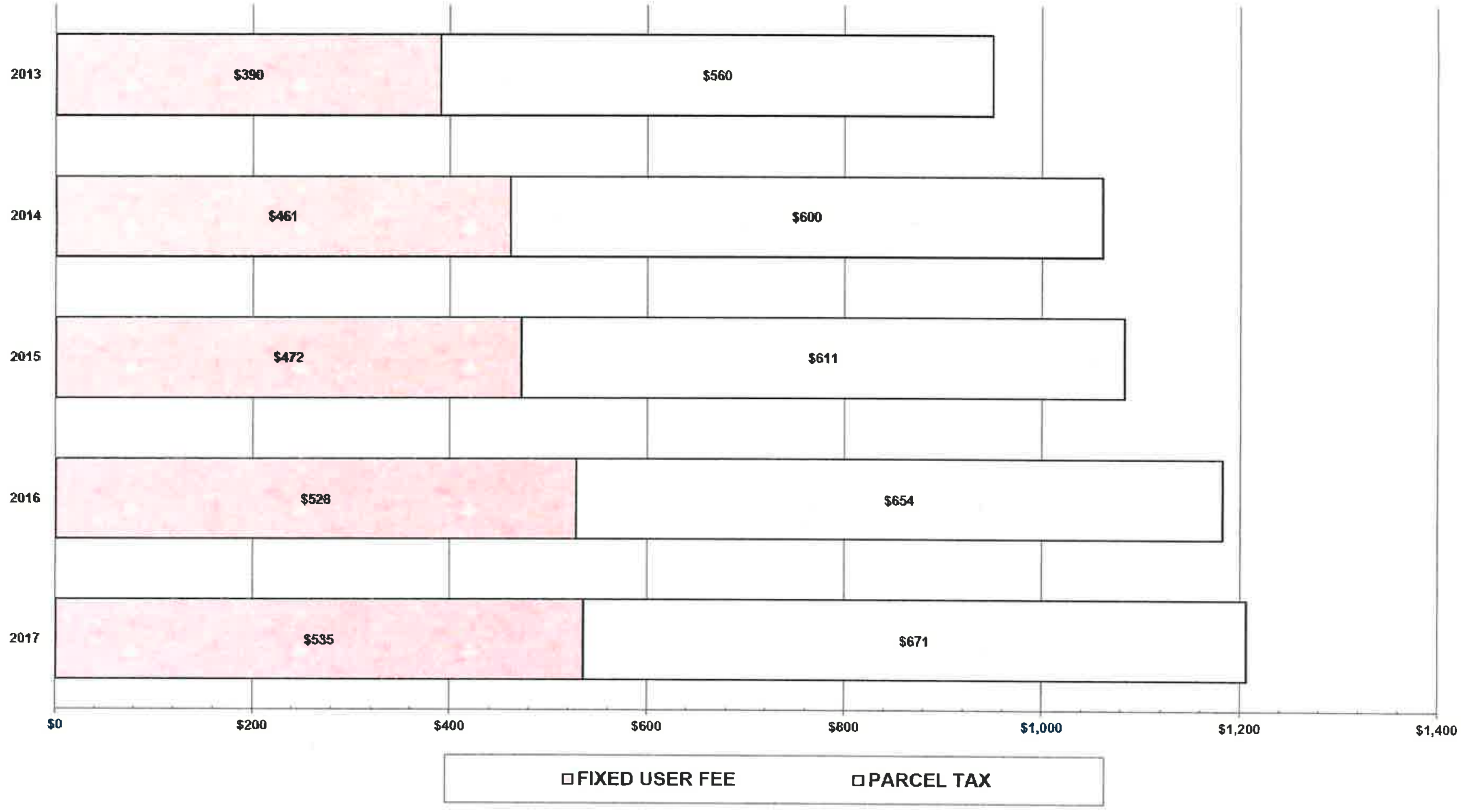
Bylaw No. 1785 (February 14, 1990)

Lyall Harbour Boot Cove Water (Saturna)	2016 BOARD BUDGET	2016 ESTIMATED ACTUAL	BUDGET REQUEST 2017 CORE BUDGET	2017 ONGOING	2017 ONE-TIME	2017 TOTAL	FUTURE PROJECTIONS 2018	2019	2020	2021
OPERATING COSTS:										
Repairs & Maintenance	4,800	3,000	4,860	-	-	4,860	4,960	5,060	5,160	5,260
Allocations	11,260	11,260	18,160	-	-	18,160	18,530	18,900	19,270	19,660
Water Testing	6,240	6,240	6,380	-	-	6,380	6,510	6,640	6,770	6,910
Electricity	4,560	4,560	4,630	-	-	4,630	4,720	4,810	4,910	5,010
Supplies	3,420	5,150	3,450	-	-	3,450	3,520	3,590	3,660	3,730
Labour Charges	92,830	94,290	88,230	-	-	88,230	89,990	91,790	93,630	95,500
Contingency	-	-	-	-	-	-	-	-	-	-
Other Operating Expenses	9,310	9,970	9,410	-	-	9,410	9,590	9,780	9,970	10,160
TOTAL OPERATING COSTS	**132,420**	**134,470**	**135,120**	-	-	**135,120**	**137,820**	**140,570**	**143,370**	**146,230**
*Percentage Increase over prior year			2.0%			2.0%	2.0%	2.0%	2.0%	2.0%
DEBT/RESERVES										
Transfer to Maintenance Reserve	1,500	1,500	1,500	-	-	1,500	1,530	1,560	1,590	1,620
Transfer to Capital Reserve Fund	14,990	12,890	19,650	-	-	19,650	16,970	14,190	11,360	8,480
MFA Debt Principal	21,470	21,470	21,470	-	-	21,470	21,470	21,470	21,470	21,470
MFA Debt Interest	18,430	18,430	18,430	-	-	18,430	18,430	18,430	18,430	18,430
TOTAL DEBT / RESERVES	**56,390**	**54,290**	**61,050**	-	-	**61,050**	**58,400**	**55,650**	**52,850**	**50,000**
Deficit	-	-	-	-	-	-	-	-	-	-
TOTAL COSTS	**188,810**	**188,760**	**196,170**	-	-	**196,170**	**196,220**	**196,220**	**196,220**	**196,230**
FUNDING SOURCES (REVENUE)										
Estimated balance c/fwd to from 2016 to 2017	-	-	-	-	-	-	-	-	-	-
Balance c/fwd from 2015 to 2016	3,520	3,520	-	-	-	-	-	-	-	-
Connection Charges	-	-	-	-	-	-	-	-	-	-
User Charges	(83,990)	(83,990)	(85,670)	-	-	(85,670)	(85,670)	(85,670)	(85,670)	(85,670)
Grants in Lieu	-	-	-	-	-	-	-	-	-	-
Other Revenue	(190)	(140)	(190)	-	-	(190)	(190)	(190)	(190)	(190)
TOTAL REVENUE	**(80,660)**	**(80,610)**	**(85,860)**	-	-	**(85,860)**	**(85,860)**	**(85,860)**	**(85,860)**	**(85,860)**
REQUISITION - PARCEL TAX	**(108,150)**	**(108,150)**	**(110,310)**	-	-	**(110,310)**	**(110,360)**	**(110,360)**	**(110,360)**	**(110,370)**
*Percentage increase over prior year										
User Charges			2.0%			2.0%	0.0%	0.0%	0.0%	0.0%
Requisition			2.0%			2.0%	0.0%	0.0%	0.0%	0.0%
Combined			2.0%			2.0%	0.0%	0.0%	0.0%	0.0%

Service: 2.640 Lyall Harbour Boot Cove Water (Saturna) Committee: Electoral Area Services

Year	Taxable Folios	Parcel Tax	SFE's	User Charge	Tax & Charges	Bylaw	Assessments $(000's)
2011	170	$560.00	158	$325.00	$885.00	3799	57,270
2012	171	$560.00	159	$375.00	$935.00	3823	56,059
2013	171	$560.00	159	$390.31	$950.31	3892	55,690
2014	171	$600.00	159	$461.14	$1,061.14	3924	50,582
2015	171	$611.11	159	$472.48	$1,083.59	3987	48,842
2016	174	$654.18	159	$528.24	$1,182.42	4074	48,842
2017	173	$671.11	160	$535.44	$1,206.54		

CAPITAL REGIONAL DISTRICT
LYALL HARBOUR / BOOT COVE (SATURNA) WATER
FUNDING ANALYSIS
2013-2017



Actual Costs 2013-2016, Projected 2017
Prepared by CRD Finance
10/20/2016

CAPITAL REGIONAL DISTRICT CAPITAL PLAN

CAPITAL BUDGET FORM
2017 & Forecast 2018 to 2021

Service #: 2.640
Service Name: Lyall Harbour Boot Cove Water (Saturna)

By Capital Expenditure											
No.	Project Code	Capital Project Description	Asset Class	Funding Source	Carry Forward	2017	2018	2019	2020	2021	Total Project Budget
13-01	Renewal	Strategic Asset Management Plan	E	Grant	15,000			-	-	-	20,000
16-01	Renewal	Dam Safety Improvements - Money Lake Dam No. 1 Soil Investigation	E	Res	2,500			-	-	-	40,000
				Grant	2,500						
17-01	Renewal	Dam Safety Improvements - Toe Berm - Ph 1	E	Res	-	22,500	-	-	-	-	45,000
				Grant		22,500					
17-02	Renewal	Paint Recirc Pipe and Ancillary Work	E	Res		2,000					2,000
17-03	New	Gillilan Lane Isolation Valve	E	Res		7,000					7,000
17-04	Renewal	Dam Safety Improvements-Seismic Design	E	Res		40,000					
17-05	New	Pre-treatment assessment	E	Res		5,000					
18-01	Renewal	Dam Safety Improvements - Toe Berm - Ph 2	E	Res			22,500				45,000
				Grant			22,500				
18-02	Renewal	Cover Recirc Pipe	E	Res			2,000				2,000
19-01	Replacement	Air Valve Replacement - Ph 2	Eq	Res				3,500			20,000
				Grant				16,500			
19-02	Replacement	PRV Bypass Assembly Replacement	E	Res				8,000			8,000
19-03	Replacement	Standpipe and Valve Replacement	Eq	Res				8,000			5,000
20-01	Replacement	Chlorine Injection Pump	Eq	Res					7,000		3,000
21-01	Replacement	Source Water Reliability Study	E	Res	-	-	-	-	-	15,000	15,000
		TOTAL ANNUAL CAPITAL EXPENDITURE			20,000	99,000	47,000	36,000	7,000	15,000	212,000

Funding Source Codes	
Debt	= Debenture Debt (new debt only)
ERF	= Equipment Replacement Fund
Grant	= Grants (Federal, Provincial)
Cap	= Capital Funds on Hand
Other	= Donations / Third Party Funding
Res	= Reserve Fund
STLoan	= Short Term Loans

Asset Class	
L	- Land
E	- Engineering Structure
B	- Buildings
V	- Vehicles
Eq	- Equipment

Capital Expenditure Type	
New	Expenditure for new asset only
Renewal	Expenditure replaces an existing asset and extends the service ability or enhances technology in delivering that service
Replacement	Expenditure replaces an existing asset

Service: 2.640 Lyall Harbour Boot Cove Water (Saturna) Committee: Electoral Area Services

13-01 Strategic Asset Management Plan ($15,000 Carry Forward)

The Strategic Asset Management Plan will recommend a prioritized list of infrastructure replacements, which will serve as the basis for future capital spending plans.

16-01 Dam Safety Improvements - Money Lake Dam No. 1 Soil Investigation ($5,000 Carry Forward)

The 2012 Dam Safety Review recommended a number of improvements, which have been spread out over several years. This project includes a geotechnical investigation, simple seismic stability assessment, piezometers installatino and soils collection for the toe drain design.)

17-01 Dam Safety Improvements - Toe Berm Phase 1 ($45,000 in 2017)

The 2012 Dam Safety Review recommended a number of improvements, which have been spread out over several years. This project includes Phase 1 of installation of a gravel toe berm on the downstream side of the dam.

17-02 Paint Recirculation Pipe and Ancillary Work ($2,000 in 2017)

The existing recirculation pipe and ancillary structures located on private property must be revised to blend in with the natural environment. This includes painting of the exposed sections of the recirculation pipe, revising marker stakes and valve coverings and protection of an existing culvert.

17-03 Gilliland Lane Isolation Valve ($7,000 in 2017)

An additional line valve needs to be installed at the Gilliland Lane valve cluster to provide additional flexibility for system maintenance.

17-04 Dam Safety Improvements Seismic Preliminary Design ($40,000 in 2017)

As a result of the soil investigation and seismic stability assessment completed in 2016, the consultant recommended that remedial work be completed to meet the Canadian Dam Safety Guideline. The next step in the process would be to complete a preliminary design study and the results of that study would include refined cost estimates and scope of work. This was detailed in a separate staff report for the Committee's consideration

17-05 Pre-Treatment Assessment (Ozone) ($5,000 in 2017)
The existing ozone units for pre-treatment have been onerous to operate since they were installed and commissioned in 2013 and they pose health and safety issues. It is proposed to assess the existing unit performance, need and identify alternative options for pre-treatment/oxidation.

18-01 Dam Safety Improvements - Toe Berm Phase 2 ($45,000 in 2018)

The 2012 Dam Safety Review recommended a number of improvements, which have been spread out over several years. This project includes Phase 2 of installation of a gravel toe berm on the downstream side of the dam.

18-02 Cover Recirculation Pipe ($2,000 in 2018)

Cover sections of the existing recirculation pipe that are not painted to provide UV protection from the sun. It is proposed to undertake work in conjunction with 2017/2018 dam safety work (placement of surplus material excavated from toe drain installation project).

19-01 Air Valve Replacement Ph 2 ($20,000 in 2019)

The air valves are 35 years old and are corroded, giving rise to safety concerns.

19-02 PRV Bypass Assembly Replacement ($8,000 in 2019)

The inlet and outlet piping at the East Point, Narvaez and Boot Cove PRV stations is very corroded and there is no way to isolate the stations to replace or maintain the pressure reducing valves. It is proposed that new inlet and outlet piping be installed with 100mm gate valves and bypass piping so that customers are not without water when PRV's are being serviced.

19-03 Standpipe and Valve Replacement (**$8,000** in 2019)

The standpipe valves at 119 and 155 East Point Road are seized and inoperable. Therefore, the operators cannot use them for flushing or draining of the mains. It is proposed that the valves and the corroded 50mm supply line to the standpipe be replaced. **The scope of work and material pricing was re-evaluated. It was determined that the budget needed to be increased form $5,000 to $8,000 to accommodate the required**

20-01 Chlorine Injection Pump ($7,000 in 2020)

Install an additional chlorine injection pump to address dosing requirements related to fluctuating water demands.

21-01 Source Water Vulnerability Study (15,000 in 2021)

Study to determine the medium to long term vulnerability of the source water (Money Lake) and its viability as a water source (quantity and quality) for the LHBC system in light of pressures such as projected demand changes and climate change.

Reserve Schedule

Reserve Fund: 2.640 Lyall Harbour Boot Cove Water (Saturna) Capital Reserve Fund - Bylaw 1785

Reserve Cash Flow

Fund: 1025 Fund Center: 101369	Estimate	Budget				
	2016	2017	2018	2019	2020	2021
Beginning Balance	105,876	82,349	25,499	17,969	12,659	17,019
Transfer to Cap Fund	(25,500)	(76,500)	(24,500)	(19,500)	(7,000)	(15,000)
Transfer from Operating Budget		19,650	16,970	14,190	11,360	8,480
		-	-	-	-	-
Transfer from Cap Fund	1,973	-	-	-	-	-
Interest Income*		-	-	-	-	-
Ending Balance $	**82,349**	**25,499**	**17,969**	**12,659**	**17,019**	**10,499**

<u>Assumptions/Background:</u>

To fully fund capital expenditure plan

* Interest should be included in determining the estimated ending balance for the current year. Interest in planning years nets against inflation which is not included.

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REPORT TO LYALL HARBOUR / BOOT COVE WATER LOCAL SERVICE COMMITTEE MEETING OF FRIDAY, NOVEMBER 18, 2016

SUBJECT **DRAFT STRATEGIC ASSET MANAGEMENT PLAN FOR LYALL HARBOUR BOOT COVE WATER SYSTEM**

ISSUE

To provide the Lyall Harbour Boot Cove Water Local Service Committee (Committee) with a draft copy of the Strategic Asset Management Plan (SAMP) for the Lyall Harbour / Boot Cove water system.

BACKGROUND

The Committee requested that the Capital Regional District (CRD) staff complete a SAMP to ensure that the water system can continue to deliver safe and reliable drinking water for the community in a sustainable manner well into the future.

The scope of the SAMP was to identify the system's assets, age, condition and approximate life expectancy. In addition, the SAMP identifies regulatory requirements, level-of-service expectations, design capacities and approximate costs required to renew or replace infrastructure in the future. Finally, based on a future capital plan, a long-term financial plan has been prepared with the intent of predicting annual costs to the service in order to maintain a reliable and well-functioning system in a responsible manner.

In general, the water system performs well, and has sufficient capacity to provide service to the entire 100 hectare service area (with 173 parcels).

The proposed short-term (0-5 years) upgrades can be funded from the Capital Reserve Fund (with no additional increases to the users). However, some infrastructure is nearing 40 years old and will need to be renewed or replaced in the mid-to-long-term. It is expected that loans will be required to fund some of the larger scope capital projects. However, the exact timing, extent and cost of future replacement projects are highly dependent on level of service/risk tolerance, and market conditions.

The current financial status of the Maintenance Reserve, Capital Reserve Fund, and the proposed 5-year Capital Plan are included in the Finance package as part of the 2017 Operating and Capital Budget. It is suggested that the Committee review the attached SAMP and then a workshop be held in the near future to review it in detail and adjust as required to balance future work with annual costs. Any major future capital improvements may utilize the capital reserve fund solely or in combination with an increase in parcel tax and/or supplementary funding opportunities from grants.

ALTERNATIVES

Alternative 1

That the Lyall Harbour Boot Cove Water Local Service Committee receive this report and draft Strategic Asset Management Plan (SAMP) and provide comments back to CRD staff so that the

SAMP can be finalized by December 31, 2016.

Alternative 2

That the Lyall Harbour Boot Cove Water Local Service Committee requests staff for additional information which can be provided at a subsequent meeting.

IMPLICATIONS

Alternative 1 – By receiving this report and providing comments back to CRD staff, the SAMP can be finalized by year end and the proposed Financial Plan in the SAMP can be implemented in 2017.

Alternative 2 – By requesting CRD staff to provide additional information, will delay the finalization of the SAMP and postpone implementation of the Financial Plan.

CONCLUSION

A draft Strategic Asset Management Plan has been prepared for the Lyall Harbour Boot Cove Water Local Service Committee and overall the water system performs well, however the some improvements are proposed over the next 20 years to improve and maintain the water service.

RECOMMENDATION

That the Lyall Harbour Boot Cove Water Local Service Committee receive this report and draft Strategic Asset Management Plan (SAMP) and provide comments back to CRD staff so that the SAMP can be finalized by December 31, 2016.

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MC:ls
Attachments: 1

CRD

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REPORT TO LYALL HARBOUR/BOOT COVE WATER LOCAL SERVICE COMMITTEE MEETING OF FRIDAY, NOVEMBER 18, 2016

SUBJECT **MONEY LAKE DAM NO.1 – SOIL INVESTIGATION AND SEISMIC STABILITY ASSESSMENT**

ISSUE

To investigate the soil conditions and assess the seismic stability of the existing Money Lake Dam No.1

BACKGROUND

The last report related to dam safety improvements at Money Lake Dam No.1 (the Dam) was presented to the Lyall Harbour Boot Cove Water Local Service Committee (Committee) on November 7, 2014. The report summarized the results of the Dam Safety Review (DSR) that was completed by Tetra Tech EBA (TTEBA) in 2011. TTEBA submitted the final 2011 DSR report in April 2012 and provided a list of recommendations for actions in order to the meet the requirements of the British Columbia Dam Safety Regulation (Regulation) of the Water Act, as well as Canadian Dam Association (CDA) Dam Safety Guidelines (2013 Edition). This report specifically provides an update on progress and results related to the recommendation to complete a *Soils Investigation and Seismic Stability Assessment* (SI&SSA) study at the Dam.

As of February 2016, the Water Act has been replaced by the Water Sustainability Act. The Regulation has also been updated under the new Act. For the purpose of this report, the requirements under the Regulation for dam owners remain mostly the same as those documented in the previous November 7, 2014 committee report.

TTEBA noted in the 2011 DSR report that there is little information regarding the dam embankment materials of the foundation and recommended completing a SI&SSA study. The investigation would include a drilling program that would be conducted to obtain soils information for a simple seismic analysis. During drilling, TTEBA recommended that piezometers be installed to monitor the groundwater level within the dam in the future, which is consistent with CDA guidelines. Further, the drilling program would collect soils samples to assist with the design of a "*Gravel Berm/Toe Drain*" (toe drain) to improve dam stability. TTEBA provided a cost estimate to CRD to complete the study and a total budget of $40,000, including CRD staff effort which was approved by the Committee.

In July 2016, TTEBA was awarded the contract to complete the Soil Investigation and Seismic Assessment for the Dam. The scope of work consists of the following tasks:

- Complete a drilling program and evaluate the geotechnical characteristics of the dam's foundation soils;
- Install piezometers to monitor groundwater levels within the dam;
- Test soil samples to classify the dam fill and foundation soils;
- Assess seismic stability to verify whether the dam meets the minimum requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2013 Edition); and
- Prepare a report summarizing the findings and proposed mitigation works.

TTEBA's soil investigation was successfully completed in August 2016, including drilling five (5) boreholes, collecting soil samples and installing three (3) piezometers. TTEBA completed the seismic modelling and analysis and prepared a technical report with the conclusions and recommendations. The report was finalized by TTEBA and submitted to CRD on October 13, 2016. A copy of the final report is attached as Appendix A. A summary of the study conclusions is as follows:

- Laboratory analysis of soil samples collected during drilling investigation shows that the dam fill and foundation soils consist of layers of sand-type soils that are susceptible to liquefaction during a design seismic event (1 in 2475 year return period seismic event), reducing the performance level of the dam during the simulated design earthquake;
- Seismic modelling results show that the dam's upstream and downstream slopes:
  - do meet the minimum CDA Dam Safety recommendations for the static cases; and
  - do not meet the CDA Dam Safety Guidelines for both pseudo-static and post-earthquake slope stability conditions;

TTEBA recommended to the CRD to take action to improve the seismic stability of the Dam and provided two (2) options for remediation, as follows:

Option 1 – Upgrade Existing Dam

To reduce the risk level of a major dam failure and meet CDA Dam Safety Guidelines, TTEBA proposes that the downstream slope of the Dam be reinforced. It is more important to reinforce the downstream face of the Dam, since a failure of the upstream embankment may cause water quality issues but may not lead to a major dam failure. Reinforcing the downstream embankment could be accomplished by installing an earthfill buttress along the entire length of the downstream slope. During the design earthquake, there may be deformation to the Dam's embankments and water may leak from the Dam. However, the reinforcement of the downstream slope will greatly reduce the risk of a sudden dam failure and will provide protection to downstream population and infrastructure to a level that meets current CDA Dam Safety Guidelines.

Water currently seeps through the Dam and left abutment and is recirculated to the reservoir using a pump and above ground conveyance piping. Seepage levels are routinely monitored by CRD Operations staff. TTEBA does not consider the current level of seepage to negatively affect the overall stability of the dam, as long as the existing drainage and recirculation system is maintained. As part of Option 1, seepage can continue to be allowed to flow through the Dam and abutment, and seepage flow levels routinely monitored by CRD Operations staff. TTEBA has identified options to stop the seepage from occurring, however, the cost to complete this additional remediation is considered very high and may not significantly improve the overall stability of the Dam.

Estimating the construction cost of the option was not included in TTEBA's scope of work. The CRD has estimated the high level "order of magnitude" cost to be between $350,000 and $650,000, excluding applicable taxes. A brief summary of the order of magnitude cost estimate is included as Appendix B1.

Option 2 – Construct New Dam

TTEBA identified replacing the Dam as a more conservative and robust approach to reducing risk of a major dam failure. This is an expensive option that would likely involve the following construction tasks (or similar):

- Isolate the existing Dam from the reservoir with construction of a cofferdam (i.e. install sheet pile wall, aquadam, concrete lock block etc.);
- Install a temporary water supply pipeline to maintain existing level of water service;
- Deconstruct the existing Dam and excavate to competent bedrock, and haul away spoil material;
- Supply and deliver a large volume of granular fill suitable for dam construction;
- Construct a new earth fill embankment dam;
- Remove the dam isolation system (i.e. cofferdam) and temporary water supply pipeline; and
- Install dam monitoring equipment.

The design of a new dam would include the previously recommended toe drain improvements. Additionally, the new dam could be designed to reduce seepage through the embankment, as well as the sandstone foundation. Construction of the new dam would require that the water supply be isolated from the construction zone and would require design and installation of a temporary water supply pipeline in order to maintain level of drinking water service to residents.

Again, estimating the construction cost of Option 2 was not included in TTEBA's scope of work. The CRD has estimated the high level "order of magnitude" cost to be between $2,400,000 and $4,400,000, excluding applicable taxes. A brief summary of the CRD's order of magnitude cost estimate is included as Appendix B2.

With both options, TTEBA's recommendation from the 2011 DSR report to design and construct a new toe drain still applies, in order to improve dam stability. The Dam's performance will be improved with a new toe drain and until such time as it is installed, the Dam is at greater risk of slope failure. The current budget includes $90,000 (Phase 1 of $45,000 in 2017 and Phase 2 of $45,000 in 2018) to complete the design and construction of the new toe drain. Depending on the option selected, the scope of the new toe drain will need to be updated. With this new information prepared by TTEBA, if the toe drain was to be installed as planned and remedial work were to proceed there would be uncertainty of how the remedial work may affect a newly installed toe drain until remedial work is approved and detailed (for instance a new toe drain could be demolished with any remedial work). The order of magnitude cost estimates above exclude the cost to design and install a new toe drain, because this cost is already in the current budget.

Results of the SI&SSA study show that the Dam does not meet the CDA Dam Safety Guidelines for seismic stability criteria. Moving forward, the completion of seismic stability improvements to the Dam will require a multiphase project delivery plan, regardless of which option is selected. The process to complete any remedial work may be as follows:

- Approve funding for a preliminary design. Upon completion of the preliminary design the scope of work (construction details, materials, logistics, etc.) and cost estimates would be prepared. This work could be funded from the Capital Reserve Fund.
- Remedial work will most likely need supplementary capital funding and therefore, a referendum or Alternative Approval Process (AAP) could be considered to obtain electorate assent for a loan authorization bylaw.
- The CRD typically conducts a public engagement process to educate and inform the public or customers of the need for the project.
- Electoral assent by way of a referendum or AAP would follow thereafter to approve a Loan Authorization Bylaw.

- If the electorate approve the funding, then an engineering consultant could be retained to complete the final design, technical specifications, and provide construction support and contract administration. After that, the project would be tendered and a contractor hired.
- The CRD, with support from the engineering consultant, would prepare regulatory permit applications, obtain approvals, and coordinate with stakeholders (e.g. private property owner).
- The construction phase would include mobilization, completion of the remedial work, and demobilization from the site.
- Depending on the option selected, the dam upgrades or newly constructed dam may require commission services (e.g. instrumentation set-up, valve testing, etc).

ALTERNATIVES

Alternative 1

That the Lyall Harbour/Boot Cove Water Local Service Committee direct CRD staff to:

1. Keep the phase 1 and 2 toe drain work in the 2017 and five (5) year capital budget and defer the project until a preliminary design is completed for the remedial work, and
2. Include a new capital project related to completing a preliminary design for remedial work based on a buttress system (Option 1) for an amount of $40,000 with funding from the Capital Reserve Fund.

Alternative 2

That the Lyall Harbour/Boot Cove Water Local Service Committee direct CRD staff to:

1. Keep the phase 1 and 2 toe drain work in the 2017 and five (5) year capital budget and defer the project until a preliminary design is completed for the remedial work, and
2. Include a new capital project related to completing a preliminary design for remedial work based on rebuilding the dam (Option 2) for an amount of $40,000 with funding from the Capital Reserve Fund.

IMPLICATIONS

Alternative 1 - Selecting Alternative 1 will lead to upgrading the existing Dam to improve seismic stability and meet CDA Dam Safety Guidelines for seismic resistance. The dam upgrade is a risk management approach that will lower the magnitude of the capital cost investment, lower the risk of a major dam failure, and can be constructed within a shorter period of time.

After a design seismic event, the upgraded Dam is anticipated to settle and displace and may need urgent repairs. The level of service may be temporarily reduced while repairs are made to the Dam. In order to complete repairs, emergency response funds should be reserved over upcoming years. Additionally, non-structural improvements by means of an updated Dam Emergency Plan (DEP) would need to be prepared.

Compared with a complete dam rebuild (Alternative 2), the upgrading option is considered to be the less robust of the two (2) options, but will meet the CDA Dam Safety Guidelines. Routine monitoring of the Dam's performance will need to continue (e.g. weekly inspections, DSR's, routine piezometer readings, etc.).

Alternative 2 - Selecting Alternative 2 will lead to the full replacement of the existing Dam to improve seismic stability and meet the CDA Dam Safety Guidelines for seismic resistance. This is the most robust option, and will reduce the risk of a major dam failure more so than selecting Alternative 1. It is anticipated that a completely rebuilt dam will perform better during a design seismic event, and level of repairs required after an earthquake will be less than Alternative 1.

The cost of reconstructing the Dam is anticipated to be an order of magnitude greater than Alternative 1. Water service would likely be temporarily interrupted and require the installation of a temporary water supply line. Reconstructing the Dam would require that the existing dam area be isolated from the reservoir, by means of constructing a temporary cofferdam. Cofferdams are expensive and time-consuming to install, and would require additional planning and permitting effort with regulatory agencies (e.g. DFO, MFLNRO, etc.).

Construction of a new dam will require that a new DEP be prepared to plan for emergency response. As well, routine monitoring of the dam's performance will need to continue (e.g. weekly inspections, DSR's, routine piezometer readings, etc.).

CONCLUSION

TTEBA completed the 2011 DSR and identified the SI&SSA study and a high priority follow up study in order to determine if the Dam meets the CDA Dam Safety Guidelines for seismic resistance. The follow up study revealed that soils within the dam fill and foundation are mostly granular sandy fill that is susceptible to liquefaction during an earthquake. Additionally, modelling results have shown that the Dam does not meet the minimum CDA Dam Safety Guidelines for both the pseudo-static and post-earthquake slope stability conditions. TTEBA recommended that the CRD take action to improve the seismic stability of the Dam.

TTEBA identified two options within the SI&SSA study: Option 1 – Upgrade Existing Dam and Option 2 – Construct New Dam. The CRD has completed an order of magnitude construction cost estimate for each of the two options, for the purpose of comparing the economic implications of both options. Option 1 – Upgrade Existing Dam is a risk management based approach that is estimated to cost $493,000, which is anticipated to be an order of magnitude less in cost than Option 2 – Construct New Dam. Option 1 requires that structural and non-structural improvements be completed in order to meet the CDA Dam Safety Guidelines and reduce risk of a major dam failure. A coarse rockfill buttress could be constructed at the downstream face of the Dam, providing structural reinforcement and increasing seismic resistance. After the earthquake hits, the level of service to the community may temporarily be affected while repairs to the Dam are completed. The existing DEP would need to be revised to account for the changes to emergency procedures. Existing seepage levels through the dam and foundation would remain unchanged.

It is anticipated that the previously recommended design and construction of a new toe drain can be incorporated into the larger dam remediation project. There is currently $90,000 in the capital budget (Phase 1 of $45,000 in 2017 and Phase 2 of $45,000 in 2018) to complete the toe drain work.

It is proposed to maintain the existing capital plan whereby the toe drain work would be approved, but the work not commence until such time that a preliminary design is prepared for the remedial dam work so not to waste the toe drain effort. Should the remedial work be delayed for more than one year, then the toe drain work should proceed and any future remedial work should accommodate the new toe drain.

After selecting the preferred option, completing the dam safety improvements will require that a multiphase plan be developed that will include completing the next phases: completing preliminary design and cost estimates, supplementary capital funding, public engagement, procuring engineering consulting services, detailed design, tendering, construction, and commissioning phases.

RECOMMENDATION

That the Lyall Harbour/Boot Cove Water Local Service Committee direct CRD staff to:

1. Keep the phase 1 and 2 toe drain work in the 2017 and five (5) year capital budget and defer the project until a preliminary design is completed for the remedial work, and

2. Include a new capital project related to completing a preliminary design for remedial work based on a buttress system (Option 1) for an amount of $40,000 with funding from the Capital Reserve Fund.

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Attachments:

1. Appendix A – Tetra Tech EBA Final Report titled *Money Lake Dam No.1 – Soils Investigation and Seismic Assessment*
Appendix B1 – Order of Magnitude Cost Estimate for Option 1
2. Appendix B2 – Order of Magnitude Cost Estimate for Option 2

TETRA TECH EBA

OQM | Organizational Quality Management Program

APPENDIX A

Money Lake Dam #1 Engineering Assessment
Lyall Harbour/Boot Cove, Saturna Island

PRESENTED TO

The Capital Regional District

OCTOBER 13, 2016
ISSUED FOR USE
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CONSULTING ENGINEERS & SCIENTISTS • www.eba.ca

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EXECUTIVE SUMMARY

Tetra Tech completed an Engineering Assessment for Money Lake Dam # 1 (Dam) based on recommendations made in the 2011 Dam Safety Review (DSR) by Tetra Tech EBA.

This Engineering Assessment included the following tasks:

- A geotechnical exploration of the dam to evaluate the geotechnical characteristics of the dam and its foundation. The geotechnical exploration was completed in August 2016 and included:
  - Drilling five boreholes to evaluate the geotechnical characteristics of the dam and foundation;
  - Installation of three stand pipe piezometers to gather piezometric data on the internal conditions of the dam;
  - Completion of Standard Penetration Testing (SPT) and Dynamic Cone Penetration Testing (DCPT) to assess the consistency/density of the encountered soils; and
  - Collection of selected representative soil samples for geotechnical laboratory testing.
- Laboratory testing of soil samples including 38 moisture contents and 10 sieve analyses;
- Geotechnical engineering analyses to verify whether the dam meets the minimum requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2013 Edition) including:
  - Seepage analysis;
  - Liquefaction triggering analysis;
  - Residual strength calculations for liquefiable soils;
  - Stability analysis (Static, Pseudo-static, Post-earthquake); and
  - Erosion Assessment.
- Preparation of a Report summarizing the findings and proposed mitigation works.

Tetra Tech made the following conclusions:

- Factors of safety greater than 1.5 were calculated for both the upstream and downstream slopes of the dam under static conditions (CDA recommended FoS = 1.5), indicating the stability of the embankment meets the minimum CDA static recommendations;
- Factors of safety below 1.0 were calculated for both the upstream and downstream pseudo-static analysis (CDA recommended FoS = 1.0), considering the full PGA of 0.48 g for the 1 /2,475 seismic event, indicating the stability of the embankment does not currently meet the minimum CDA pseudo-static recommendations. Deformations up to 65 cm will likely result from the design seismic event, assuming no liquefaction, for this condition, freeboard will be reduced and the remaining freeboard will mitigate overtopping of the dam;
- Factors of safety below 1.0 were calculated for the post-earthquake slope stability analysis (CDA recommended FoS = 1.2), for both the upstream and downstream slopes, indicating the embankment does not currently meet the minimum CDA recommendations. Factors of safety below 1.0 for post-earthquake also indicate the potential for a flow slide to occur. Such flow slides may cause release of the reservoir;
- Repair of the dam will be required following the design seismic event; and

- Based on the erosion assessment, the embankment and foundation soils are susceptible to two forms of internal erosion; piping erosion and suffusion. There is a downstream filter/toe drain at the Dam, however it is not known if it extends down to the underlying bedrock. Installing a filter/toe drain, downstream of the existing filter, extending to bedrock, would limit the potential internal erosion.

Tetra Tech recommends the following be undertaken to meet the CDA guideline recommendations and to improve dam safety at the Dam:

- Remedial measures be implemented to reduce the risk of internal erosion;
- Remedial measures be implemented to reduce the impacts of a seismic event;
- Record monitoring well levels and lake level on a monthly basis;
- Update the Dam Emergency Plan (DEP) and Emergency Preparedness Plan (EPP) for the Dam; and
- The Liquefaction During Earthquake condition, should be analyzed, during conceptual design, to consider the effects of a longer duration earthquake (i.e., the subduction event).

Tetra Tech has outlined conceptual options to address the recommendations include Option 1: Complete dam removal and construction of a new dam, and Option 2: Risk Management: Adding a downstream buttress and filter/toe drain, and updating the DEP and EPP appropriately.

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ACRONYMS & ABBREVIATIONS

AMSL	Above Mean Sea Level
APEGBC	Association of Professional Engineers and Geoscientists of British Columbia
BH	Borehole
CDA	Canadian Dam Association
CSR	Cyclic Stress Ration
CRD	Capital Regional District
CRR	Cyclic Resistance Ratio
DCPT	Dynamic Cone Penetration Testing
DEP	Dam Emergency Plan
DSR	Dam Safety Review
EPP	Emergency Preparedness Plan
FoS	Factor of Safety
MC	Moisture Content
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MW	Monitoring Well
Mw	Moment Magnitude
NBCC	National Building Code of Canada
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
Sa(T)	Spectral Accelerations
SPT	Standard Penetration Testing
USC	Unified Soil Classification
Su res	Residual Shear Strength

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of The Capital Regional District and their agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than The Capital Regional District, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement. Tetra Tech EBA's General Conditions are provided in Appendix A of this report.

1.0 INTRODUCTION

The Capital Regional District (CRD) retained Tetra Tech EBA Inc. (Tetra Tech) to undertake an Engineering Assessment of Money Lake Dam # 1 (Dam), to address some of the recommendations developed during the 2011 Dam Safety Review (DSR) of the Dam, finalized in April 2012 by Tetra Tech.

The BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Dam Safety Section has currently assigned the Dam a consequence classification of "High" in accordance with the BC Dam Safety Regulation (latest update February 2016) and the Canadian Dam Association (CDA) Dam Safety Review Guidelines (2013 Edition). The consequence classification was last reviewed as part of the DSR completed in 2012.

This Engineering Assessment included the following tasks:

- A geotechnical exploration of the dam to evaluate the geotechnical characteristics of the dam and its foundation. The geotechnical exploration was completed in August 2016 and included:
  - Drilling five boreholes to evaluate the geotechnical characteristics of the dam and foundation;
  - Installation of three stand pipe piezometers to gather piezometric data on the internal conditions of the dam;
  - Completion of Standard Penetration Testing (SPT) and Dynamic Cone Penetration Testing (DCPT) to assess the consistency/density of the encountered soils; and
  - Collection of selected representative soil samples for geotechnical laboratory testing.
- Laboratory testing of soil samples including 38 moisture contents and 10 sieve analyses;
- Geotechnical engineering analyses to verify whether the dam meets the minimum requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2013 Edition) including:
  - Seepage analysis;
  - Liquefaction triggering analysis;
  - Residual strength calculations for liquefiable soils;
  - Stability analysis (Static, Pseudo-static, post earthquake); and
  - Erosion Assessment.
- Preparation of a Report summarizing the findings and proposed mitigation works.

This report presents a summary of Tetra Tech's explorations and engineering analyses and provides updated conclusions and recommendations with respect to improving the performance of the dam in accordance of the BC Dam Safety Regulation and the CDA Dam Safety Guidelines.

2.0 BACKGROUND REVIEW

2.1 Site Description

The Dam is located on Saturna Island, BC, about 2 km southeast of the BC Ferries terminal at Lyall Harbour, as shown on Figure 1. The dam can be accessed by Harris Road, an unpaved road up the valley.

The Dam is generally a homogeneous earthfill embankment structure, which provides storage for domestic water supply for a service area downstream.

Table 1: Money Lake Dam Dimensions

Dam Height	6.9 m
Crest Width	4 m(1)
Dam Length	46 m
Upstream Slope	2H:1V
Downstream Slope	2H:1V
Spillway width	4.3 m
Chute width	2.4 m
Water Supply Intake Pipe Diameter (material)	150 mm (polyvinyl chloride)
Reservoir Total Storage Volume	72,000 m^3

(1) The crest width has been documented as 7 m in some reports however 4 m has been confirmed by survey by the CRD.

The reservoir receives surface runoff from the Money Lake watershed, mostly during fall and winter. The watershed is defined by the crest of Mt. Fisher and the crest of Mt. Warburton Pike (Willis Cunliffe Tait, 1978). The topography of the area is generally characterized by steep slopes and correspondingly rapid runoff.

Table 2: Money Lake Watershed Parameters

Catchment Area	1.17 km^2
Lake Area	0.02 km^2

Table 3: Money Lake Dam Elevations

Normal Operating Level	150.5 m
Crest Elevation	152 m
Water Supply Pipe Intake invert elevation	145.2 m
Median watershed basin elevation	230 m

Note: Elevations are referenced above mean sea level (amsl)

2.2 Historical Design and Construction

The following is a summary of significant Dam milestones:

- 1978 Original Dam Construction (Mr. John Money) – The fill used for the dam was fractured sandstone, which was ripped and spread across the dam and compacted with tracked equipment.
- 1979 West End of Dam Raised (Mr. John Money) – The dam was raised over an existing roadway (Harris Road). 1979 as-built drawings are included in Appendix B.
- 1981 Dam Raised (CRD) – Construction details are unknown but as-built survey sketches from 1984 are included in Appendix B.
- 1986 Concrete Spillway Constructed (CRD) – General arrangement drawings of the dam and concrete spillway are included in Appendix B.
- Late 1990s (CRD) – Seepage started being recirculated to improve reservoir level.
- 2007 to 2010 Site Inspection/Seepage Monitoring (Thurber) – A series of site inspections was undertaken to address ongoing seepage issues at the dam.

- 2007 Trench Inspection (Thurber) – A testpit was excavated to a maximum depth of 4.8 m, extending approximately 15 m from the west abutment contact with the slope. The upper 2 m is described as compact sandy silt with the underlying embankment fill consisting of compact silty gravelly sand. Where the excavation encountered the west abutment, the material encountered was sand, gravel and boulder mixture which was inferred to be loose and the underlying bedrock was weathered and highly fractured. Seepage was observed at the contact between the bedrock and the embankment fill.
- 2008 Circulation System Upgraded (CRD) – The reservoir levels improved after this upgrade.
- 2012 Upgrades were completed at the Dam to collect seepage downstream of the left (west) abutment contact.
- 2014 Survey Work (CRD) – The CRD completed a topographical survey of the dam and spillway.
- 2015 A new log boom was constructed.

2.3 Geological Setting

The surface soils consist of a thin layer of granular material over sandstone, conglomerates, and shale rock. The topsoil material appears to be generally well drained with variations depending upon soil conditions and local topography (Willis Cunliffe Tait, 1978).

2.4 Environmental Approvals for 2016 Drilling Program

Tetra Tech completed an assessment of potential harm to fish and fish habitat which was submitted to the CRD. The letter, dated August 9, 2016, included best management practices used in geotechnical drilling explorations to reduce impact on the surrounding natural environment.

3.0 SUBSURFACE EXPLORATION

Tetra Tech conducted a subsurface exploration between August 10 and 12th, 2016 using a track mounted sonic drill rig owned and operated by Drillwell Enterprises Ltd. of Duncan, BC.

The subsurface exploration of the dam, included:

- Drilling five boreholes to evaluate the geotechnical characteristics of the dam and foundation;
- Installation of three standpipe piezometers to gather piezometric data for the dam;
- Completion of Standard Penetration Testing (SPT) and Dynamic Cone Penetration Testing (DCPT) to assess the consistency/density of the encountered soils; and
- Collection of selected representative soil samples for geotechnical laboratory testing.

The drilling was supervised by Ms. Cori Creba, EIT who logged the encountered subsurface conditions and collected representative samples. A continuous written log was maintained in the field providing a visual description of the encountered soil profile, including the consistency, moisture content and plasticity of the materials.

The locations of the boreholes (BH16-04 and 05, MW16-01, 02 and 03) were measured relative to existing infrastructure and are shown on Figure 2. Tetra Tech completed a levelling survey to measure ground surface elevations at the borehole and monitoring well locations, these elevations are referenced to the 2014 CRD survey.

3.1 General Site Conditions

The following site conditions were observed during the August 2016 geotechnical exploration:

- The upstream and downstream slopes were covered in grass with nettles and other weeds growing along the spillway contact and along the left abutment contact with the natural slope (Photos 1 through 7);
- The old road, that was decommissioned when the dam was raised in 1979, is visible along the west side of the lake (Photo 5);
- The log boom was upgraded in 2015 (Photo 8);
- The west bank, downstream of the left abutment contact, was saturated approximately 1 m above the ditch elevation, indicating water is seeping out of the natural slope;
- Captured water is routinely pumped back into the reservoir via a 100 mm PVC pipe in the spillway channel (Photo 10); and
- The spillway was dry during the drilling exploration (Photos 11 and 12).

4.0 ENCOUNTERED SUBSURFACE CONDITIONS

4.1 Borehole Results

The borehole locations, elevations and completion details from the drilling program are provided in Table 4. The borehole locations are shown on Figure 2 and the Borehole Logs are included in Appendix C.

Table 4: Borehole Completion Details

Location ID	Ground Surface Elevation (m)	Termination Depth (m)	Northing (m)	Easting (m)	Location Description
MW16-01 (1)	145.7	5.8	5403719	486862	Downstream toe
MW16-02	152	8.8	5403697	486857	Crest of dam
MW16-03	152	8.8	5403702	486849	Crest of dam
BH16-04 (2)	145.9	4.3	5403719	486860	Downstream toe
BH16-05	148.3	6.4	5403706	486853	Downstream toe

(1) MW – Monitoring Well/Piezometer

(2) BH – Borehole

- Borehole MW16-01 (Photo 14) and BH16-04 were completed at the downstream toe of the dam, east of the access road, in the vicinity of the maintenance shed. The soil profile at the downstream toe consisted of gravel, underlain with sand, with sandstone bedrock encountered at depth.
- Boreholes MW16-02 and MW16-03 (Photo 19) were completed along the crest of the dam near the highest portion of the embankment. The soil profile at the highest section consisted of silty sand fill underlain with sandstone bedrock at depth. The fill was loose to compact with densities indicating little compaction effort during fill placement.

- Borehole BH16-05 was completed on the west side of the access road at the downstream toe of the dam. The soil profile at this location consisted of gravel, underlain with interbedded sand and silt, encountering sandstone bedrock at depth.

Laboratory testing included 38 moisture content tests and 10 sieve analysis. The results of which are summarized in Table 5.

Table 5: Summary of Laboratory Testing Results

Location ID	Sample Depth (m)	Classification Tests		Particle Size Distribution (%)		
		MC [1] (%)	USC [2]	GRAVEL	SAND	FINES
MW16-02	1.2- 1.5	10.7	SM	12	56	32
	1.5- 2.7	13.1	SM	4	61	35
	4.3- 5.0	14.0	SM	0	71	29
MW16-03	1.8- 2.4	12.5	SM	3	60	37
	3.0-3.7	17.4	SM	7	63	30
	4.3-4.9	11.2	SM-SP	10	61	29
	5.5-6.1	20.3	SM	11	67	22
	6.7- 7.3	18.7	SM	1	64	35
BH16-04	1.2-1.8	10.6	GM	57	37.8	5.2
	1.8-2.7	13.7	SM	26	61	13

(1) Moisture Content

(2) Unified Soil Classification

Based on Tetra Tech's review of the borehole logs, laboratory testing results and review of background information, the following material types were encountered during the drilling exploration:

- Boreholes through the dam crest (MW16-02 and MW16-03):
  - Topsoil and grass approximately 100 mm thick, underlain by;
  - Embankment fill, generally comprising of loose to compact silty sand, to depths of 3.8 to 5.5 m in boreholes MW16-02 and MW16-03, respectively, underlain by;
  - Organics (possible original ground surface or fill) were encountered at 3.8 m in borehole MW16-02;
  - Silty sand (SM) (possible fill or weathered sandstone) was encountered at depths of 4.3 m and 5.5 m in boreholes MW16-02 and MW16-03, respectively; and
  - Sandstone bedrock was encountered at depths of 5.0 m and 7.6 m in boreholes MW16-02 and MW16-03, respectively.
- Boreholes at the downstream toe (MW16-01, BH16-04 and BH16-05):
  - Topsoil and grass approximately 100 mm thick, underlain by;
  - Dense to loose gravel (possible fill) at 0.1 m depths (SPT values in gravelly soils could be influenced by the presence of large particles) underlain by;

- Very loose sand and silt was encountered at 1.2 m, 1.8 m and 3.5 m in boreholes MW16-01, BH16-04 and BH16-05, respectively, underlain by; and
- Sandstone bedrock was encountered at 2.0 m, 3.0 m and 5.2 m in boreholes MW16-01, BH16-04 and BH16-05, respectively.

Interpreted geotechnical sections both parallel and perpendicular to the dam crest are presented in Figures 3 and 4.

A summary of the general in situ properties from the field and laboratory testing is provided in Table 6.

Table 6: Summary of Encountered In Situ Geotechnical Properties

Material	SPT N-Value (blows/ft)	DCPT N-Value (blows/ft)	Fines Content, FC (%)	Color
Embankment Fill (1979 Dam Raise)(1)	12- 19	9 – 26	32 - 37	Brown
Embankment Fill (1978 Original Dam)	6 - 21	10 - 42	29 - 35	Grey
Gravel(2)	1 -36	NA	10 - 20	Brown
Sand/Silt	2 - 16	3 - 5	29 - 60	Grey and Black
Sandstone Bedrock	75+	76 +	NA	Brown

(1) The DCPT N value of 82, at 1 m depth, observed in borehole MW16-02 is not considered representative. It is possible that the cone was pushing on a sandstone cobble which may have caused a high blow count.

(2) SPT values in gravelly soils could be influenced by the presence of large particles.

4.2 Groundwater Conditions

Groundwater was measured in monitoring wells MW16-01, MW16-02 and MW16-03 on August 12, 2016. The corresponding lake level was 149.0 m amsl. Groundwater was measured in boreholes BH16-04 and BH16-05 on August 12, 2016, during drilling.

Table 7: Summary of Groundwater Conditions

Groundwater Reading Location	Water Level Elevation (m amsl)
MW16-01	144.9
MW16-02	147.4
MW16-03	145.8
BH16-04 (1)	144.9
BH16-05 (1)	144.9

(1) Groundwater was measured in BH16-04 and BH16-05 during drilling.

Turbid water was observed in MW16-02 during measurement.

5.0 GEOTECHNICAL ASSESSMENT

5.1 General

The following analyses were completed as part of the geotechnical assessment, and are discussed in the following sections:

- Seepage analysis;
- Liquefaction triggering analysis;
- Residual strength calculations for liquefiable soils;
- Stability analysis (Static, Pseudo-static, Post-earthquake); and
- Internal Erosion Assessment.

5.2 Canadian Dam Association (CDA) Criteria

Section 6.6 of the CDA Dam Safety Guidelines (2013 Edition) provides accepted minimum slope stability Factor of Safety (FoS) for static analysis and for various seismic loading conditions for embankment dams. The FoS is the ratio of the forces resisting a slope failure to the forces driving a slope failure. A slope with a FoS of 1.0 is at equilibrium (i.e., the forces causing slope movement are equal to the forces resisting slope movement). A FoS of 1.0 indicates that the slope is marginally stable and likely deforming, and higher values of FoS indicate higher levels of stability. Minimum required FoS for slope stability provided by CDA for both static and seismic assessments are summarized in Tables 8 and 9.

Table 8: Factor of Safety for Slope Stability – Static Assessment

Loading Conditions	Minimum Factor of Safety	Slope
End of construction before reservoir filling	1.3	Upstream and Downstream
Long Term	1.5	Upstream and Downstream
Full or partial rapid drawdown(1)	1.2	Upstream

(1) Higher factors of safety may be required if drawdown occurs relatively frequently during normal operation.

Table 9: Factor of Safety for Slope Stability – Seismic Assessment

Loading Conditions	Minimum Factor of Safety	Slope
Pseudo-Static (Seismic)	1.0	Upstream and Downstream
Post-earthquake	1.2	Upstream and Downstream

The MFLNRO Dam Safety Section has currently assigned the Dam a consequence classification of "High" in accordance with the BC Dam Safety Regulation and CDA Dam Safety Review Guidelines, based on the consequence classification review completed as part of the 2012 DSR. Section 6.3 of the CDA Dam Safety Guidelines (2013 Edition) provides Annual Exceedance Probability Earthquakes or design earthquakes for dam classes. Based on a "High" classification, the annual probability of exceedance of the design earthquake should be the 1/2,475 year seismic event.

Rapid drawdown was not included in the current analysis as a mode for rapidly drawing down the water level at Money Lake does not appear to be present. The capacity of the 150 mm water supply pipe would allow for gradual and not rapid drawdown to occur.

5.3 Geotechnical Model Parameter Estimation

Soil parameters for the encountered materials have been determined using a combination of the in-situ testing results, the laboratory testing results, published data for similar soil types and empirical correlations with in-situ and/or laboratory testing.

Based on a review of the geotechnical information obtained from the site exploration, the geotechnical parameters summarized in Table 10 below were utilized in various analyses. Low soil strength values were observed during the geotechnical exploration and were analysed for susceptibility to liquefaction. For example, low soil strengths included SPT N-Values (blow counts per foot) as low as 1 in BH16-04.

Table 10: Summary of Geotechnical Parameters for Analyses

	Effective Cohesion, c' (kPa)	Internal Angle of Friction, f (°)	Bulk Unit Weight, g (kN/m³)	Post-Earthquake: Su,res as f(overburden: initial vertical effective) , minimum Su,res (kPa)
Embankment Fill (1979 Dam Raise)	0	35	19	NA
Embankment Fill (1978 Original Dam)	0	30	18	NA
Sand/Silt	0	28	18	0.05 – 0.08, 5
Filter	0	35	18	NA
Rockfill (1)	0	40	20	NA
Sandstone Bedrock	10	45	20	NA

(1)Gravel encountered in boreholes MW16-01, BH16-04 and BH16-05 was modelled as Rockfill based on review of information provided on drawing VI 6553-1-18.

5.4 Seepage Analysis

The purpose of the seepage analysis is to:

- Assess pore water levels to be used in the stability analysis; and
- Determine seepage gradient for the internal erosion assessment.

Based on soil properties determined during the geotechnical exploration and review of related reference material, estimated hydraulic conductivities for each of the soil units described previously are summarized in Table 11 below. A two-dimensional finite element steady state seepage analysis was conducted for interpreted geotechnical section B (Figure 4) using these estimated hydraulic conductivities and estimated lake levels as input into the Seep/W program.

Table 11: Estimated Hydraulic Conductivity Parameters

Soil Type	Saturated Hydraulic Conductivity, k_{sat} (m/s)
Embankment Fill (1979 Dam Raise)	1 x 10^{-8}
Embankment Fill (1978 Original Dam)	1 x 10^{-8}
Sand/Silt	1 x 10^{-5}
Rockfill	1 x 10^{-4}
Filter	1 x 10^{-3}
Sandstone Bedrock	1 x 10^{-9}

(Cedergren, 1989)

Seepage analyses were completed for the lake at full operating level estimated at 150.5 m and for a reduced lake level estimated at 148.0 m. The estimated flow fields are provided in Figures E1 and E2, Appendix E. The results compared well with the water levels observed in the monitoring wells and during the drilling exploration.

5.5 Seismic Data

Seismic data for the site were obtained from Natural Resources Canada (National Research Council Canada, 2015), as tabulated in Table 12. Various earthquake return periods are presented below. Both the 1/2475 year event (design seismic event) and the subduction event were analyzed as part of the liquefaction analysis.

Table 12: 2015 National Building Code of Canada Seismic Hazard Values

Seismic Event	Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa (0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
1/475	0.310	0.473	0.591	0.598	0.516	0.270	0.150	0.034	0.011	0.257	0.346
1/1,000	0.419	0.641	0.796	0.807	0.709	0.383	0.220	0.059	0.020	0.346	0.492
1/2,475	0.582	0.884	1.097	1.109	0.985	0.551	0.326	0.100	0.035	0.476	0.712
Subduction	0.221	0.366	0.474	0.530	0.527	0.387	0.262	0.095	0.334	0.226	0.453

Sa - Spectral Acceleration, given in units of g (9.81 m/s^2)

PGV – Peak Ground Velocity

PGA – Peak Ground Acceleration

Mean hazard values are recommended for typical seismic hazard computations for dam design (Canadian Dam Association, 2013). The relative contribution of the earthquake sources to the seismic hazard in terms of distance and magnitude can be obtained by deaggregation of the seismic hazard result. The deaggregation data for the National Building Code of Canada (NBCC) 2015 design model has been obtained from Earthquakes Canada, which provides deaggregation of the mean hazard for the Dam for the 1/2475 year event, as summarized in Table 13.

Table 13: Design Earthquake Magnitudes for Money Lake Dam # 1, Saturna Island, BC

Ground Motion Parameter		Sa(0.05)	Sa(0.1)	Sa (0.2)	Sa (0.3)	Sa (0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
Magnitude (Mw)	Mean	6.98	7.02	7.15	7.27	7.43	7.88	8.17	8.69	8.77	7.15	7.70
	Mode	7.15	7.15	7.15	7.45	7.45	8.95	8.95	8.95	8.95	7.15	7.45

Mw – moment magnitude

Magnitudes of 7.15 Mw and 9.0 Mw were used for the 1/2475 year event and the subduction event, respectively.

5.6 Liquefaction Triggering Assessment

Liquefaction is defined as the significant loss of strength due to cyclic/seismic loading and associated pore water pressure increase that can cause a saturated soil to behave as a fluid. Liquefied soils will have a residual strength that can be significantly less than when the soil is in a non-liquefied state. Liquefaction occurs in loose granular, or fine-grained soils, below groundwater level.

Tetra Tech completed a liquefaction analysis to determine the potential for liquefaction as well as to estimate potential reconsolidation settlements and lateral displacements based on the methods outlined in:

- May 2007 Task Force Report – Geotechnical Design Guidelines for Buildings on Liquefiable Sites In Accordance with NBC 2005; and
- Idriss and Boulanger, 2008, Soil Liquefaction During Earthquakes.

The analysis was completed based on the DCPT data for MW16-02 and SPT data for MW16-03 and BH16-04 and the following input parameters:

Table 14: Input Parameters for Liquefaction Assessment

Parameter	Value	
Earthquake Return Period	1/2475 year event	Subduction Event
PGA (at firm ground)	0.48 g	0.23 g
Magnitude	7.15 Mw	9.0 Mw
Groundwater Level	Varies by borehole	Varies by borehole
Soil Density above Groundwater level	19 kN/m^3	19 kN/m^3
Soil Density below Groundwater level	20 kN/m^3	20 kN/m^3

The analysis consisted of:

- Calculating Cyclic Resistance Ratio (CRR) from SPT and DCPT data for sand-like soils;
- Applying appropriate scaling factors to CRR to obtain the scaled CRR. The scaling factors include a magnitude scaling factor and a factor to account for effective overburden stress;
- Calculating Cyclic Stress Ratio (CSR) using Seed's simplified approach ($CSR = 0.65(a_{max}/g)(\sigma_{v0}/\sigma'_{v0})r_d$); and
- Determining the Factor of Safety against liquefaction by comparing CSR to the scaled CRR.

The Factor of Safety against liquefaction is obtained as the ratio between CRR and CSR. In general, a soil layer with a Factor of Safety (FS_{LIQ}) greater than 1.1 is considered not susceptible to liquefaction.

Liquefiable soils with FS_{LIQ} below 1.1 were encountered in Boreholes MW16-02, MW16-03 and BH16-04. A summary of the liquefiable layers is presented in Table 15.

Table 15: Liquefaction Results

Earthquake	Borehole	Depth of liquefiable soils below ground surface[1] (m)	Calculated FoS	Figure
1/2475	MW16-02	4.5 – 4.9	0.4 – 0.5	F1
	MW16-03	6.2 - 7.6	0.8 – 0.9	F2
	BH16-04	1.2 - 3	0.2 - 0.4	F3
Subduction	MW16-02	4.5 – 4.9	0.5 – 0.6	F4
	MW16-03	6.2 – 7.6	1.0	F5
	BH16-04	1.2 – 3.0	0.3 – 0.5	F6

[1] The top depths of liquefiable soils are limited by groundwater elevations, soils above the groundwater elevations are potentially liquefiable if groundwater levels are raised.

Figures showing the results of liquefaction triggering assessment are included in Appendix F.

5.6.1 Post Seismic Residual Shear Strength

The post-seismic residual shear strength ($S_{u,res}$) of liquefiable sand-like soils (i.e., $FS_{LIQ} < 1.1$) was estimated using the approach proposed by Idriss and Boulanger (2008). Based on this approach a $S_{u,res}/\sigma'_v$ ratio of 0.05 was selected, subject to a minimum residual shear strength of 5 kPa at the toe of the dam based on the SPT data in BH16-04. A $S_{u,res}/\sigma'_v$ ratio of 0.08, subject to a minimum residual shear strength of 5 kPa, was selected beneath the dam based on the DCPT data from MW16-02 and SPT data in MW16-03.

5.7 Stability Analysis

Section B, shown on Figure 2, was used in the analysis, and shows the dam at its maximum height with the geometry and soil profile of the model based on results of the geotechnical exploration and the information provided on the 1979 as-built drawing (VI 6553-1-18) in Appendix B. An interpreted geotechnical cross section of Section B is shown on Figure 4.

The stability of a slope under static loading generally depends on the following three factors:

- The geometry of the slope and any internal interfaces or discontinuities/defects;
- The groundwater level; and
- The strength of the soils and materials (including material interfaces) within the slope.

The model was analyzed considering the three conditions outlined below:

- **Static Slope Stability – Long Term (Figures E3 and E4, Appendix E):** The static stability of the dam has been evaluated by Tetra Tech. A two-dimensional stability analysis (utilizing GeoStudio Slope/W 2007 software) was used to determine the FoS of the critical failure circle though the dam. The FoS was found using the Morgenstern Price, limit equilibrium analysis technique. This method was chosen over others because it is considered more accurate as it takes into account the internal forces associated with distortion of a sliding mass of deformable material. A slip surface entry and exit range was defined to limit the analysis range to global failures encompassing the entire dam slopes. Engineering judgement was exercised to verify the appropriateness of the selected slip surfaces.

- **Seismic/Pseudo-static Slope Stability (1/2475 Event - Figures E5 through E8, Appendix E):** Initial screening for seismic slope stability analysis includes applying the magnitude of the Peak Ground Acceleration (PGA) for the design earthquake as a horizontal force acting on the soil mass. If factors of safety for this initial screening are above 1.0, no further analysis is required. Should a factor of safety of less than 1.0 be obtained from the pseudo-static analysis then it is likely that the embankment will undergo significant permanent deformation along the calculated slip surface and a simplified deformation analysis (e.g., (Newmark, 1965), (Bray & Travasarou, 2007), etc.) approach is recommended as the second stage of analysis to confirm that the embankment has adequate freeboard after the design earthquake event. Should the second stage of analysis yield unfavourable results, then a series of more sophisticated analysis approaches (e.g., Finite Element/Difference Analysis) are recommended.

- **Post-earthquake Condition (Figures E9 and E10):** The static Post-earthquake condition takes into account the reduced strength of liquefied soils resulting from the design seismic event. The static Post-earthquake condition assumes that liquefaction will occur after shaking caused by the earthquake has stopped. It was assumed that the liquefiable soil layer identified in BH16-04, MW16-02 and MW16-03 are connected and that they extend upstream of the dam crest.

5.7.1 Pore Water Conditions

Pore water pressure conditions in the embankment were interpolated from monitoring well readings at MW16-01, MW16-02 and MW16-03.

The highest seasonal reservoir level was assumed to be 150.5 m which is the spillway sill elevation. Tetra Tech reviewed seasonal lake level records from 2006 up to 2016, provided by the CRD, and the lowest seasonal lake level of 148.0 m was observed in October and November 2006.

The results of the stability analysis are summarized in the following sections and presented in Appendix E.

5.7.2 Slope Stability Analysis Results

The results of the analysis, shown in Table 16, indicate that for Section B, both the upstream and downstream slopes of the dam have satisfactory factors of safety under static conditions.

Factors of safety as low as 1.4, correlating to shallow failures of the upstream slope, were calculated during the slope stability analysis. We have considered factors of safety of 1.4 for these shallow failures acceptable, based on engineering judgement and our experience observing the performance of similar slopes. The CDA minimum required FoS for static long term steady state seepage is not applicable to these shallow failures, as they are not critical to dam safety (i.e., they would not result in loss of reservoir) and the lowered lake level is considered an unusual loading condition (i.e., it will likely only occur a few months of the year at most).

Table 16: Static Slope Stability Analysis Results

Loading Conditions	Slope	Figure	Calculated FoS	Minimum Required CDA FoS
Static long-term (steady state seepage, highest seasonal reservoir level)	Downstream	E3	1.8	1.5
Static long-term (steady state seepage, lowest seasonal reservoir level)	Upstream	E4	1.5	1.5
Full or partial rapid drawdown[1]	Upstream	NA	NA	1.2

1. Not considered an applicable loading condition as the reservoir does not have the ability to be drawn down rapidly.

Factors of safety below 1.0 were calculated for both the upstream and downstream pseudo-static analysis, considering the full PGA of 0.48g for the 1/ 2475 seismic event, indicating the stability of the embankment does not currently meet the minimum CDA pseudo-static recommendations. Simplified deformation analysis was completed by determining yield coefficients for various slip surfaces and calculating the associated displacements using the Bray and Travasarou method of analysis, assuming liquefaction has not occurred. Table 17 shows the yield coefficients and expected displacements resulting from the design seismic event, in the case of no liquefaction.

Table 17: Pseudo-static Slope Stability Analysis Results

Loading Conditions	Slope	Figure	Yield Coefficient	Calculated Displacement (cm)
Seismic pseudo-static (PGA, steady state seepage, highest seasonal reservoir level)	Downstream	E5	0.22	< 40
Seismic pseudo-static (PGA, steady state seepage, highest seasonal reservoir level)	Downstream	E6	0.17	< 60
Seismic pseudo-static (PGA, steady state seepage, lowest seasonal reservoir level)	Upstream	E7	0.23	< 30
Seismic pseudo-static (PGA, steady state seepage, lowest seasonal reservoir level)	Upstream	E8	0.10	< 65

Post-earthquake slope stability analysis considers the residual strength of the liquefied soil, which was calculated as part of the liquefaction analysis in Section 5.6.1. Reduction of the shear strength of liquefiable soils to their residual strength is caused by the cyclic stresses from earthquake shaking.

Factors of safety below 1.2 were calculated for the post-earthquake slope stability analysis, for both the upstream and downstream slopes, indicating the stability for post-earthquake analysis does not currently meet the minimum CDA recommendations. Factors of safety below 1 for post-earthquake also indicate the potential for a flow slide to occur. Flow slides occur when the residual strength of the liquefied soil is reduced below the static gravitational forces. (Kramer, 1996).

Table 18: Post Earthquake Slope Stability Analysis Results

Loading Conditions	Slope	Figure	Calculated FoS	Minimum CDA FoS
Post-earthquake (PGA, steady state seepage, highest seasonal reservoir level)	Downstream	E9	0.6	1.2
Post-earthquake (PGA, steady state seepage, lowest seasonal reservoir level)	Upstream	E10	0.8	1.2

5.7.3 Liquefaction During Earthquake Condition

It is possible that, for a longer duration earthquake, such as the subduction event, the loose sand could lose strength (i.e., liquefy) during the shaking, this is considered the Liquefaction During Earthquake condition.

The Liquefaction During Earthquake condition, should be analyzed, during conceptual design, to consider the effects of a longer duration earthquake (i.e., the subduction event). It was not analyzed in this assessment because the factors of safety for the static Post-earthquake Condition do not meet the CDA recommended values, and therefore some remediation of the dam is required.

For this condition, a horizontal acceleration and the residual strength of liquefied soils are analyzed together. To provide an estimate of how the embankment might perform in such a situation, potential embankment deformations can be estimated using the sliding block method (Newmark, 1965). The yield coefficient (i.e., the acceleration at which the slope begins to move), is then determined while assigning liquefied strengths to the loose sand zones. The relative displacement is then calculated using the ratio of the yield coefficient (Ky) and the PGA from the design event based on empirical data, which consider a large number of acceleration time-histories.

5.8 Internal Erosion Assessment

Piping potential (one mechanism of internal erosion) was identified as a concern at the Dam during the 2011 DSR. It was recommended that a toe drain or other piping measures be implemented. Tetra Tech did not receive drawings VI 6553-1-18 and 19 from August 1979, as part of the 2012 DSR and were unaware that a filter had been installed as part of the dam raise in 1979. Sieve results from the drilling investigation for the embankment fills have been compared to the filter specifications provided on drawing VI 6553-1-19, shown on Figure 5. Tetra Tech determined that the filter specifications meet the filter criteria and would allow free flow of water while holding back erodible material within the embankment fill. However, there is potential for piping erosion where the filter does not meet the bedrock surface and it is unclear whether the filter was extended down to the bedrock surface as no construction records are available for review.

Due to the risk that the filter does not extend to the bedrock, an internal erosion assessment has been completed for the embankment fills and foundation soils at The Dam.

5.8.1 General

Typically there are four different mechanisms in which internal erosion occurs (Fell, MacGregor, Stapledon, Bell, & Foster, 2015):

1. Concentrated Leak Erosion
2. Backward Erosion (Piping Erosion)
3. Contact Erosion
4. Suffusion

Tetra Tech analyzed laboratory results for samples obtained during the drilling exploration and determined that the embankment and foundation soils do not show a high susceptibility to concentrated leak erosion, or contact erosion because of the absence of cohesive soils, in which those types of erosion are more likely to occur. However, the embankment and foundation soils were found to be susceptible to piping erosion, and suffusion.

5.8.2 Backward Erosion (Piping Erosion)

Soil piping is a form of internal erosion, in which fine soil particles are carried by water through the dam forming a continuous pipe through the dam. These soil particles are often deposited as sand boils, which can be an indication of piping through the dam.

All of the following criterion have to be satisfied for soil piping to occur:

- The overlying soil must be able to form a roof to the pipe (soil fines content >15 % will likely hold a roof). *Based on the sieve analyses for the Dam, fines contents above 15% indicate that the dam embankment fills and foundation soils could hold a roof to the pipe.*

- Crack filling action does not stop the erosion process. *Gradation of the upstream rip rap zone is not available, therefore it is uncertain whether crack filling would occur.*

- Flows in the developing pipe will not be restricted by hydraulic losses in upstream and downstream zones. *Upstream and downstream rockfill zones may provide hydraulic losses to restrict piping, however these zones may not extend through any foundation soils to the bedrock surface, therefore there is potential for piping of the foundation soils.*

- The hydraulic gradient must cause large enough pressures to initiate erosion. *Hydraulic gradients required to prevent piping are estimated to be less than 1/25 for SAND (SM) soils (Department of Regional Economic Expansion, 1981). Based on the geometry of Section B the Hydraulic gradient is greater than 1/25.*

With the ability for the embankment and foundation soils to hold a roof, the unknown properties of the granular zone upstream of the core, the absence of any upstream zoning restricting pipe development and a high enough hydraulic gradient to initiate erosion. Tetra Tech concluded that the embankment fills and foundation soils are susceptible to piping erosion.

5.8.3 Suffusion

Suffusion occurs when water flows through internally unstable widely graded or gap graded cohesionless soils. Small particles of soil are transported by seepage flow through the pores of coarser particles.

All of the following criteria have to be satisfied for suffusion to occur:

- The size of the finer soil particles must be smaller than the size of the constrictions between the coarser particles;

- The voids of the basic skeleton formed by the coarser particles must be under filled; and

- The velocity of flow through the soil must be high enough to move the finer soil particles through the constrictions between the larger soil particles.

Gradations from soil samples obtained from the drilling exploration for MW16-02 and MW16-03 are not widely or gap graded. However, the existing seepage issues, occurrences of turbid seepage in the past, and ongoing depositions of silt fines at the centre downstream manhole are indications of erosion through the dam fill and/ or foundation soils. This along with high fines noted in monitoring well MW16-02 during water level measurements indicate that suffusion may be occurring within the Dam.

6.0 DISCUSSION

6.1 Risk Management

The design earthquake event used in this analysis is the 1/2475 year event, as recommended by the CDA. Tetra Tech understands that designing to such a low probability event can result in high remediation costs, if the dam were to be required to maintain normal function after a significant seismic event. By taking a risk management approach the dam owner would accept some damage will result from a significant seismic event, and repair will be required. In this report remediation is defined as preventative work and repair is defined as work done once failures have occurred. Remediation costs can then be reduced, by designing the dam to maintain safety of the public, but not to maintain normal function after an earthquake. The CRD would need to make the Dam a priority in any earthquake disaster emergency plans they currently maintain, and plan for disruption in the water supply system at the Dam.

Tetra Tech is available to discuss the risk informed approach process with the CRD.

6.2 Liquefaction

Liquefaction assessment is based on water levels measured in the dam during the drilling exploration; higher groundwater levels are expected in wetter months. Groundwater levels should be recorded when the lake is at the full supply level with lake level readings taken at the same time.

The liquefaction triggering assessment was completed for both the 1/2475 year event and the subduction event. Liquefiable soils were calculated for both seismic events with the results summarized in Table 15 and graphical representation included in Appendix F.

6.3 Slope Stability

6.3.1 Pseudo-static

At the normal operating level of 150.5 m, the freeboard is 1.5 m (based on crest elevation of 152 m amsl). With calculated maximum displacements (along the failure surfaces) of 65 cm and 50 cm, for the upstream and downstream slopes, respectively, resulting from the design seismic event, freeboard would be reduced from 1.5 m to 0.85 m and 1.0 m, respectively. With maintained freeboard of 0.85 m to 1.0 m, overtopping failure is unlikely, however, maintenance and repair would likely be required following the design seismic event. The pseudo-static condition considers liquefaction has not occurred after or during the seismic event.

6.3.2 Post-earthquake

Factors of safety below 1.0 for the upstream and downstream post-earthquake case indicate that a flow slide would likely occur as a result of the design seismic event. Some remediation of the dam is required to meet the CDA recommended Factors of Safety of 1.2 for the post-earthquake condition.

The Liquefaction During Earthquake condition, should be analyzed, during conceptual design, to consider the effects of a longer duration earthquake (i.e., the subduction event).

6.4 Internal Erosion

Based on historical drawing VI 6553-1-19 from August 1979, a filter was installed on the downstream slope of the Dam. The filter gradations provided on the drawing were checked against the dam fill gradations and the filter criteria is met. However, there is potential for erosion where the filter does not meet the bedrock surface and it is unclear whether the filter was extended down to the bedrock surface as no construction records are available for review.

Occurrences of turbid seepage in the past, ongoing depositions of silt fines at the centre downstream manhole and turbid water observed in MW16-02 (Photo 20) during the drilling exploration, are indications of erosion through the dam fill and/ or foundation soils.

It is noted that the construction of a filter and drainage system (toe drain) would reduce the probability of failure caused by piping erosion and suffusion. The purpose of a filter/toe drain is to limit internal erosion potential by holding back erodible material, while allowing water to drain freely away from the dam.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Tetra Tech made the following conclusions:

- Factors of safety greater than 1.5 were calculated for both the upstream and downstream slopes of the dam under static conditions (CDA recommended FoS = 1.5), indicating the stability of the embankment meets the minimum CDA static recommendations;
- Factors of safety below 1.0 were calculated for both the upstream and downstream pseudo-static analysis (CDA recommended FoS = 1.0), considering the full PGA of 0.48 g for the 1 /2,475 seismic event, indicating the stability of the embankment does not currently meet the minimum CDA pseudo-static recommendations. Deformations up to 65 cm will likely result from the design seismic event, assuming no liquefaction, for this condition, freeboard will be reduced, however, remaining freeboard should prevent overtopping of the dam;
- Factors of safety below 1.0 were calculated for the post-earthquake slope stability analysis (CDA recommended FoS = 1.2), for both the upstream and downstream slopes, indicating the embankment does not currently meet the minimum CDA recommendations. Factors of safety below 1.0 for post-earthquake also indicate the potential for a flow slide to occur. Such flow slides may cause release of the reservoir;
- Repair of the dam will be required following the design seismic event; and
- Based on the erosion assessment, the embankment and foundation soils are susceptible to two forms of internal erosion; piping erosion and suffusion. There is a downstream filter/toe drain at the Dam, however it is not known if it extends down to the underlying bedrock. Installing a filter/toe drain, downstream of the existing filter, extending to bedrock, would limit the potential internal erosion.

Tetra Tech recommends the following be undertaken to meet the CDA guideline recommendations and to improve dam safety at The Dam:

- Remedial measures be implemented to reduce the risk of internal erosion;
- Remedial measures be implemented to reduce the impacts of a seismic event;
- Record monitoring well levels and lake level on a monthly basis;
- Update the Dam Emergency Plan (DEP) and Emergency Preparedness Plan (EPP) for the Dam; and
- The Liquefaction During Earthquake condition, should be analyzed, during conceptual design, to consider the effects of a longer duration earthquake (i.e. the subduction event).

7.1 Remedial Options

Tetra Tech has outlined conceptual options to address the above recommendations include Option 1: Complete dam removal and construction of a new dam, and Option 2: Risk Management: Adding a downstream buttress and filter/toe drain, and updating the DEP and EPP appropriately.

It should be noted that Tetra Tech has considered undertaking ground improvement of the liquefied soils, however this option does not address the erosion issues within the dam (i.e., installation of a toe drain would still be required) and it could result in high remedial costs.

Option 1: Major Rehabilitation: Complete dam removal and construction of a new dam

Complete dam removal and construction of a new dam would mean high remediation costs up front, however the new dam would be designed to meet the CDA recommended factors of safety for static, seismic and post earthquake conditions. The new dam would also be designed to mitigate erosion potential and to reduce seepage through the dam.

Option 2: Risk Management: Downstream buttress and filter/toe drain, and updates to DEP/EPP

One solution Tetra Tech has used successfully in the past is to provide a coarse rockfill buttress on the downstream toe to reduce the impacts of failure. A filter/toe drain would be incorporated into the design of the buttress to address potential erosion.

Installation of a buttress on the downstream slope of the dam would not mitigate failure of the upstream slope. The primary purpose of the buttress would be to provide adequate mass to the dam so that the downstream slope remains in place and a sudden discharge of water would not occur during or shortly after a seismic event that would cause complete failure of the upstream slope and crest of the dam with associated loss of freeboard and subsequent overtopping failure. Following the seismic event that causes failure of the upstream slope, the retained water would discharge at a rate which would reduce downstream impacts. The buttress would not, however, constitute a permanent post seismic event stabilization measure as it will leak significantly after failure of the upstream slope of the dam. The CRD would need to make the Dam a priority in the DEP and EPP, as repair of the dam would be required. The simplicity of construction of a buttress is considered appropriate for the setting of this project.

It should be noted that installation of a buttress and filter/toe drain would not aid in reducing the amount of seepage that is escaping the dam. Reduction of seepage through the dam would require cutting off seepage upstream or within the dam core. This could be done by installing a membrane on the upstream slope of the dam or a cutoff wall could be installed through the crest of the dam. It should be noted that if the stability issue and erosion issue are addressed by constructing a buttress with a filter/toe drain, the seepage issues on their own do not present a dam safety concern, but is considered an operational issue.

Tetra Tech is available to discuss the buttress option, among other remedial options to determine the best application for this project.

8.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

Oct 13, 2016

J. D. SINCLAIR
31580

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/dr

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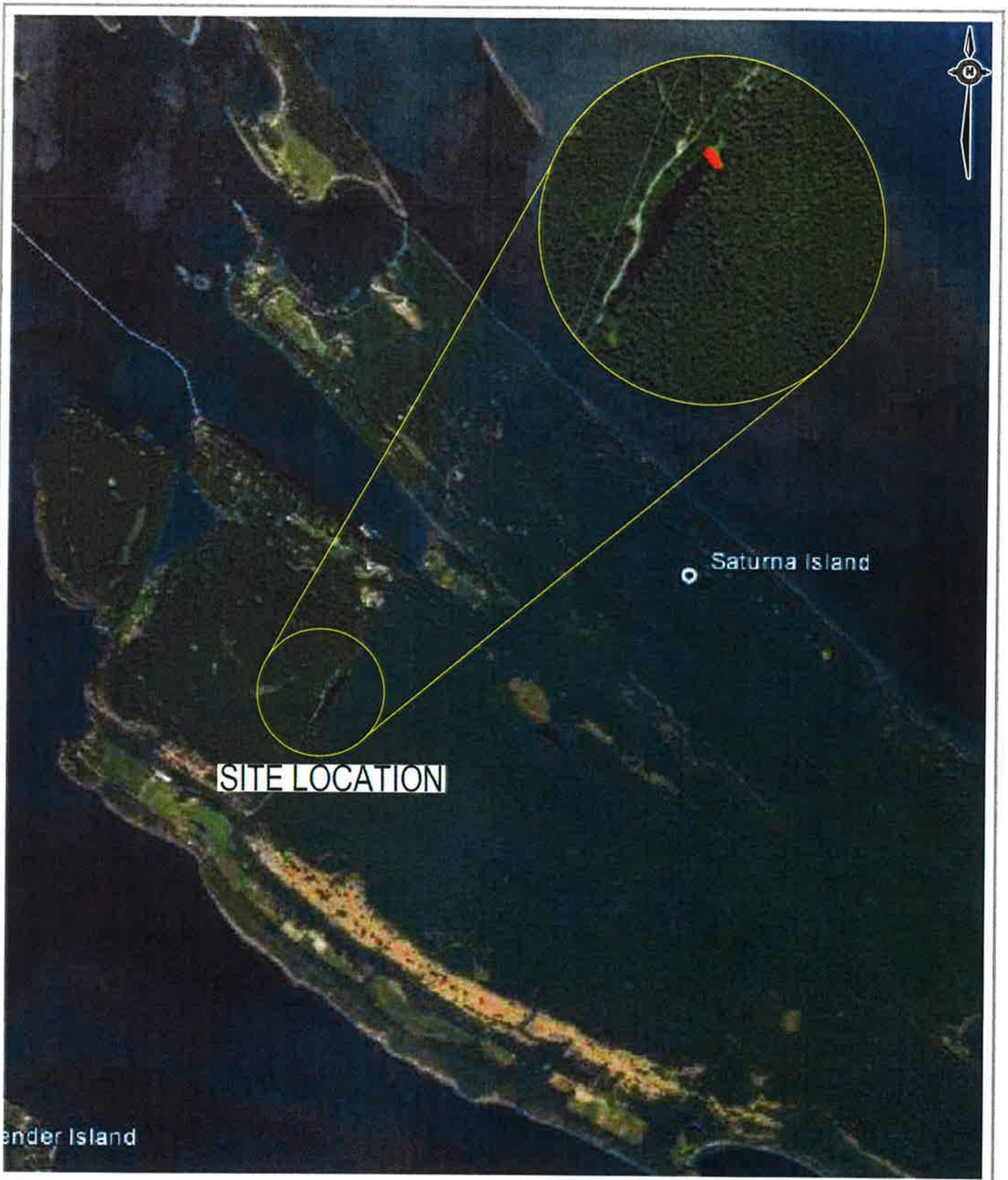
FIGURES



NOTES

BASED ON GOOGLE EARTH IMAGE

ISSUED FOR USE

CLIENT

CRD

TETRA TECH EBA

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

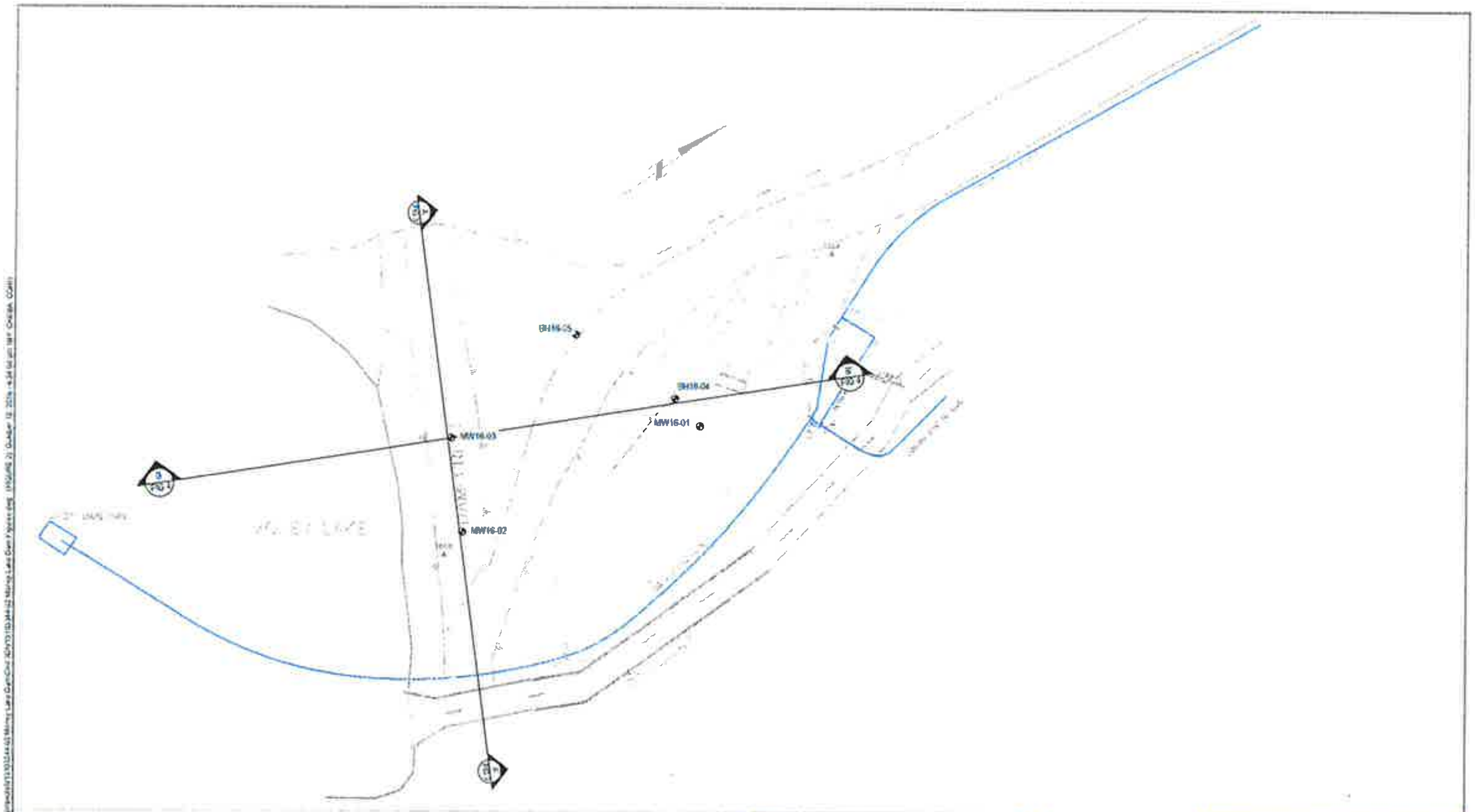
SITE LOCATION PLAN

PROJECT NO.	DWN	CKD	REV
V13103344-02	CC	JDS	0

OFFICE	DATE
NANAIMO	October 12, 2016

Figure 1

Q:\Nanaimo\Engineering\N131\Projects\projects\V13103344-02 Money Lake Dam\Civil 3D\V13103344-02 Money Lake Dam Figures.dwg [FIGURE 1] October 12, 2016 - 6:24:07 pm (BY: CRESBA, CORI)



LEGEND

NOTES
BASED ON TOPOGRAPHY PROVIDED BY THE CRD

0 15m
Scale: 1:300 @ 11"x17"

ISSUED FOR USE

CRD

TETRA TECH EBA

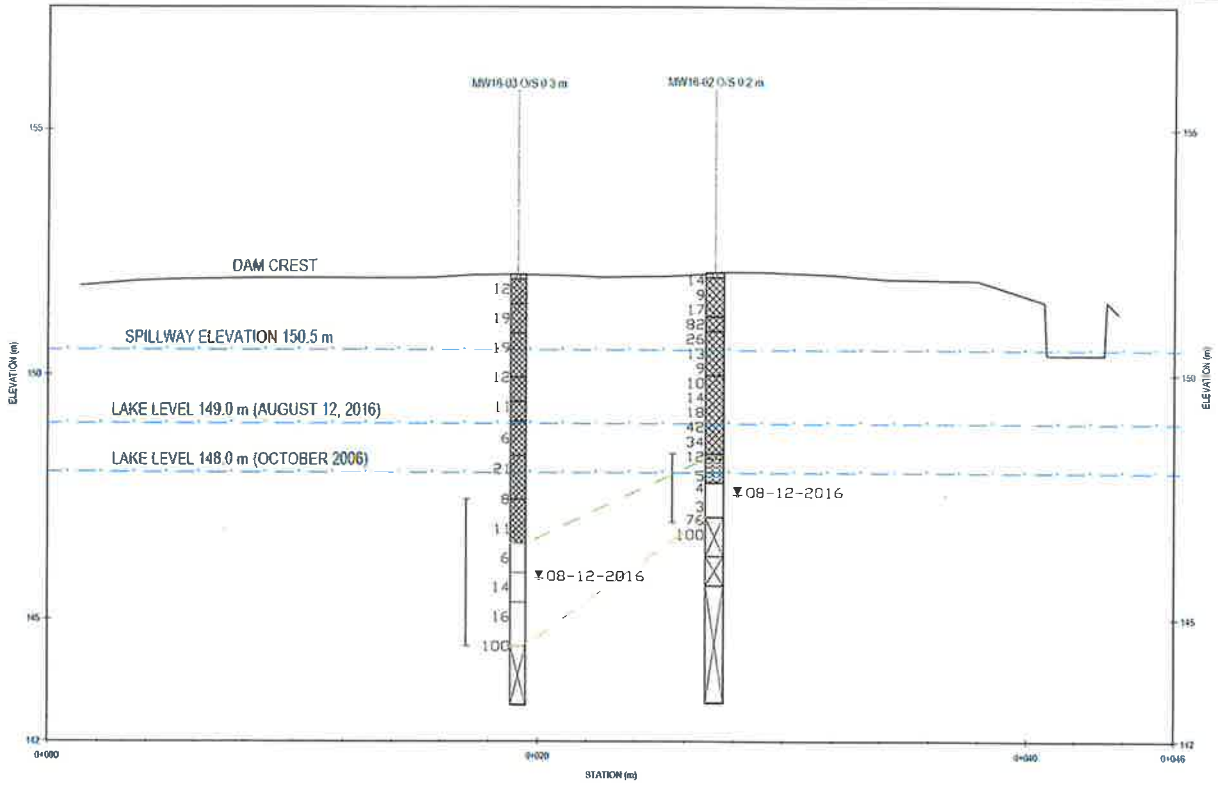
Money Lake Dam Geotechnical Exploration
Saturna Island, BC

Borehole Location Plan

PROJECT NO.	DWN	CKD	REV
Y131033402	CC	JDS	0

OFFICE	DATE
Nanaimo	October 12, 2016

Figure 2



Section A - A'

LEGEND

▨	GRAVEL	— · — ·	WATER LEVELS
▦	FILL	— —	LOOSE SAND LAYER
▥	SILT AND SAND	- - -	SANDSTONE BEDROCK SURFACE
☐	SAND	≋	ORGANICS
☒	SANDSTONE		

NOTES
BASED ON TOPOGRAPHY PROVIDED BY THE CRD

0 Vertical 2.5m
Scale 1:75 @ 11"x17"

0 Horizontal 5m
Scale 1:150 @ 11"x17"

ISSUED FOR USE

CLIENT
CRD

TETRA TECH EBA

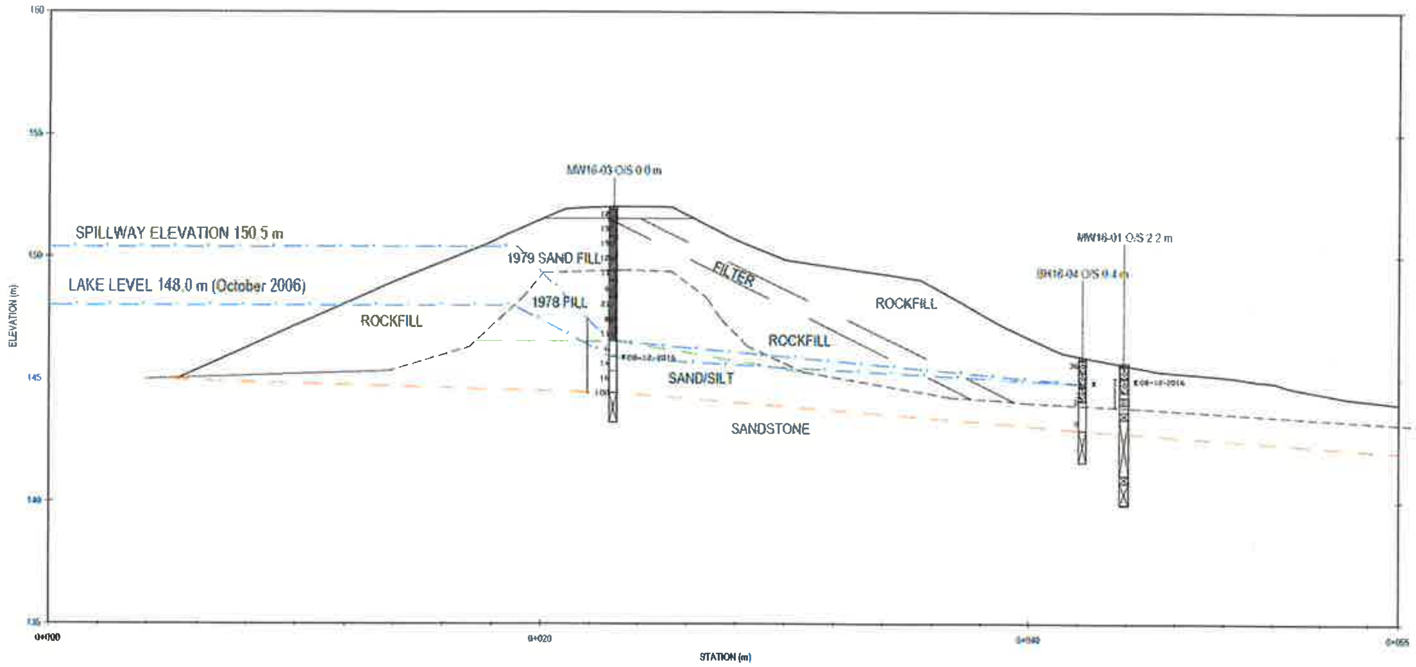
Money Lake Dam Geotechnical Exploration
Saturna Island, BC

GEOTECHNICAL CROSS-SECTION A - A'

PROJECT NO.	DWN	CKD	REV
V13103034-02	CC	JDS	0

OFFICE	DATE
Nanaimo	October 12, 2016

Figure 3



SECTION B - B'

LEGEND

▨ GRAVEL

☒ FILL

▥ SILT AND SAND

☐ SAND

☒ SANDSTONE

GROUNDWATER

FILTER

ORIGINAL GROUND SURFACE BEOFORE DAM RAISE 1979

SANO FILL 1979

SAND/SILT LAYER

SANDSTONE BEDROCK

NOTES

BASED ON TOPOGRAHPY PROVIDED BY THE CRD AND DRAWING VI 6563-L-18

0 5m

Scale 1:150 @ 11"x17"

ISSUED FOR USE

TETRA TECH

Money Lake Dam Geotechnical Exploration
Saturna Island, BC

GEOTECHNICAL CROSS-SECTION B - B'

PROJECT NO.	DWN	CKD	REV
Y13103334-02	CC	JDS	0

OFFICE	DATE
Nanaimo	October 12, 2016

Figure 4

PHOTOGRAPHS

Photo 1: Looking upstream from access road

Photo 2: Looking towards right abutment from access road

Photo 3: Left abutment contact and downstream slope

Photo 4: Looking downstream from left abutment at the dam crest


2016/08/11

Photo 5: Old road extending upstream of left (west) abutment


2016/08/10

Photo 6: Crest and upstream slope at left abutment

Photo 7: Dam crest looking towards left abutment

Photo 8: Log boom and staff gauge looking towards left side of the lake from the spillway

Photo 9: Staff Gauge

2016/08/12

Photo 10: Upstream slope looking towards left abutment from spillway

Photo 11: Spillway and bridge

Photo 12: Spillway looking downstream from bridge

Photo 13: Dam crest looking towards right abutment

Photo 14: Looking downstream from crest at MW16-01

Photo 15: Drilling at the dam crest

Photo 16: Drilling at the dam crest

Photo 17: Drilling at the downstream toe

Photo 18: MH 1 and MH2 locations and drilling BH16-05

Photo 19: MW16-02 and MW16-03 at dam crest

Photo 20: MW16-02 muddy water on end of water reading tape

APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA's Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA's Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA's instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

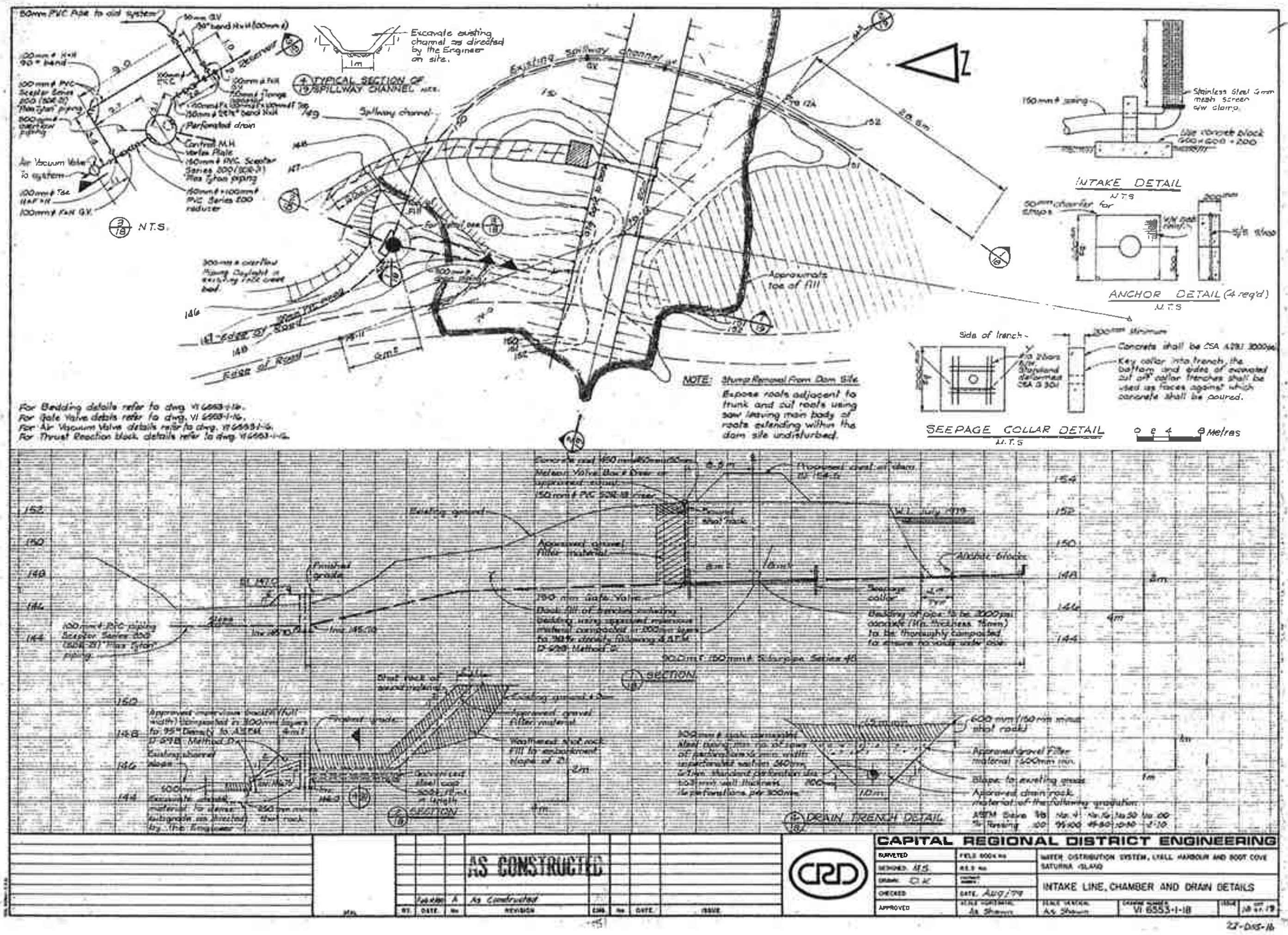
Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

HISTORICAL DRAWINGS



AS CONSTRUCTED

BY	DATE	No.	REVISION
	Aug/80	A	As Constructed

CAPITAL REGIONAL DISTRICT ENGINEERING

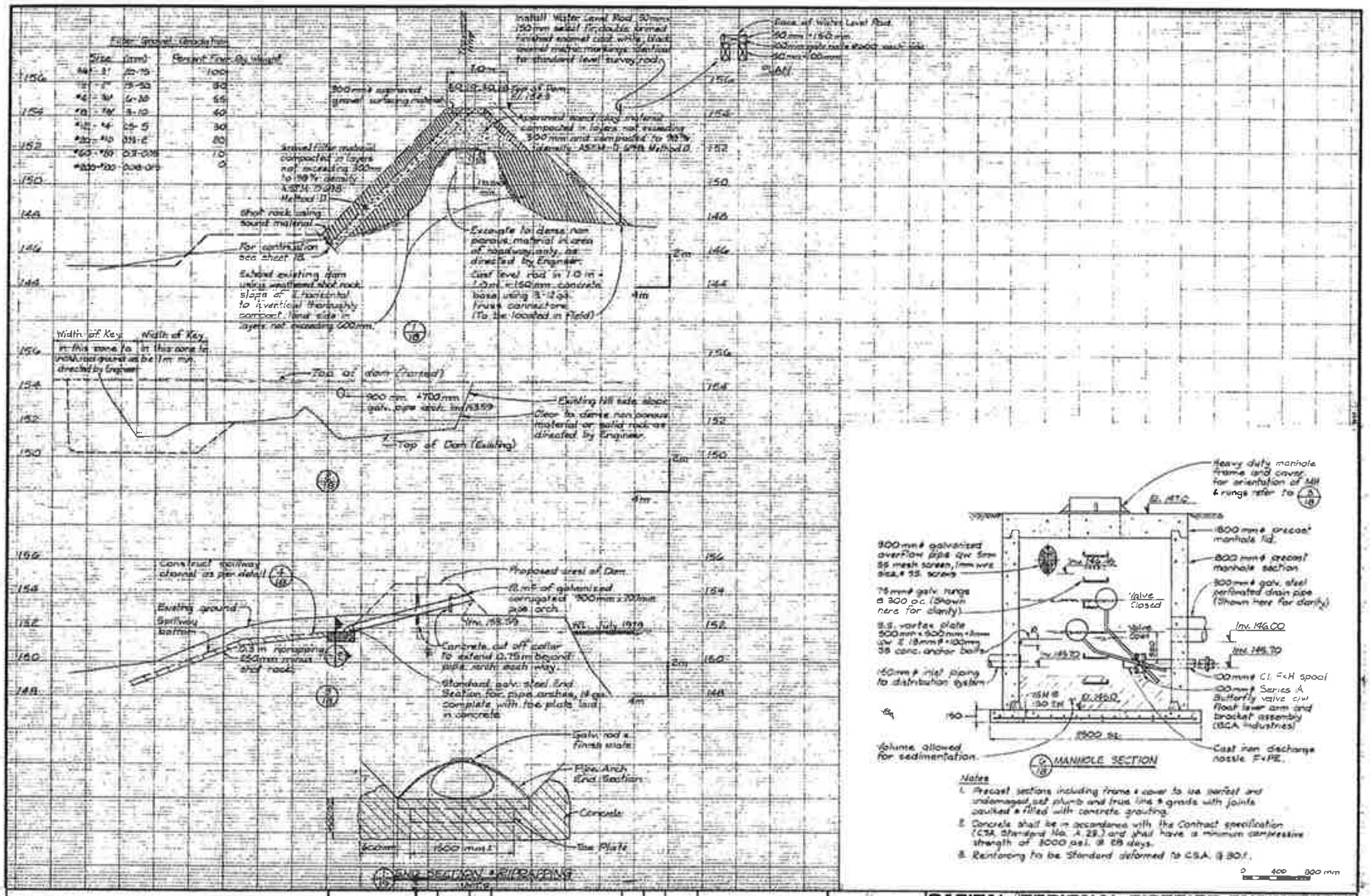
SURVEYED
DESIGNED: M.S.
DRAWN: D.K.
CHECKED
APPROVED
FIELD BOOK No.
DATE: Aug/79
SCALE HORIZONTAL: As Shown
SCALE VERTICAL: As Shown

WATER DISTRIBUTION SYSTEM, LYALL HARBOUR AND BOOT COVE SATURNA ISLAND

INTAKE LINE, CHAMBER AND DRAIN DETAILS

DRAWING NUMBER: VI 6553-1-18

27-DIS-16



Filter Gravel Gradation

Size	(mm)	Percent Fine By Weight
1½"-1"	25-19	100
½"-⅛"	13-3.2	80
#4 - ⅜"	6-38	65
#8 - #16	3-10	40
#16 - #4	25-5	30
#30-#10	0.5-2	20
#60-#30	0.3-0.05	10
#200-#100	0.08-0.15	0

Notes

1. Precast sections including frame & cover to be perfect and undamaged, set plumb and true line & grade with joints caulked & filled with concrete grouting.
2. Concrete shall be in accordance with the Contract specification (CSA Standard No. A 23.) and shall have a minimum compressive strength of 3000 psi. @ 28 days.
3. Reinforcing to be Standard deformed to CSA. G 30.1.

BY	DATE	No.	REVISION	CHD.	No.	DATE	ISSUE
	Feb/80	A	As Constructed				

SEAL

CAPITAL REGIONAL DISTRICT ENGINEERING

SURVEYED
DESIGNED M.S.
DRAWN C.K.
CHECKED
APPROVED

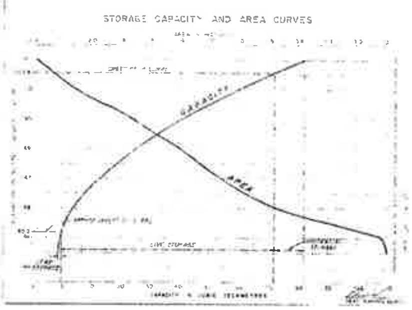
FIELD BOOK No.
R.E.S. No.
DATE Aug 1979
SCALE HORIZONTAL As Shown
SCALE VERTICAL As Shown
DRAWING NUMBER VI 6553-1-19
SHEET 19 of 19

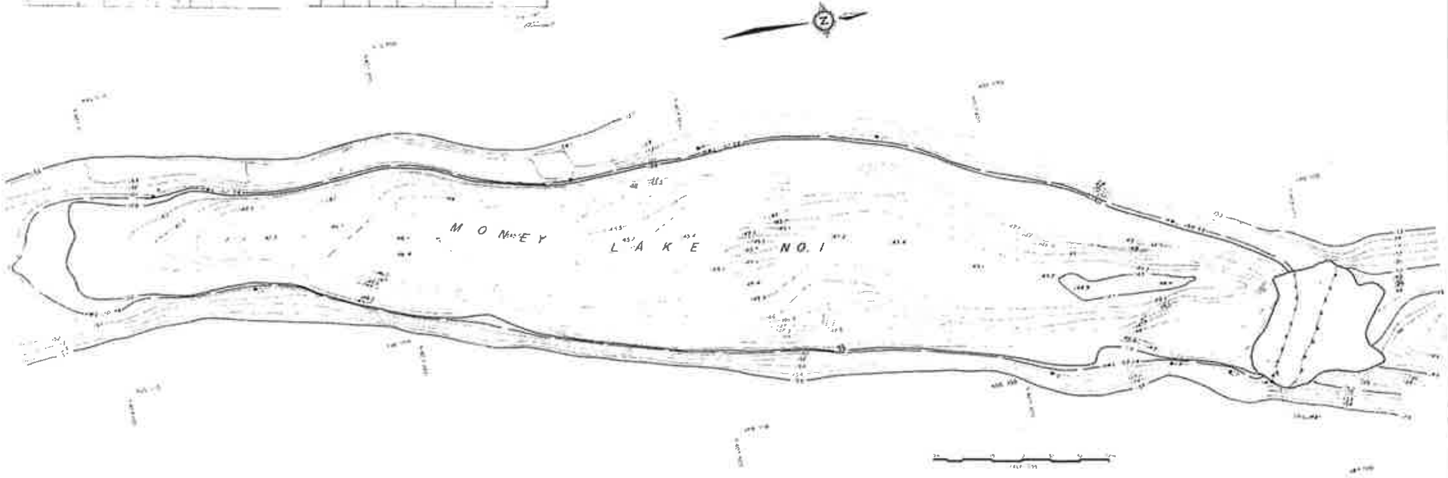
WATER DISTRIBUTION SYSTEM, LYALL HARBOUR AND BOOT COVE
SATURNA ISLAND

DAM, SPILLWAY AND MANHOLE CHAMBER DETAILS

27-DIIS-17

STORAGE CAPACITY TABLE





FOR NOTES SEE DWG. No. 4977-52

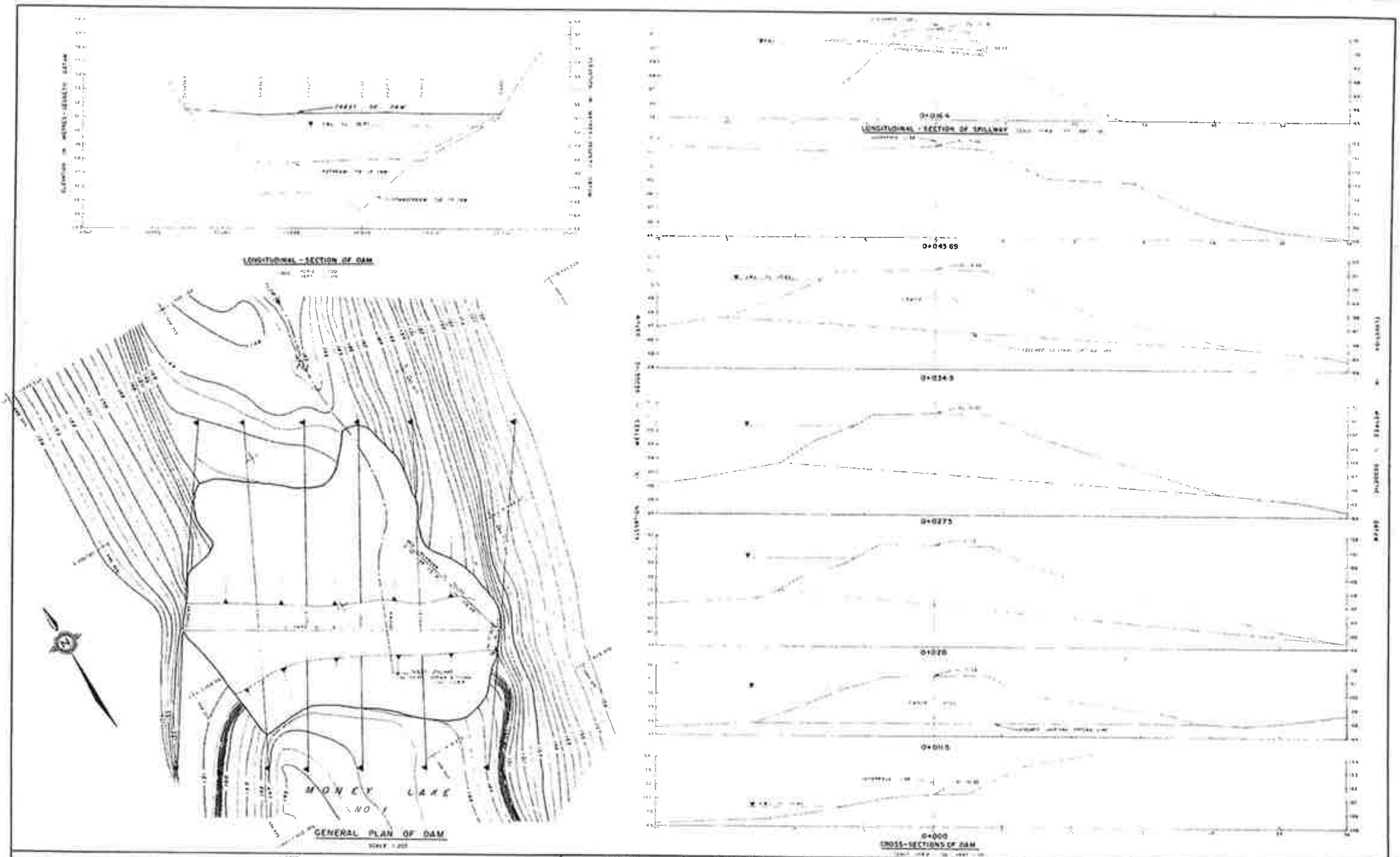
LEGEND	STORAGE LICENCES	REFERENCES	REVISIONS

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

MONEY LAKE NO I RESERVOIR

PLAN OF RESERVOIR

DDs



NOTES

LEGEND

STORAGE LICENCES

REFERENCES

REVISIONS

Province of British Columbia

Ministry of Environment
WATER MANAGEMENT BRANCH

STORAGE INVENTORY PROGRAMME
SALT SPRING ISLAND - COASTAL ISLANDS SYSTEM

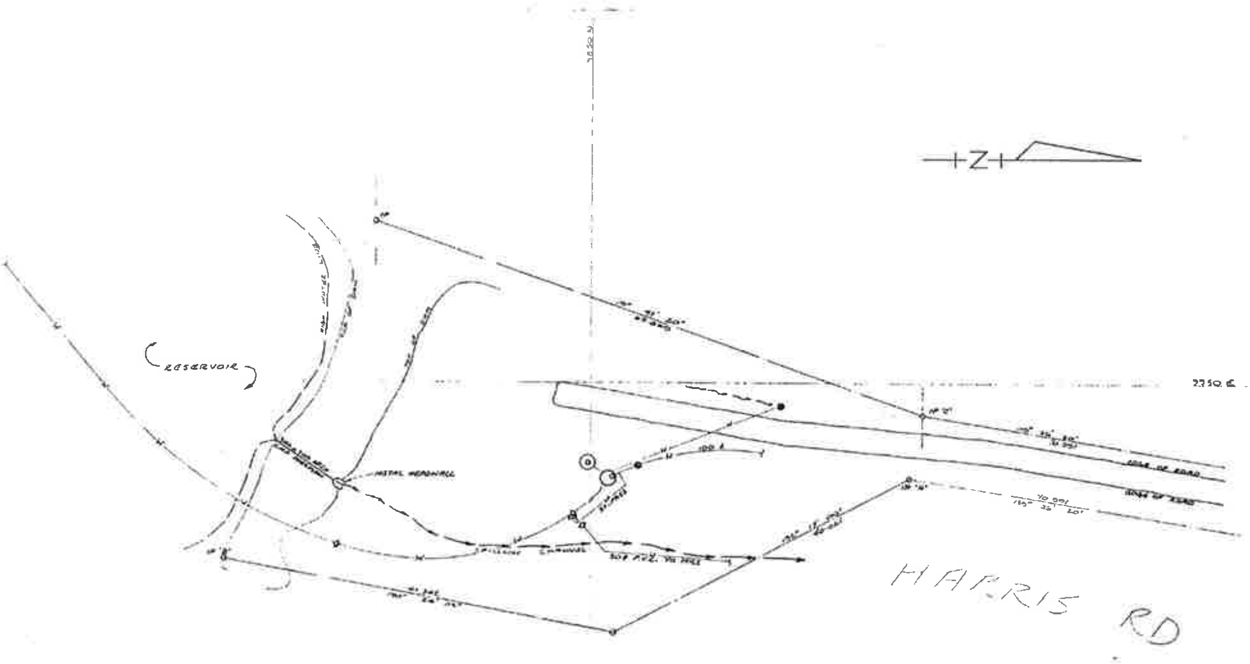
MONEY LAKE NO. I RESERVOIR
GENERAL PLAN OF DAM

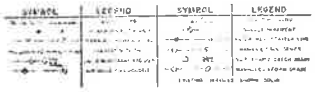
APPROVED

4977-52A

DC

27-D-01-22



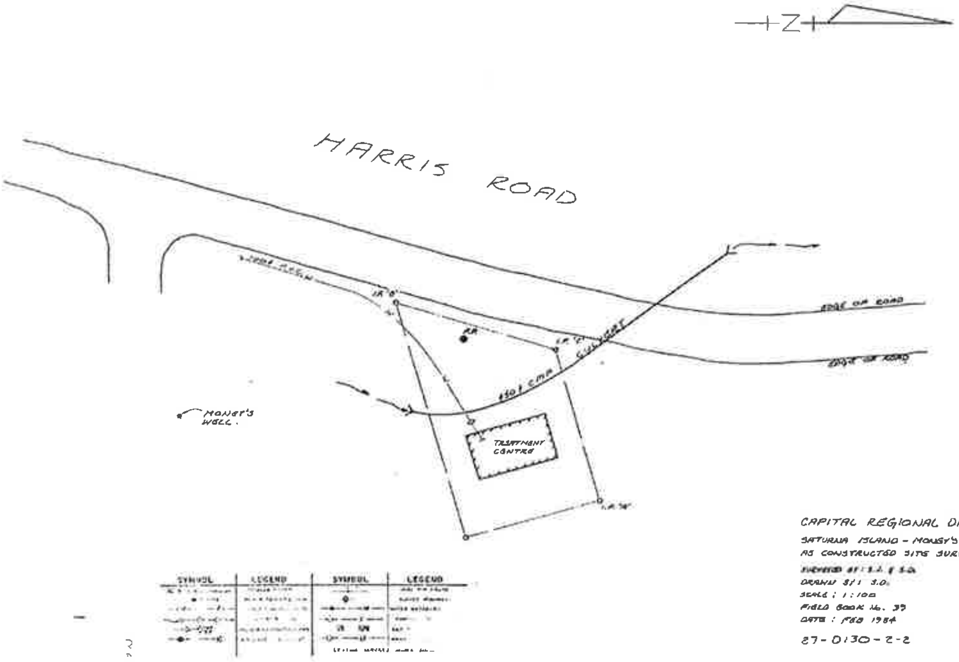


CAPITAL REGIONAL DISTRICT

SATURNA ISLAND - MONEY'S DAM
AS CONSTRUCTED SITE SURVEY

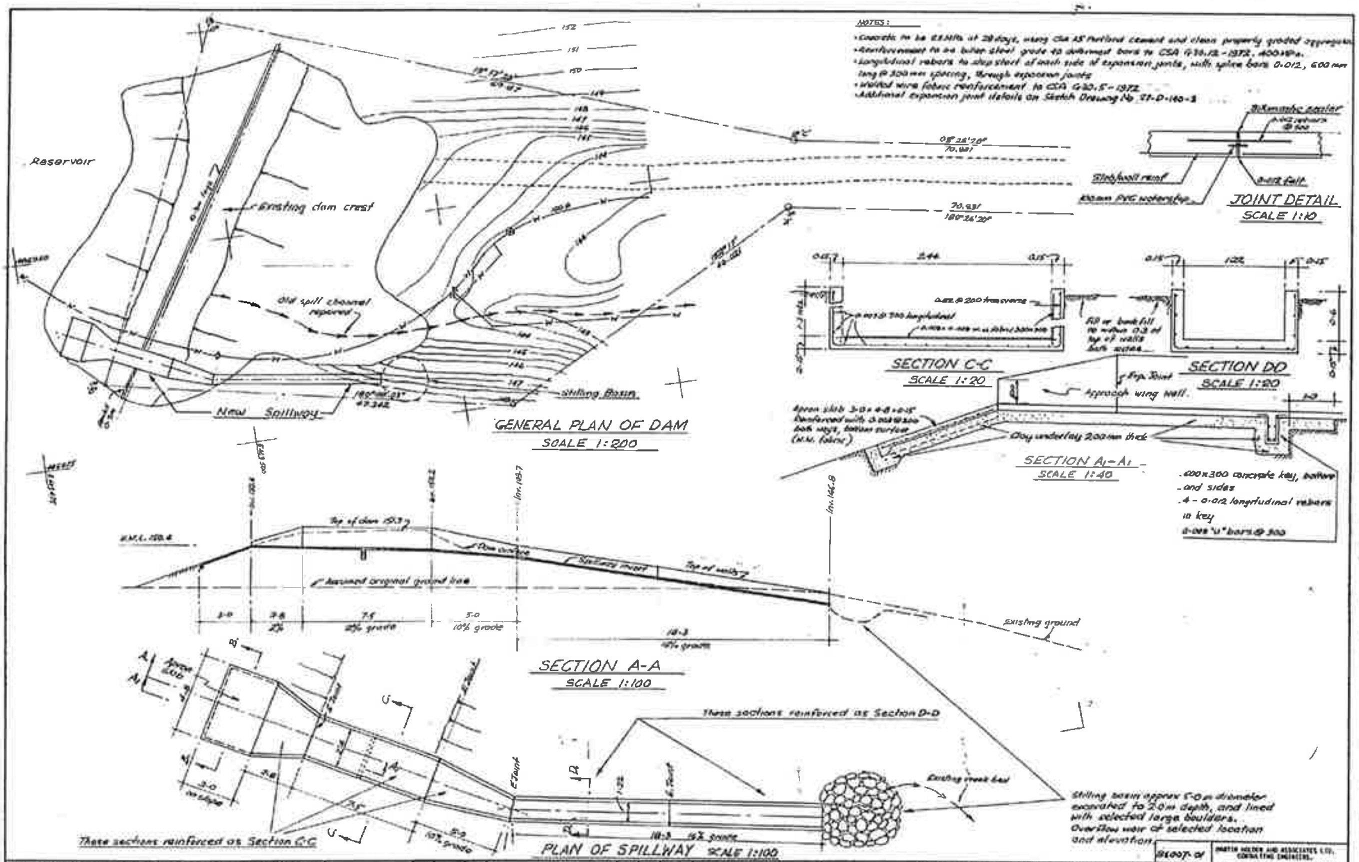
SURVEY BY : S.L. & E.D.
DRAWN BY : E.D.
FIELD BOOK No. 33
DATE JAN. 1984
SCALE : 1:200

27 - D130 - 1 - 2



CAPITAL REGIONAL DISTRICT
SATURNA ISLAND - MONEY'S DAM
AS CONSTRUCTED SITE SURVEY
SURVEYED BY : S.J. & S.O.
DRAWN BY : S.O.
SCALE : 1:100
FIELD BOOK No. 39
DATE : FEB 1984

27-0130-2-2



NOTES:

- Concrete to be 25 MPa at 28 days, using CSA 15 Portland cement and clean properly graded aggregate.
- Reinforcement to be billet steel grade 40 deformed bars to CSA G30.12-1972, 400 MPa.
- Longitudinal rebars to stop short at each side of expansion joints, with splice bars 0.012, 600 mm long @ 300 mm spacing, through expansion joints
- Welded wire fabric reinforcement to CSA G30.5-1972
- Additional expansion joint details on Sketch Drawing No 27-D-180-3

Stilling basin approx 5.0 m diameter excavated to 2.0 m depth, and lined with selected large boulders. Overflow weir of selected location and elevation.

Revisions Issue B: Channel shortened; clay [illegible] and stilling pool reduced.
Issue C: channel shortened on general plan. Aug 14 1986
Issue D: As constructed

86007-01
MARTIN HOLDEN AND ASSOCIATES LTD. CONSULTING ENGINEERS.

CAPITAL REGIONAL DISTRICT ENGINEERING

LYALL HARBOUR-BOOTCOVE WATER COM.
MONEY LAKE #1 - PROPOSED SPILLWAY
REINFORCED CONCRETE ALTERNATIVE

SURVEYED	FIELD BOOK No	
DESIGNED	R.E.S. No	
DRAWN	86-886	
CHECKED	DATE Aug 26-1986	
APPROVED	SCALE AS NOTED	SCALE AS NOTED
DRAWING NUMBER 27-D-180-1	ISSUE D	

CAPITAL REGIONAL DISTRICT

PROJECT 86-893 MONEY LAKE #1 SPILLWAY - SATURNA IS.

GEOMETRY OF SPILLWAY - AS LAID OUT AT SITE ON AUGUST 29TH 1986.

MARTIN HOLDEN AND ASSOCIATES LTD.
CONSULTING ENGINEERS,
VICTORIA, B.C.

DWG NO 27-D-140 - 05 ISSUE A
August 29-1986
M Holden PEng

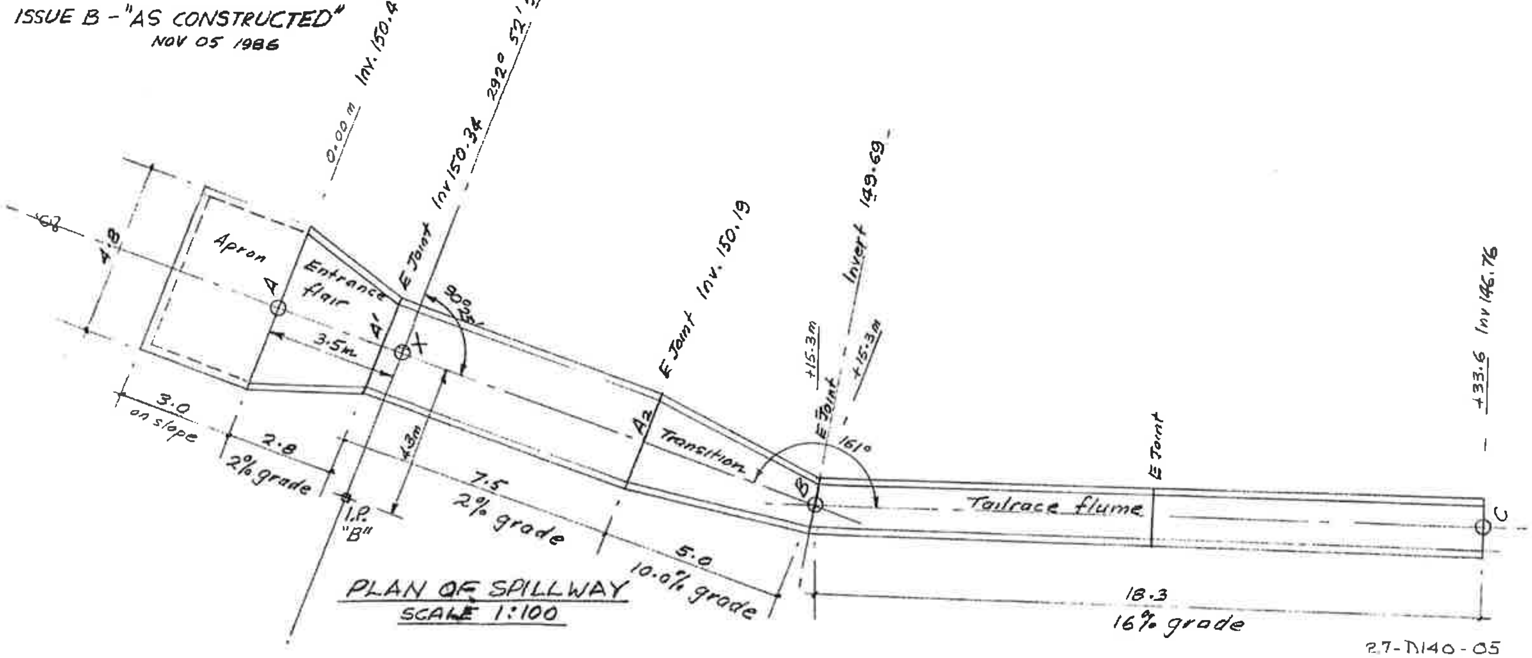
86007-05 CRD CONTRACT 86-893

ISSUE B - "AS CONSTRUCTED"
NOV 05 1986

A = Centre line at 0.00 - Start of entrance flair
Grade stake at A is invert - El. 150.4

B = Centre line at +15.3m - Downstream end of transition section. ℄ changes direction 19° here
Grade stake at B is 1.0m above invert elev. at.

C = Centre line at +33.6m - Downstream end of tailrace flume
Grade stake at C is 2.0m above invert at C.



PLAN OF SPILLWAY
SCALE 1:100

27-D140-05

APPENDIX C

BOREHOLE LOGS

The Capital Regional District

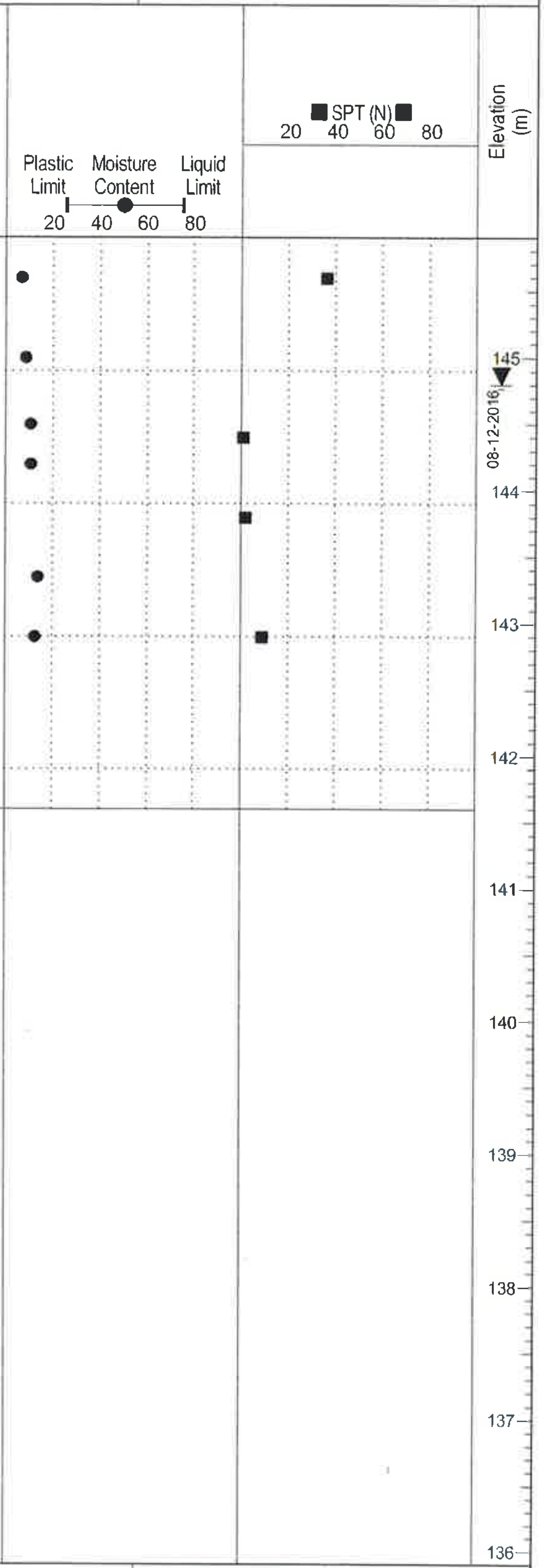
Borehole No: **BH16-04**

Project: Money Lake Dam Geotechnical Exploration	Project No: V13103344-02
Location: Money Lake Dam	Ground Elev: 145.9 m
Saturna Island, BC	UTM: 5403719.2 N; 486859.5 E; Z10 NAD83

Method: Sonic

Soil Description	Sample Number	SPT (N)	Moisture Content (%)
TOPSOIL and GRASS			
GRAVEL and SAND (GM-GP), some silt, damp, dense, brown	1 2	36	6.7
GRAVEL (GP), some sand, trace silt, wet, brown	3		8.5
- groundwater observed at depth of 1.1 m			
GRAVEL and SAND (GW), trace silt, wet, very loose, brown	5 4 6	1	10.6 10.7
SAND (SM), gravelly, some silt, wet, very loose, grey	7	2	
	8		13.7
	10 9	9	12.5
SANDSTONE (SM), silty, damp, brown, harder drilling	11 12 13 14 15		
End of borehole at 4.3 m - Target Depth Borehole was backfilled with bentonite upon completion			

Groundwater: 08-12-2016



Contractor: Drillwell Enterprises	Completion Depth: 4.3 m
Drilling Rig Type: Track Mounted Sonic	Start Date: August 12, 2016
Logged By: CC	Completion Date: August 12, 2016
Reviewed By: JDS	Page 1 of 1

TETRA TECH

The Capital Regional District

Borehole No: **BH16-05**

Project: Money Lake Dam Geotechnical Exploration	Project No: V13103344-02
Location: Money Lake Dam	Ground Elev: 148.3 m
Saturna Island, BC	UTM: 5403706 N; 486853 E; Z10 NAD83

Depth (m)	Method	Soil Description	Sample Number	Moisture Content (%)
0	Sonic	TOPSOIL and GRASS		
		SILT (ML), some clay, some sand, soft (inferred), moist, brown	1	35.8
1		GRAVEL (GP-GM), sandy, some silt, damp, brown	2	8.5
		- becomes some sand at 1.2 m	3	10.2
2			4	4
		- sample displaced by drilling between 2.3 and 2.7 m		
3		GRAVEL (GM), some silt, some sand, moist, brown	5	7.1
		- groundwater observed at 3.4 m	6	3.8
		GRAVEL (GP), cobbly, some sand, trace silt, moist, brown		
4		SAND and SILT (SM), gravelly, trace clay, trace organics, moist, grey	7	14.9
		SILT (ML), some sand, trace clay, soft, moist, grey	8	20.2
5		SANDSTONE (SM), some silt, damp, grey, harder drilling	9 10	
6			11	
		End of borehole at 6.4 m - Target Depth Borehole backfilled with bentonite upon completion		

08-12-2016

Elevation (m): 148, 147, 146, 145, 144, 143, 142, 141, 140, 139

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

TETRA TECH

Contractor: Drillwell Enterprises	Completion Depth: 6.4 m
Drilling Rig Type: Track Mounted Sonic	Start Date: August 12, 2016
Logged By: CC	Completion Date: August 12, 2016
Reviewed By: JDS	Page 1 of 1

The Capital Regional District

Borehole No: **MW16-01**

Project: Money Lake Dam Geotechnical Exploration	Project No: V13103344-02
Location: Money Lake Dam	Ground Elev: 145.7 m
Saturna Island, BC	UTM: 5403719 N; 486862; Z10 NAD83

Depth (m) | Method | Soil Description | Graphical Representation | Sample Type | Sample Number | Moisture Content (%) | Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80 | MW16-01 | Elevation (m)

Method: Sonic

Water level: 08-12-2016

Soil Description	Sample Number	Moisture Content (%)
TOPSOIL and GRASS		
GRAVEL, (GM-GP), some sand, some silt, some cobbles, wet, brown; sub angular gravel and cobbles	1	11.4
- becomes grey at 0.6 m	2	11.4
SAND (SM), some cobbles, some silt, trace gravel, moist, grey	3	11.3
SAND and SILT (SM), trace clay, moist, brown, grey and black	4	16.8
SAND (SM), silty, trace clay, moist, grey	5	15.9
SANDSTONE (SM), silty, damp, grey	6	6.6
- becomes some silt, trace clay, dry, brown, harder drilling	7	
	8	
	9	
	10	
	11	
- becomes grey and much harder drilling at 4.6 m	12	
	13	
- becomes brown at 4.9 m	14	
	15	
End of Borehole at 5.8 m - Target depth Monitoring well installed upon completion		

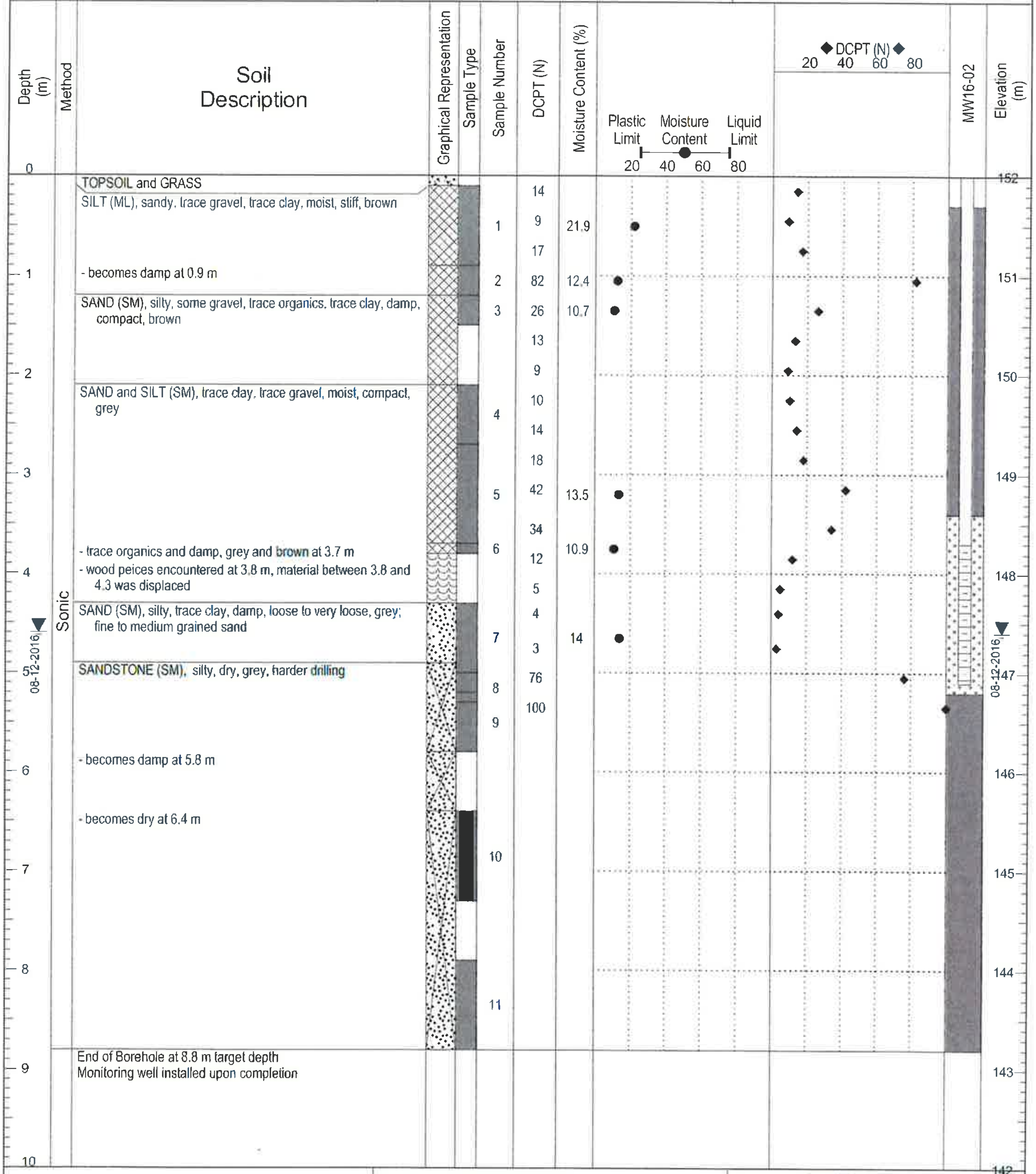
Contractor: Drillwell Enterprises	Completion Depth: 5.8 m
Drilling Rig Type: Track Mounted Sonic	Start Date: August 10, 2016
Logged By: CC	Completion Date: August 10, 2016
Reviewed By: JDS	Page 1 of 1

TETRA TECH

The Capital Regional District

Borehole No: MW16-02

Project: Money Lake Dam Geotechnical Exploration	Project No: V13103344-02
Location: Money Lake Dam	Ground Elev: 152 m
Saturna Island, BC	UTM: 5403697 N; 486857 E; Z10 NAD83



Soil Description

- TOPSOIL and GRASS
- SILT (ML), sandy, trace gravel, trace clay, moist, stiff, brown
  - becomes damp at 0.9 m
- SAND (SM), silty, some gravel, trace organics, trace clay, damp, compact, brown
- SAND and SILT (SM), trace clay, trace gravel, moist, compact, grey
  - trace organics and damp, grey and brown at 3.7 m
  - wood peices encountered at 3.8 m, material between 3.8 and 4.3 was displaced
- SAND (SM), silty, trace clay, damp, loose to very loose, grey; fine to medium grained sand
- SANDSTONE (SM), silty, dry, grey, harder drilling
  - becomes damp at 5.8 m
  - becomes dry at 6.4 m

End of Borehole at 8.8 m target depth
Monitoring well installed upon completion

Sample Number	DCPT (N)	Moisture Content (%)
	14	
1	9	21.9
	17	
2	82	12.4
3	26	10.7
	13	
	9	
	10	
4	14	
	18	
5	42	13.5
	34	
6	12	10.9
	5	
	4	
7	3	14
	76	
8	100	
9		
10		
11		

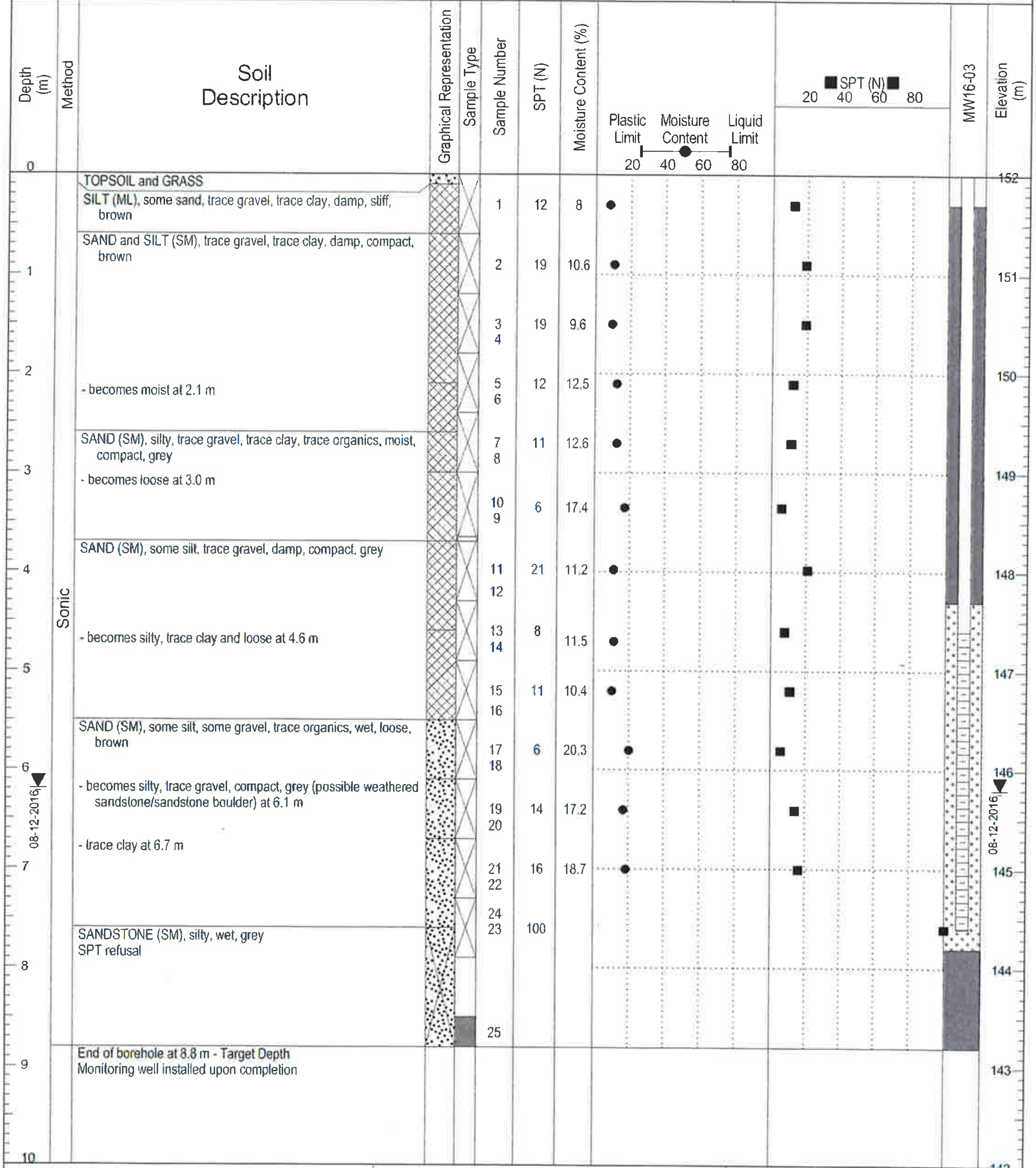
Contractor: Drillwell Enterprises	Completion Depth: 8.8 m
Drilling Rig Type: Track Mounted Sonic	Start Date: August 11, 2016
Logged By: CC	Completion Date: August 11, 2016
Reviewed By: JDS	Page 1 of 1

TETRA TECH

The Capital Regional District

Borehole No: MW16-03

Project: Money Lake Dam Geotechnical Exploration	Project No: V13103344-02
Location: Money Lake Dam	Ground Elev: 152 m
Saturna Island, BC	UTM: 5403702 N; 486849 E; Z10 NAD83



Soil Description	Sample Number	SPT (N)	Moisture Content (%)
TOPSOIL and GRASS			
SILT (ML), some sand, trace gravel, trace clay, damp, stiff, brown	1	12	8
SAND and SILT (SM), trace gravel, trace clay, damp, compact, brown	2	19	10.6
	3 4	19	9.6
- becomes moist at 2.1 m	5 6	12	12.5
SAND (SM), silty, trace gravel, trace clay, trace organics, moist, compact, grey	7 8	11	12.6
- becomes loose at 3.0 m	10 9	6	17.4
SAND (SM), some silt, trace gravel, damp, compact, grey	11	21	11.2
	12		
- becomes silty, trace clay and loose at 4.6 m	13 14	8	11.5
	15 16	11	10.4
SAND (SM), some silt, some gravel, trace organics, wet, loose, brown	17 18	6	20.3
- becomes silty, trace gravel, compact, grey (possible weathered sandstone/sandstone boulder) at 6.1 m	19 20	14	17.2
- trace clay at 6.7 m	21 22	16	18.7
	24 23	100	
SANDSTONE (SM), silty, wet, grey SPT refusal	25		

End of borehole at 8.8 m - Target Depth
Monitoring well installed upon completion

TETRA TECH

Contractor: Drillwell Enterprises	Completion Depth: 8.8 m
Drilling Rig Type: Track Mounted Sonic	Start Date: August 11, 2016
Logged By: CC	Completion Date: August 11, 2016
Reviewed By: JDS	Page 1 of 1

APPENDIX D

LABORATORY RESULTS

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Money Lake Dam Engineering Assessment	Sample No.:	361
Project No.:	V13103344-02	Date Tested:	August 16, 2016
Client:	Capital Regional District	Tested By:	BG
Address:		Page:	1 of 2

B.H. Number	Sample Number and Depth (m)	Moisture Content (%)	Visual Description of Soil
MW16-01	G2 0- 1.2	11.4	GRAVEL (GM-GP), some sand, some silt, wet, brown
	G3 1.2-1.4	11.3	SAND (SM), some silt, trace gravel, moist, brown
	G4 1.4-1.7	16.8	SAND and SILT (SM), trace clay, moist, brown and grey
	G5 1.7- 2.0	15.9	SAND (SM), silty, trace clay, moist, grey
	G6 2.0- 2.3	6.6	SANDSTONE (SM), silty, damp, grey
	G8 2.7- 3.7		SANDSTONE (SM), some silt, trace clay, weak, dry brown
MW16-02	G1 0.1-0.9	21.9	SILT (ML), sandy, trace gravel, trace clay, soft, moist, brown
	G2 0.9- 1.2	12.4	SILT (ML), sandy, trace clay, damp, brown
	G3 1.2- 1.5	10.7	SAND (SM), silty, some gravel, trace clay, damp, grey
	G4 1.5- 2.7	13.1	SAND (SM), some silt, trace clay, trace gravel, damp, grey
	G5 2.7- 3.7	13.5	SAND and SILT (SM), trace gravel, trace clay, damp, grey
	G6 3.7- 3.8	10.9	SAND (SM), some silt, trace clay, trace gravel, trace organics, damp, grey brown
	G7 4.3- 5.0	14.0	SAND (SM), silty, trace clay, fine to medium grain, damp, grey
	G8 5.3- 5.9		SANDSTONE (SM), silty, damp, grey
MW16-03	SPT1 0-0.6	8.0	SILT (ML), some sand, trace gravel, damp, brown
	SPT2 0.6-1.2	10.6	SAND and SILT (SM), trace gravel, trace clay, damp, brown
	SPT3 1.2-1.8	9.6	SAND (SM), some silt, trace gravel, damp, brown
	SPT5 1.8- 2.4	12.5	SAND (SM), some silt, damp, brown
	SPT7 2.4-3.0	12.6	SAND (SM), some silt, trace gravel, moist, brown
	SPT9 3.0-3.7	17.4	SAND (SM), some silt, some gravel, moist, brown
	SPT11 3.7- 4.3	11.2	SAND (SM-SP), some silt, trace gravel, damp, brown
	SPT13 4.3-4.9	11.2	SAND (SM-SP), some silt, trace gravel, damp, brown
	SPT15 4.9-5.5	10.4	SAND (SM), some silt, trace gravel, damp, brown
	SPT17 5.5-6.1	20.3	SAND and SILT (SM), trace organics, damp, dark brown

Reviewed By: ______________________ C.E.T.

TETRA TECH

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project: Money Lake Dam Dam Safety Review

Project No.: V13103344-02

Client: Capital Regional District

Address:

Sample No.: 361

Date Tested: August 16, 2016

Tested By: BG

Page: 1 of 2

B.H. Number	Sample Number and Depth (m)	Moisture Content (%)	Visual Description of Soil
MW16-03	G18 5.5-6.1	16.4	SANDSTONE (SM), silty, some gravel, trace clay, moist, grey
	G19 6.1-6.7	17.2	SANDSTONE (SM), silty, trace gravel, damp, grey
	G19 6.7- 7.3	18.7	SAND, silty, trace clay, moist, grey
	G23		SANDSTONE (SM), silty, wet, grey
BH16-04	SPT1 0-0.6	6.7	GRAVEL and SAND (GM-GP), some silt, damp, brown
	G3 0.6-1.2	8.5	GRAVEL (GP), some sand, trace silt, wet, brown
	G5 1.2-1.8	10.6	GRAVEL and SAND (GW), trace silt, wet, brown
	G6 1.8	10.7	GRAVEL (GM), sandy, some silt, wet, brown
	G8 1.8-2.7	13.7	SAND (SM), gravelly, some silt, wet, grey
	SPT9 3.1	12.5	SAND (SM), silty, trace gravel, damp, brown
BH16-05	G1 0-0.6	35.8	SILT (ML), some clay, some sand, soft, moist, brown
	G2 0.6-1.2	8.5	GRAVEL (GP-GM), sandy, some silt, damp, brown
	G3 1.2-2.1	10.2	GRAVEL (GP-GM), some sand, some silt, damp, brown
	G4 2.1-2.3	4.0	GRAVEL (GP-GM), some sand, some silt, damp, brown
	G5 2.7-3.4	7.1	GRAVEL (GM), some silt, some sand, moist, brown
	G6 3.4	3.8	GRAVEL (GP), cobbly, some sand, trace silt, moist, brown
	G7 3.7-4.3	14.9	SAND and SILT (SM), gravelly, trace clay, trace organics, moist, grey
	G8 4.3-5.0	20.2	SILT (ML), some sand, trace clay, soft, moist, grey
	G9 5.3-5.5		SANDSTONE (SM), some silt, weak, damp, grey

Reviewed By: ______________________ C.E.T.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: MW16-02

Depth: G3 1.2-1.7 m

Soil Description: SAND (SM), silty, some gravel, trace organics, damp

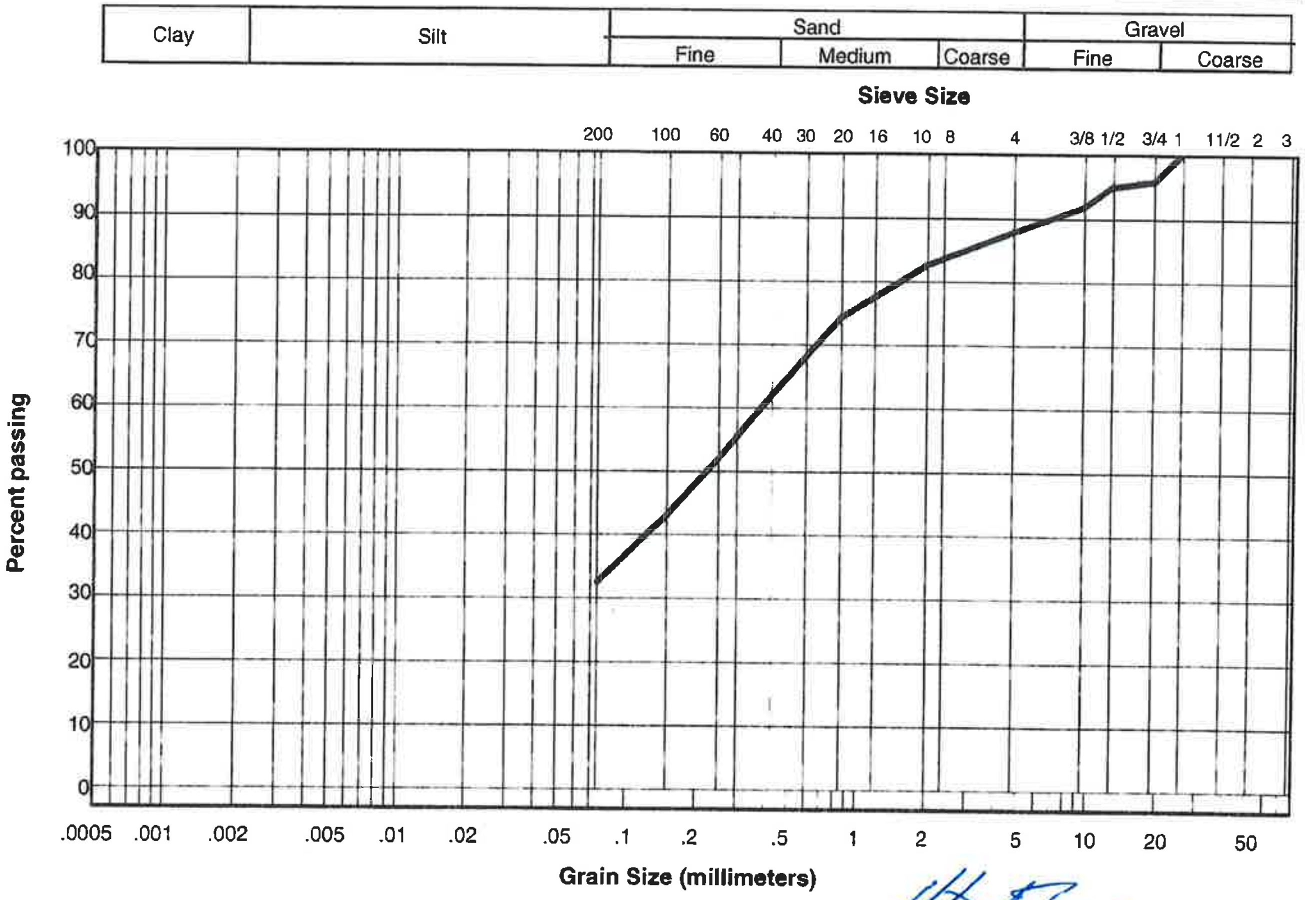
Cu:

Cc:

Natural Moisture Content: 10.7%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	100
19.000	96
12.500	95
9.500	92
4.750	88
2.000	83
0.850	74
0.425	62
0.250	52
0.150	43
0.075	32



Reviewed By: _______________ C.E.T.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: MW16-02

Depth: G4 1.5-2.7 m

Soil Description: SAND (SM) and SILT, trace gravel, trace clay, damp

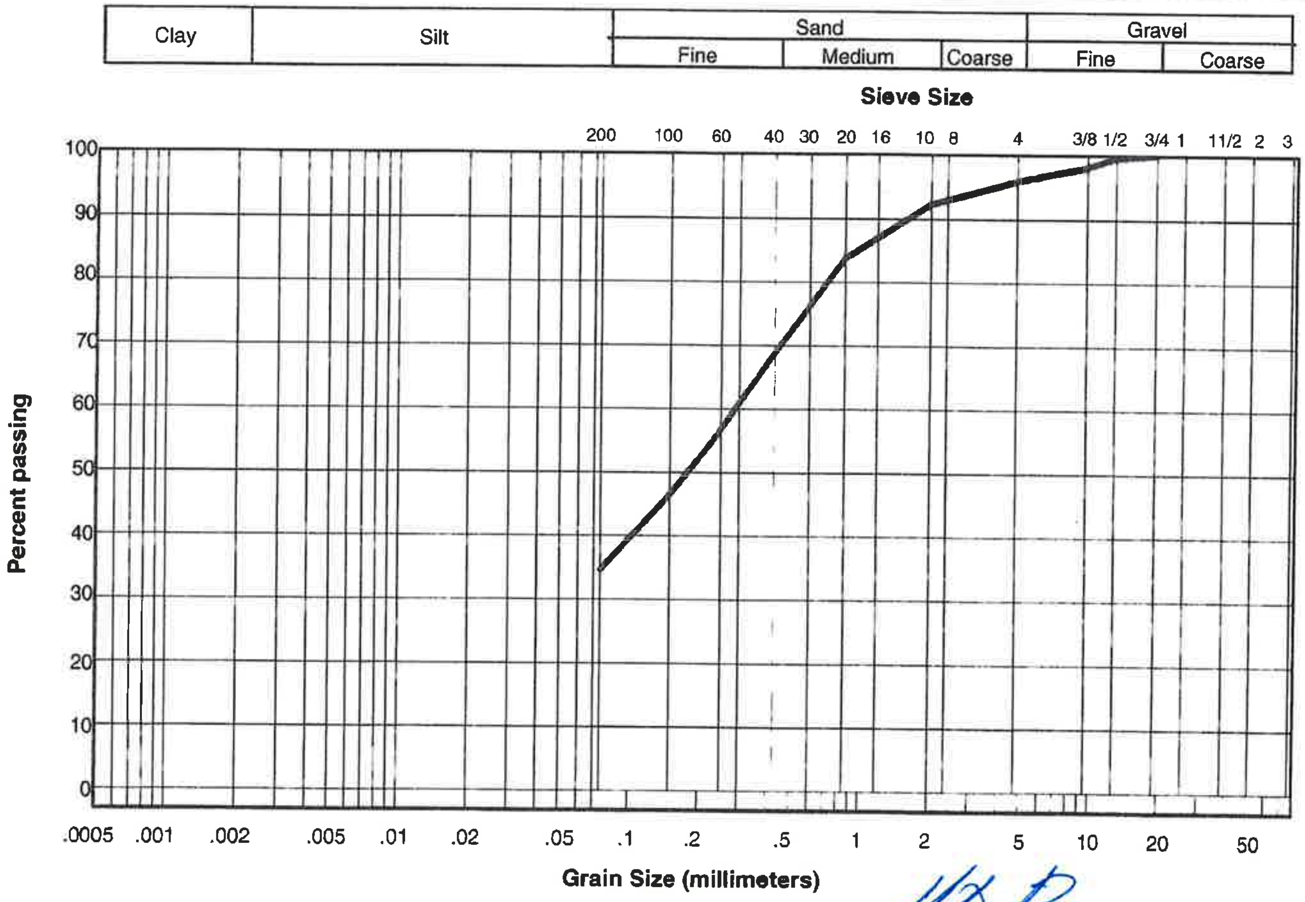
Cu:

Cc:

Natural Moisture Content: 13.1%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	100
12.500	100
9.500	98
4.750	96
2.000	92
0.850	84
0.425	69
0.250	57
0.150	47
0.075	35



Reviewed By: C.E.T.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: MW16-02

Depth: G7 4.3-5.0 m

Soil Description: SAND (SM), silty, trace clay, damp, grey

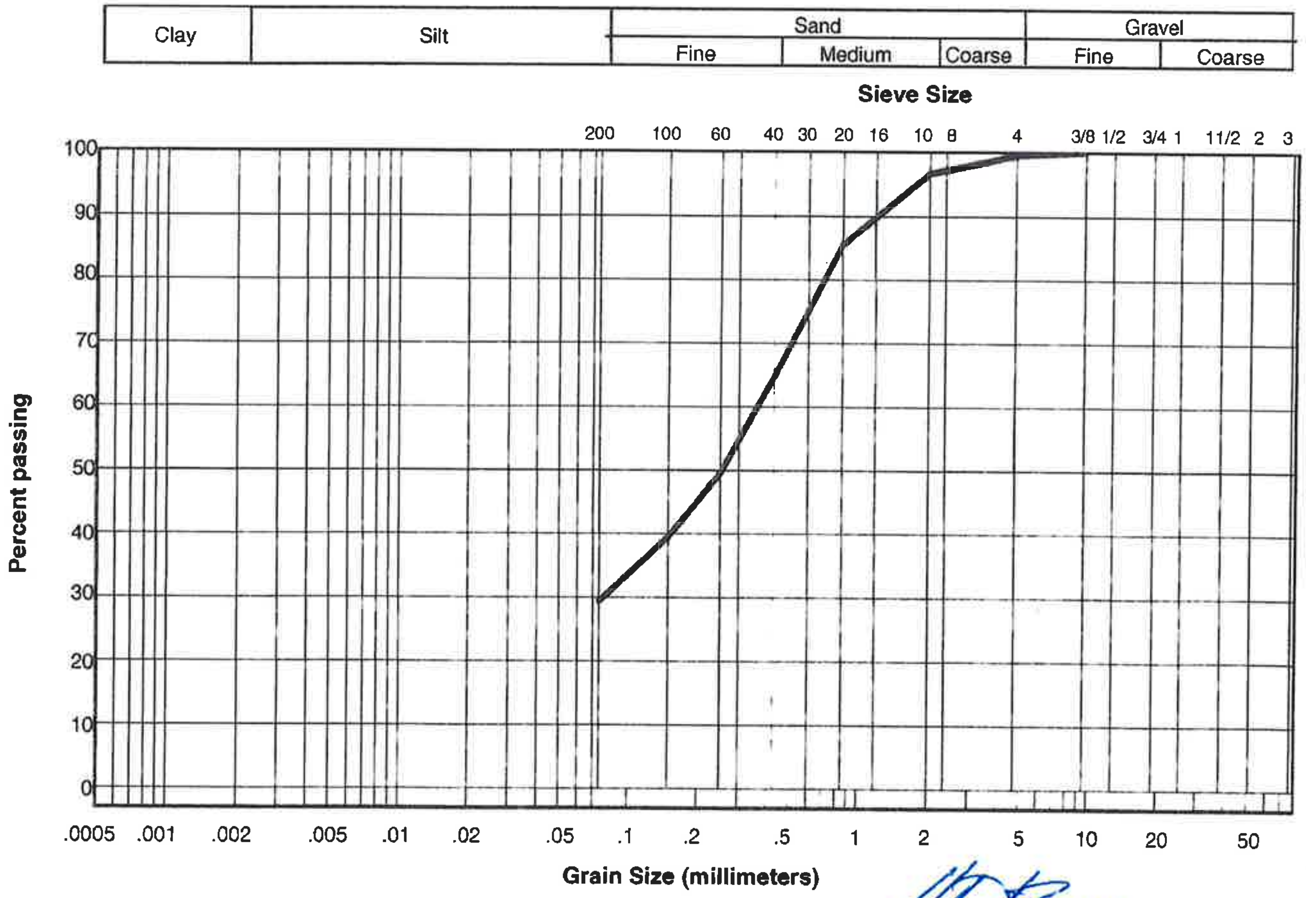
Cu:

Cc:

Natural Moisture Content: 14.0%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	#N/A
12.500	#N/A
9.500	100
4.750	100
2.000	97
0.850	86
0.425	65
0.250	50
0.150	39
0.075	29



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PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 26, 2016

Borehole Number: MW16-03

Depth: G6

Soil Description: SAND and SILT (SM), trace gravel, trace clay, damp

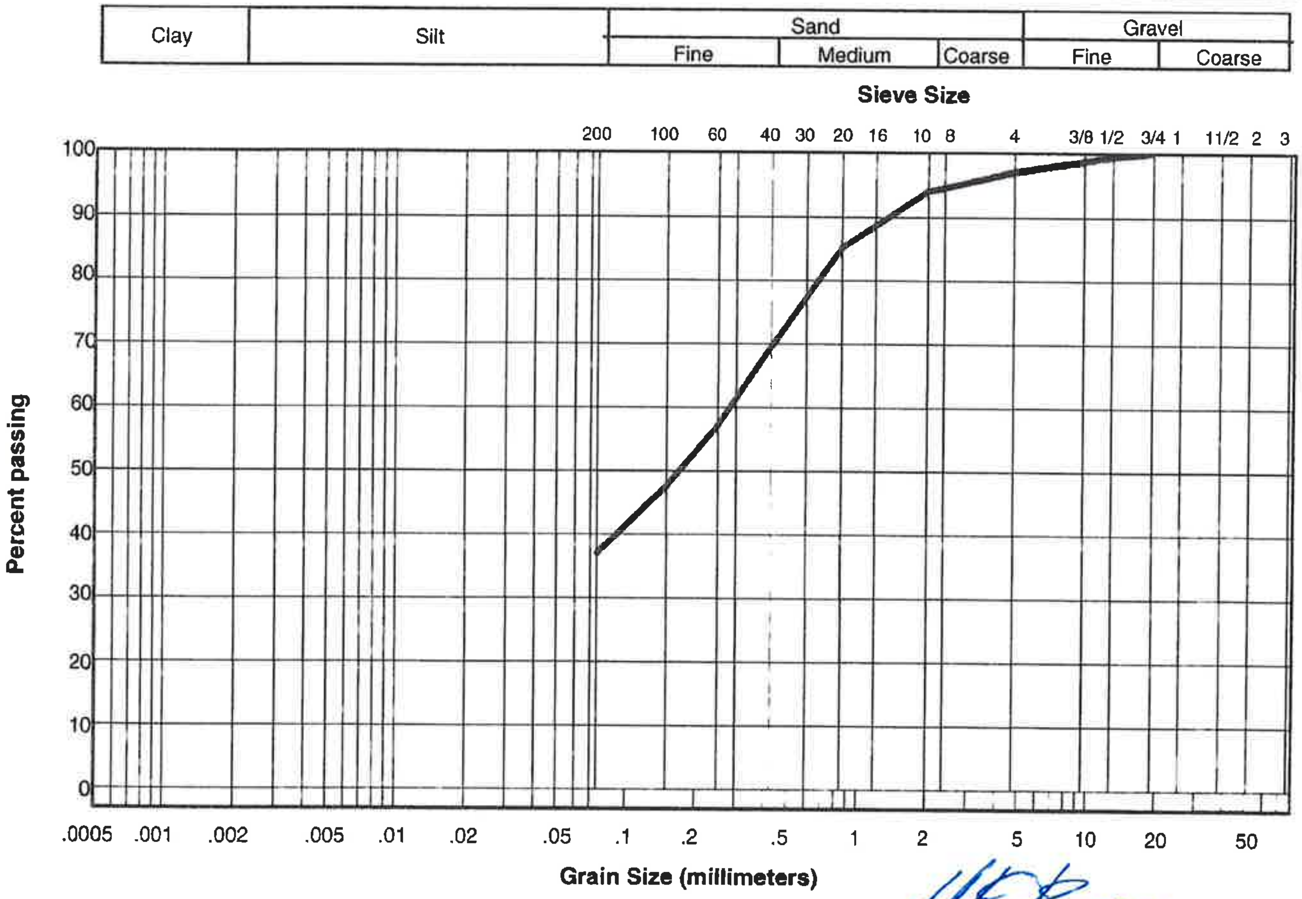
Cu:

Cc:

Natural Moisture Content: 10.3%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	100
12.500	99
9.500	99
4.750	97
2.000	94
0.850	85
0.425	70
0.250	57
0.150	48
0.075	37



Reviewed By: C.E.T.

TETRA TECH

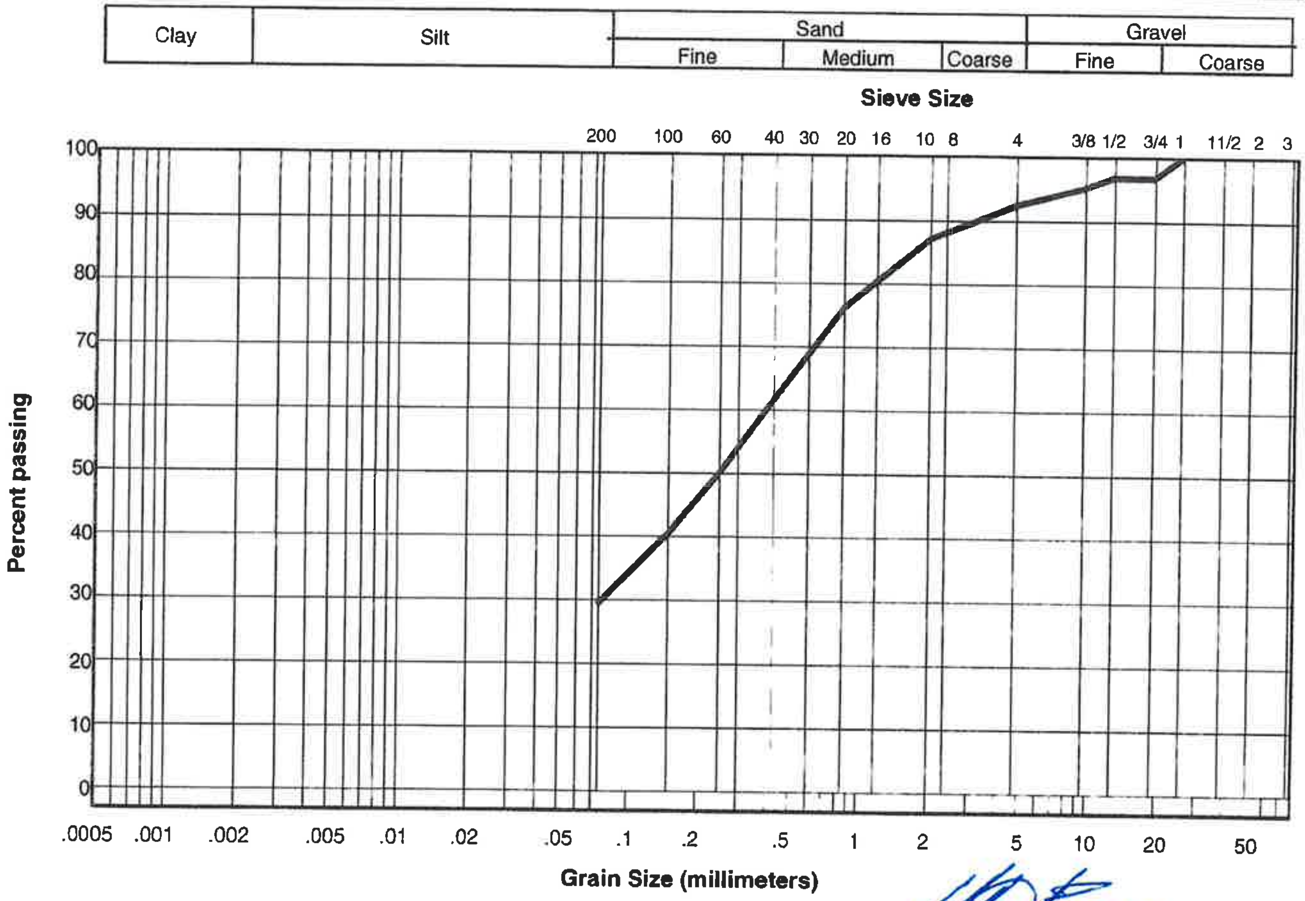
PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02
Date Tested: August 26, 2016
Borehole Number: MW16-03
Depth: G10 @ 3.0-3.7 m
Soil Description: SAND (SM), silty, trace gravel, trace clay, moist, brown
Cu:
Cc:
Natural Moisture Content: 16.6%
Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	100
19.000	97
12.500	97
9.500	95
4.750	93
2.000	87
0.850	76
0.425	62
0.250	50
0.150	40
0.075	30



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TETRA TECH

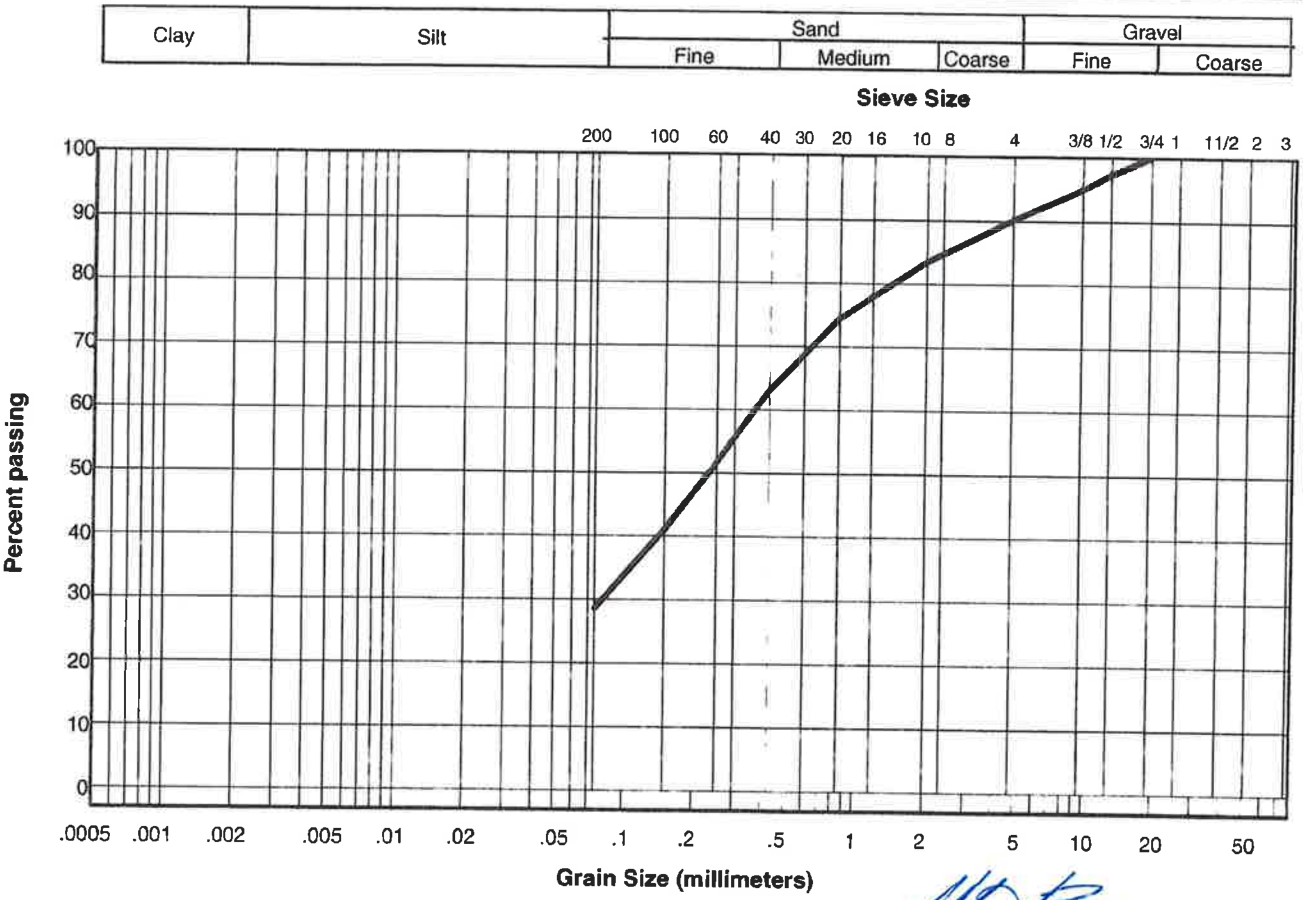
PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02
Date Tested: August 26, 2016
Borehole Number: MW16-03
Depth: G14 @ 4.6-4.9 m
Soil Description: SAND (SM), silty, trace gravel, trace clay, damp, brown
Cu:
Cc:
Natural Moisture Content: 11.5%
Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	100
12.500	97
9.500	95
4.750	90
2.000	83
0.850	75
0.425	63
0.250	52
0.150	41
0.075	29



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TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: MW16-03

Depth: G18 @ 5.5- 6.1 m

Soil Description: SAND (SM), silty, some gravel, trace clay, moist, brown

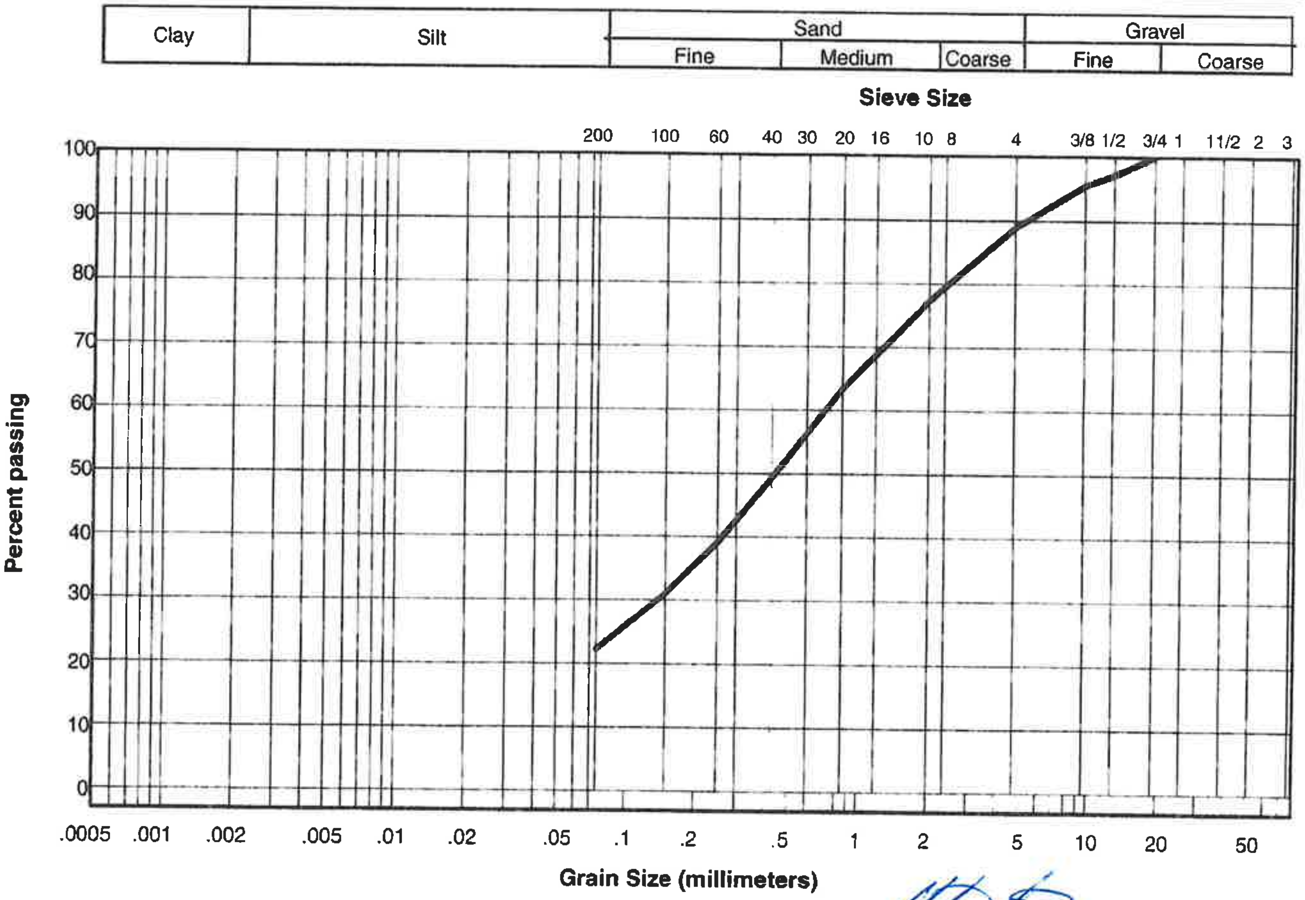
Cu:

Cc:

Natural Moisture Content: 16.4%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	100
12.500	97
9.500	96
4.750	89
2.000	77
0.850	63
0.425	49
0.250	39
0.150	31
0.075	22



Reviewed By: C.E.T.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: MW16-03

Depth: G21 @ 6.7-7.3 m

Soil Description: SAND and SILT (SM), trace gravel, moist, grey

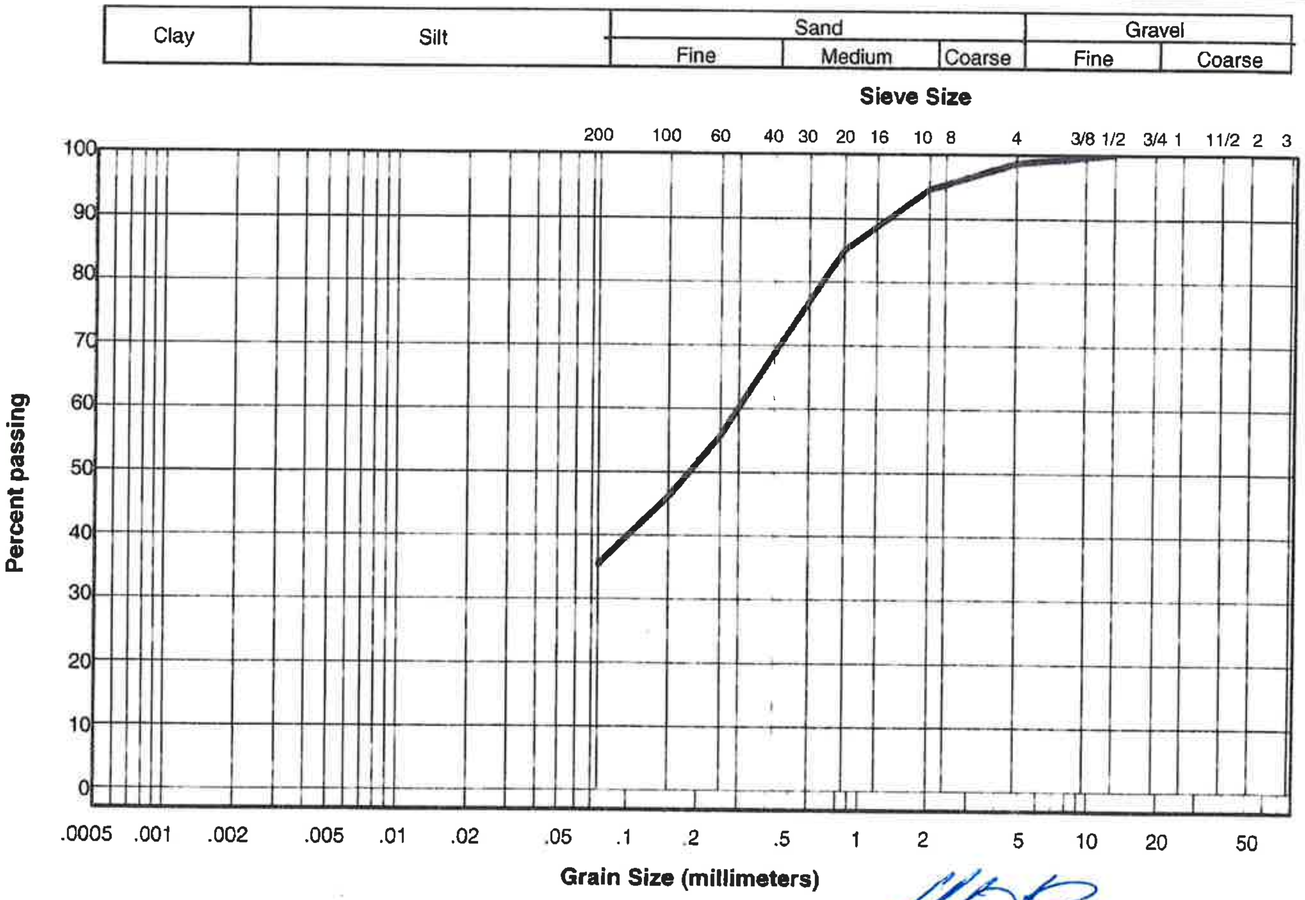
Cu:

Cc:

Natural Moisture Content: 10.7%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	#N/A
19.000	#N/A
12.500	100
9.500	100
4.750	99
2.000	95
0.850	85
0.425	69
0.250	56
0.150	46
0.075	35



Reviewed By: C.E.T.

TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02

Date Tested: August 23, 2016

Borehole Number: BH16-04

Depth: G5 @ 1.2-1.8 m

Soil Description: GRAVEL and SAND (GW), trace silt, wet, brown

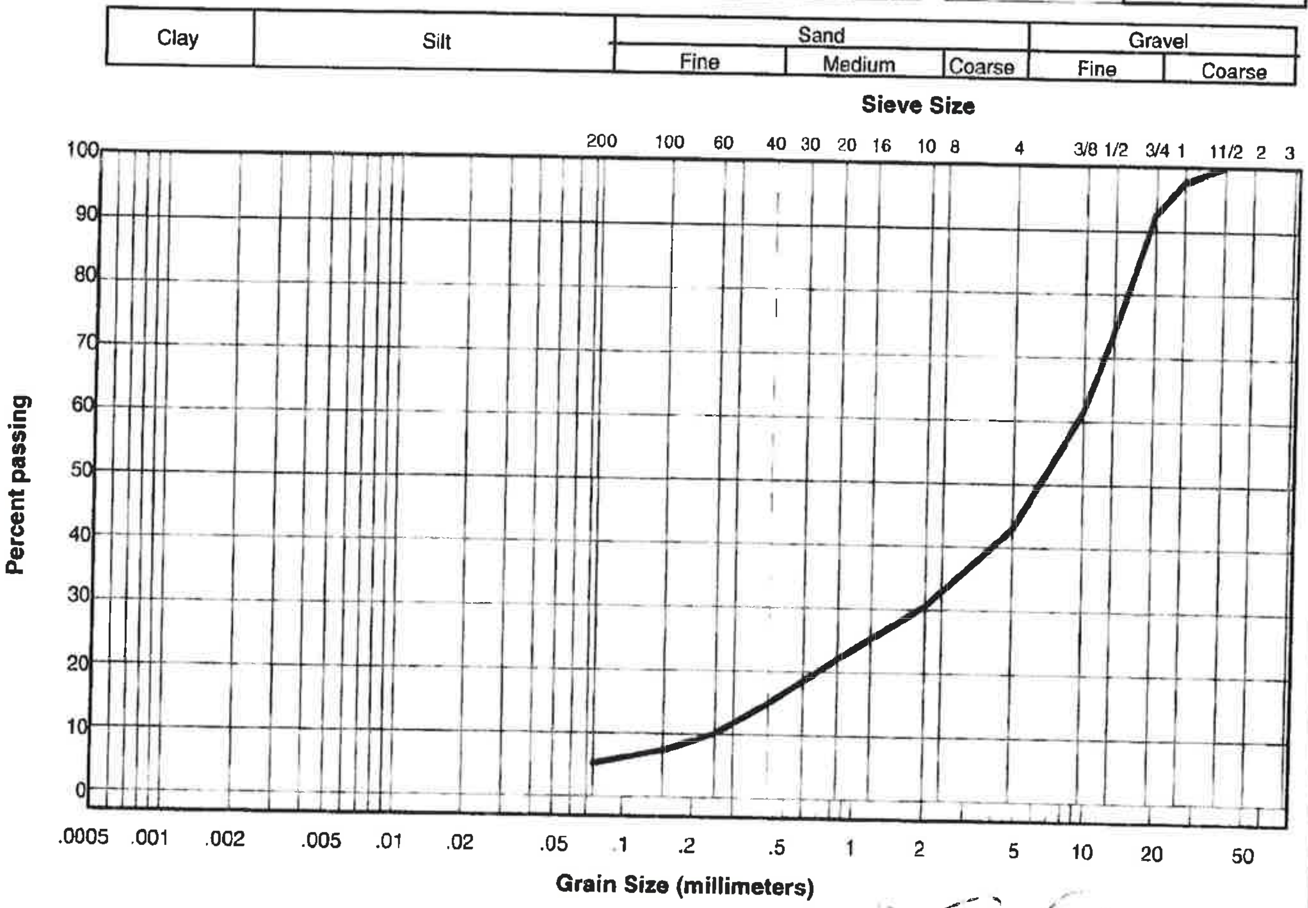
Cu: 36.6

Cc: 1.6

Natural Moisture Content: 10.6%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	100
25.000	98
19.000	93
12.500	73
9.500	61
4.750	43
2.000	31
0.850	22
0.425	15
0.250	10
0.150	7
0.075	5.2



Reviewed By: P.Eng.

TETRA TECH

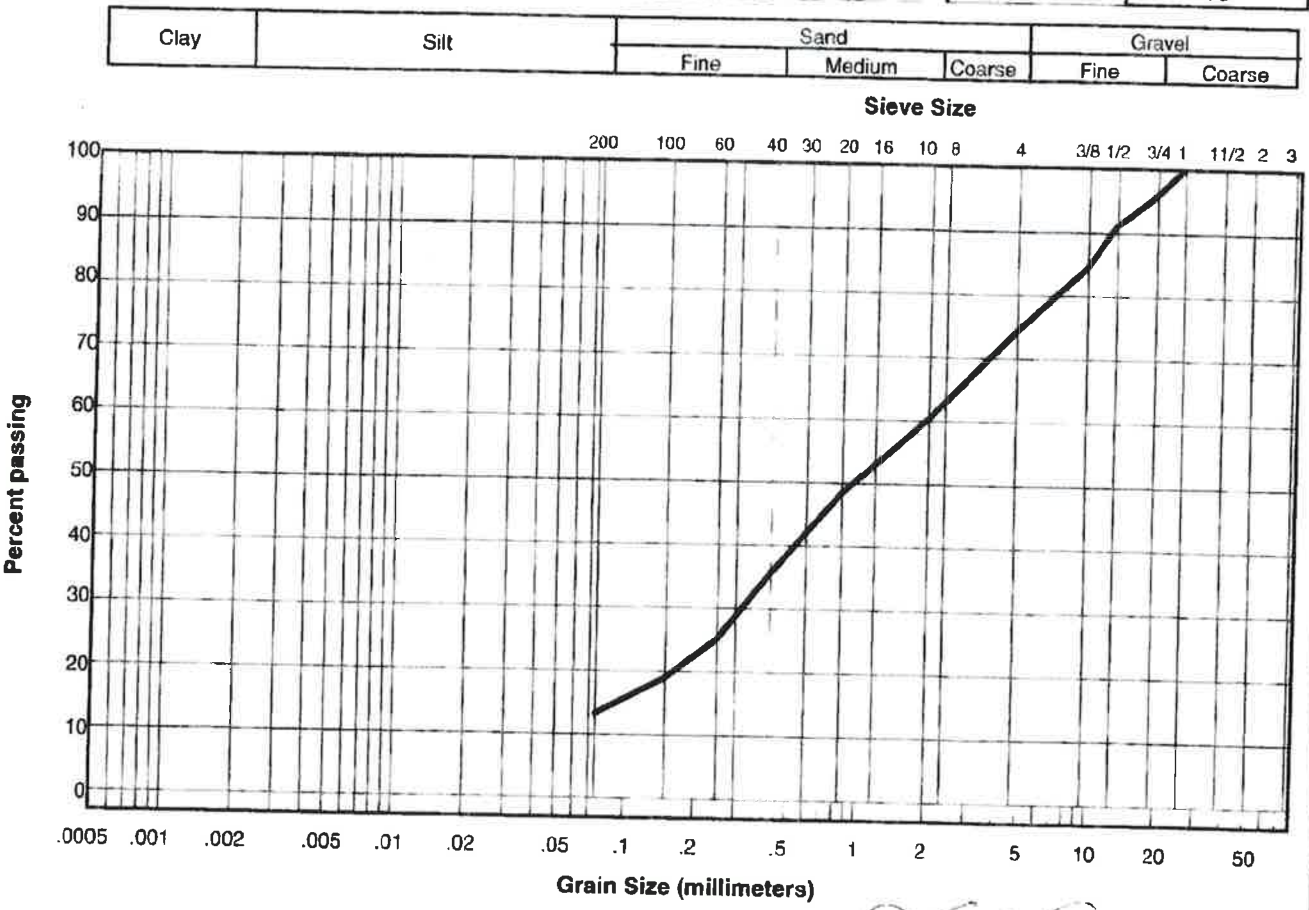
PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Money Lake Dam Engineering Assessment

Project Number: 704-V13103344-02
Date Tested: August 23, 2016
Borehole Number: BH16-04
Depth: G8 @ 1.8-2.7 m
Soil Description: SAND (SM), gravelly, some silt, wet, grey
Cu:
Cc:
Natural Moisture Content: 13.7%
Remarks:

Sieve Size (mm)	Percent Passing
50.000	#N/A
37.500	#N/A
25.000	100
19.000	96
12.500	91
9.500	85
4.750	74
2.000	60
0.850	49
0.425	36
0.250	25
0.150	19
0.075	13



Reviewed By: P.Eng.

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TETRA TECH

APPENDIX E

SLOPE STABILITY SECTIONS

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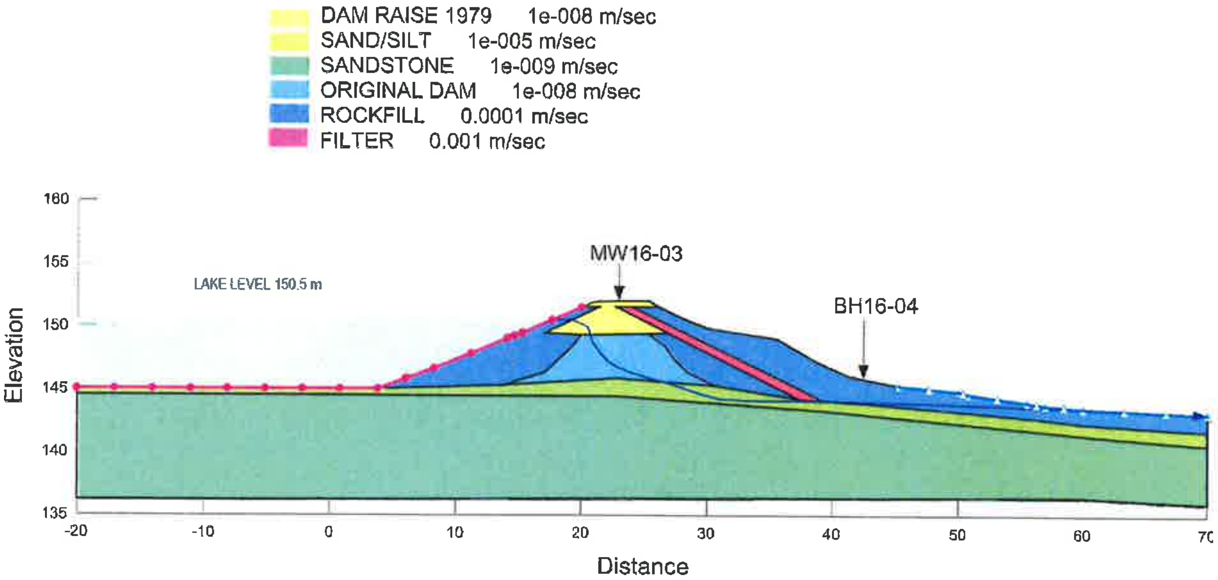

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Money Lake Dam Section B_seepage at 150.5 m_DOWNSTREAM_.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SEEPAGE ANALYSIS
LAKE LEVEL 150.5 m

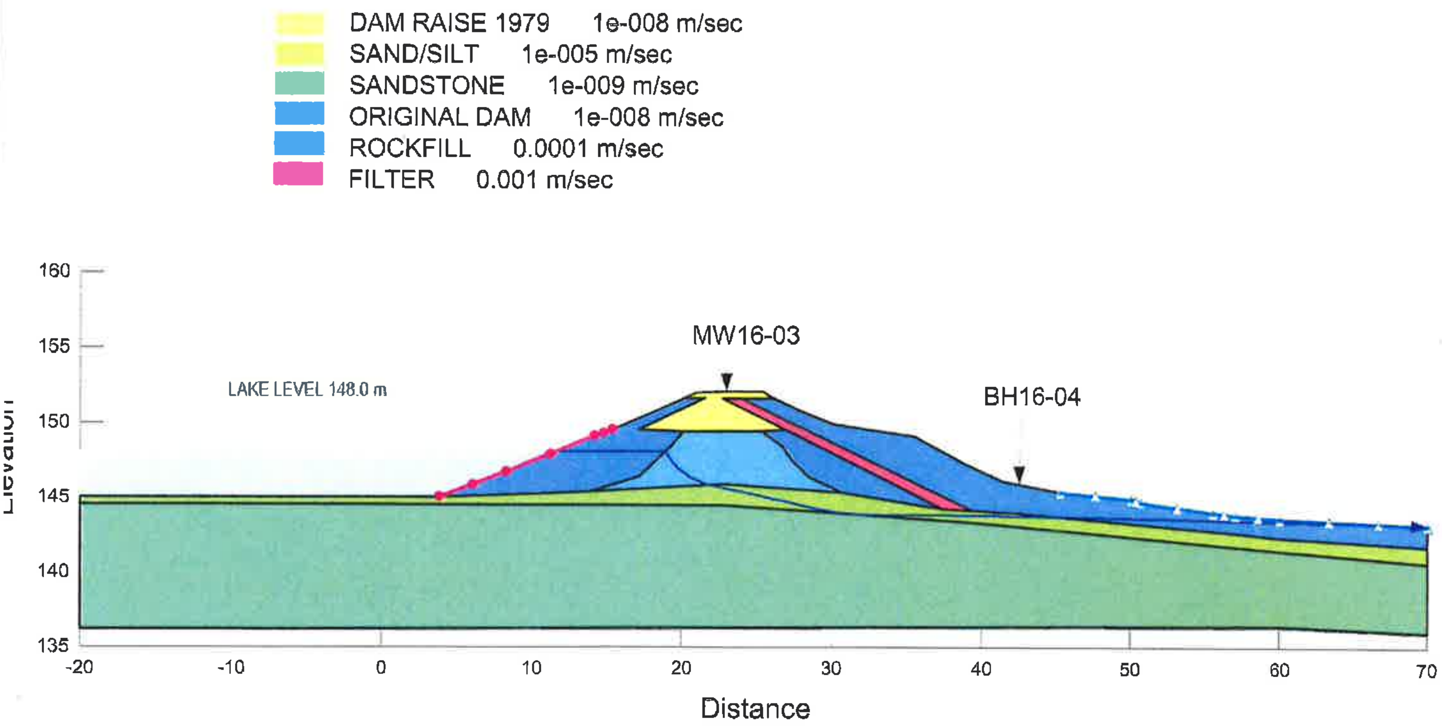
ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV
V13103344-02	BB	BP	0

OFFICE	DATE
Nanaimo	September 2, 2016

E1



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Money Lake Dam Section B_seepage at 148.0 m_UPSTREAM.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SEEPAGE ANALYSIS
LAKE LEVEL 148.0 m

ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV
V13103344-02	BB	BP	0

OFFICE	DATE
Nanaimo	October 12, 2016

E2

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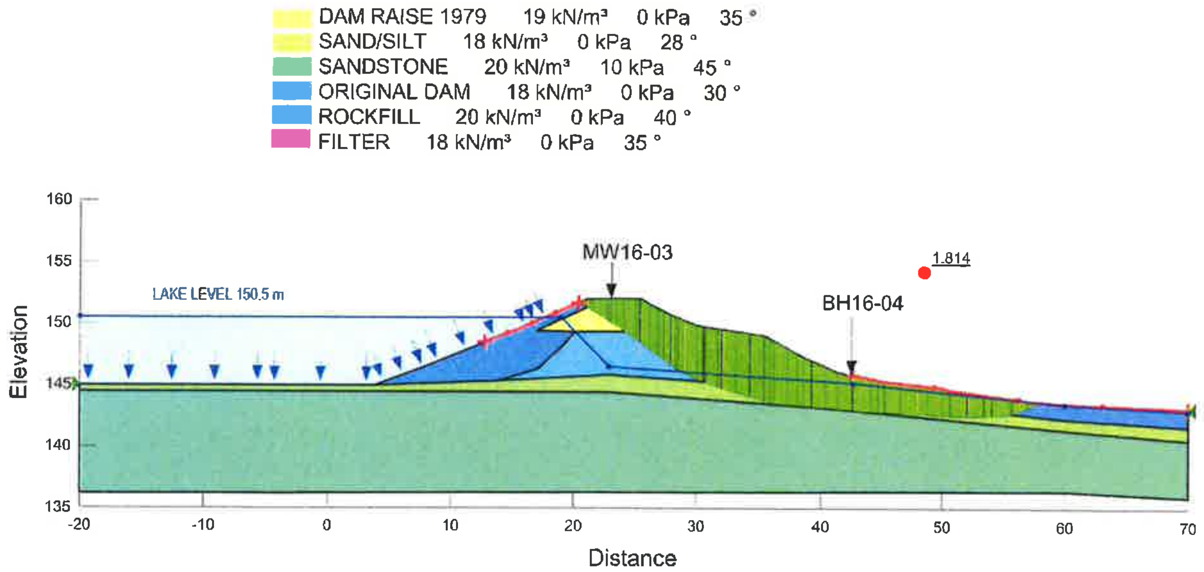

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Money Lake Dam Section B_seepage at 150.5 m_DOWNSTREAM.gsz

CLIENT

ISSUED FOR USE

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
STATIC DOWNSTREAM

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	September 2, 2016

E3

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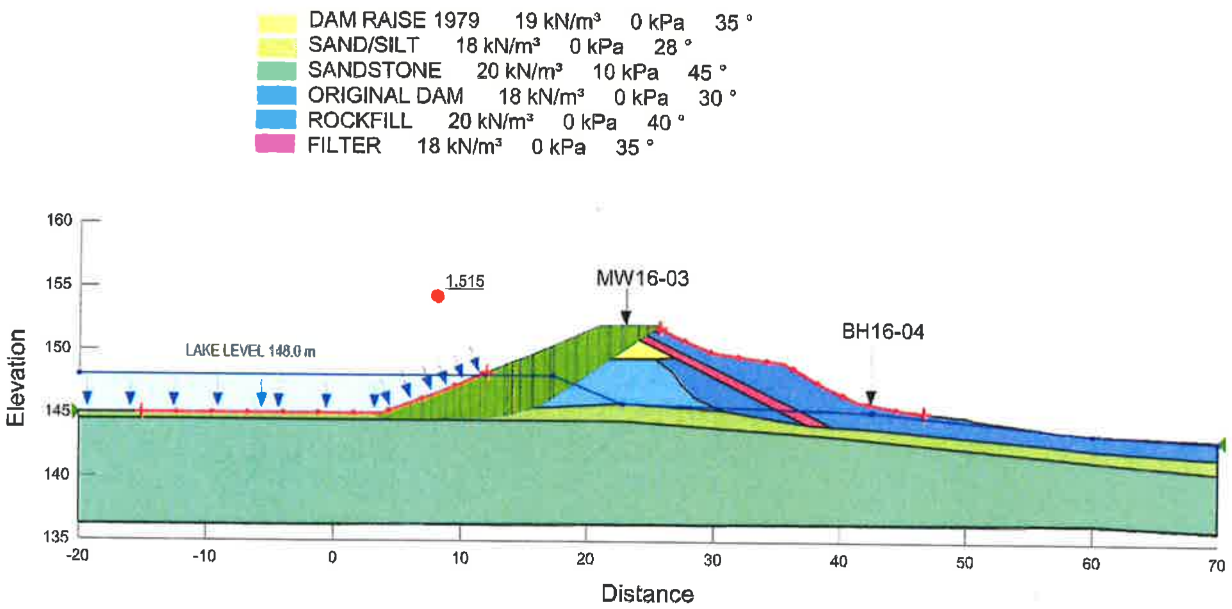

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Money Lake Dam Section B_seepage at 148.0 m_UPSTREAM.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
STATIC UPSTREAM

ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	October 12, 2016

E4

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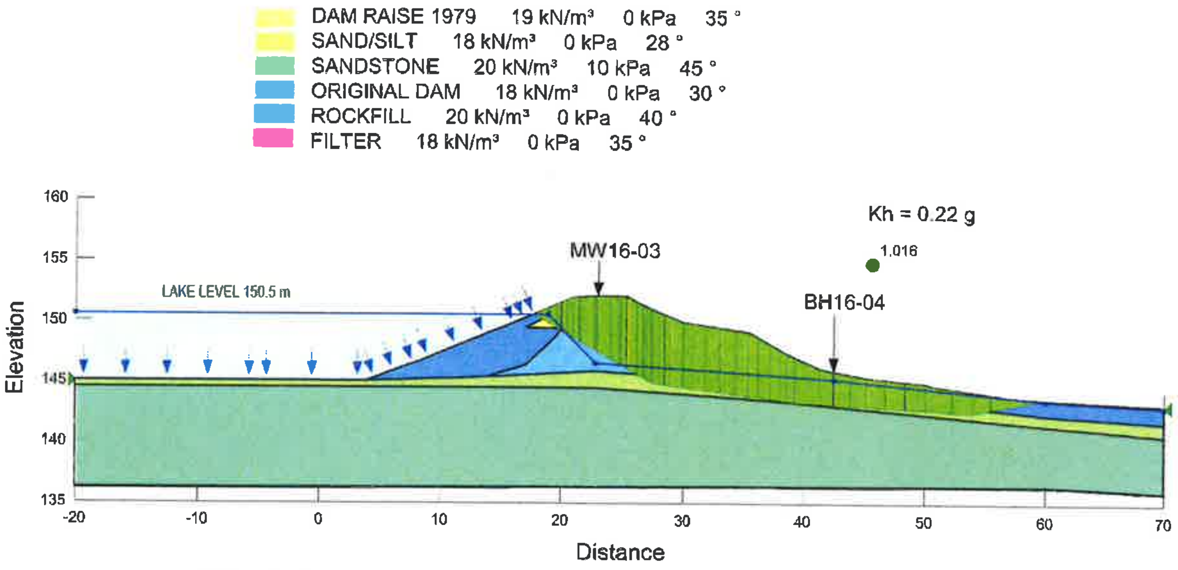

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Money Lake Dam Section B_seepage at 150.5 m_DOWNSTREAM.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
PSEUDOSTATIC DOWNSTREAM

ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	September 2, 2016

E5

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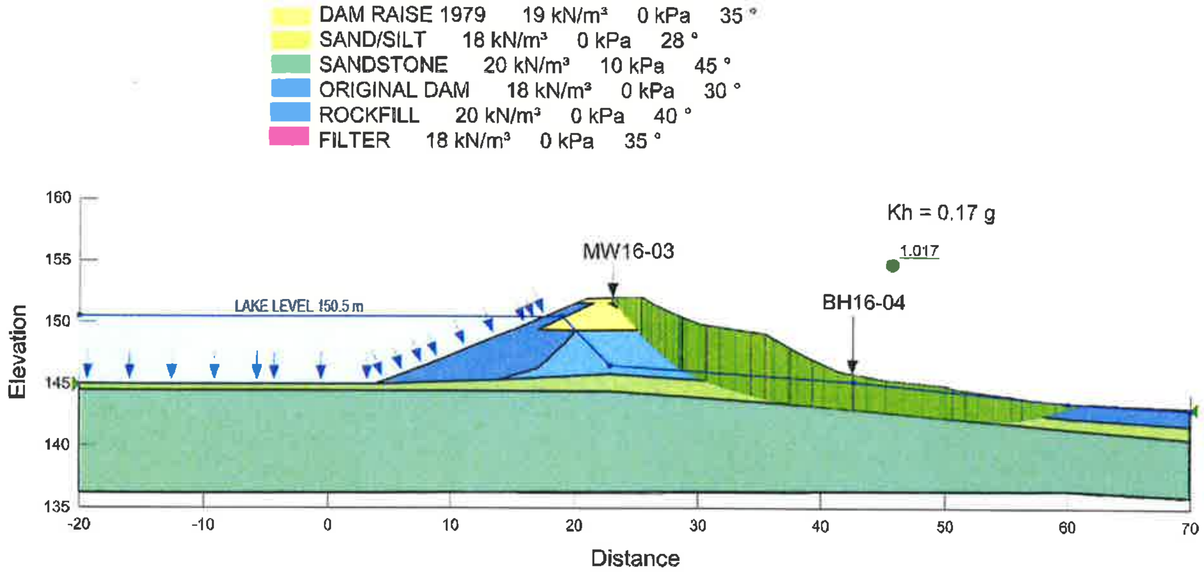

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Money Lake Dam Section B_seepage at 150.5 m_DOWNSTREAM.gsz

CLIENT

CRD

ISSUED FOR USE

TETRA TECH EBA

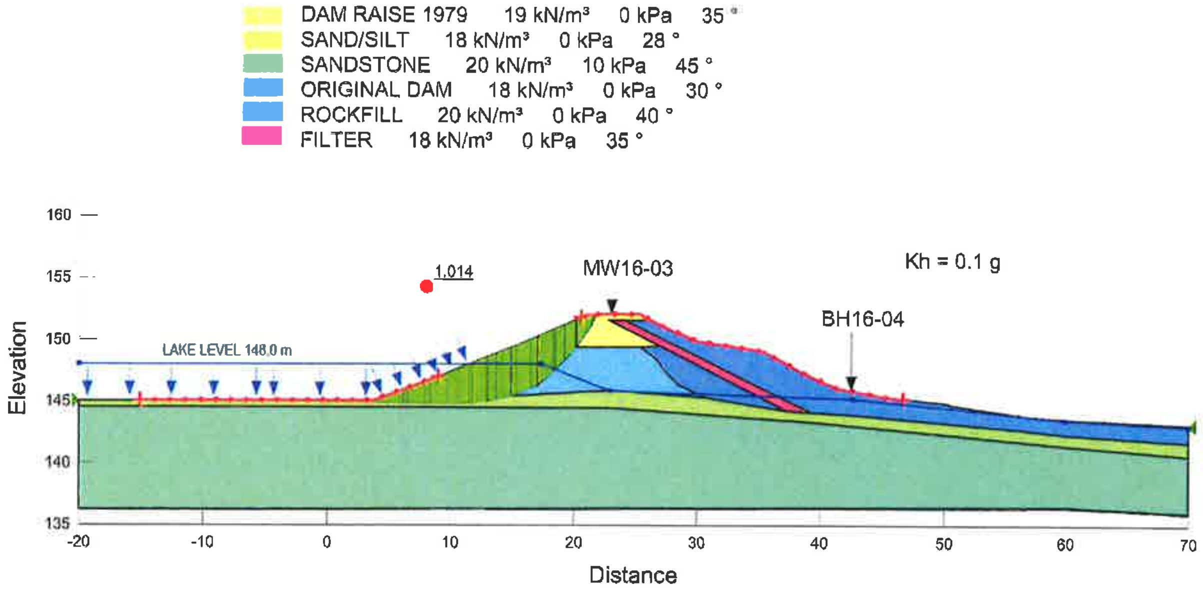
MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
PSEUDOSTATIC DOWNSTREAM

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	September 2, 2016

E6



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Money Lake Dam Section B_seepage at 148.0 m_UPSTREAM.gsz

CLIENT

CRD

ISSUED FOR USE

TETRA TECH EBA

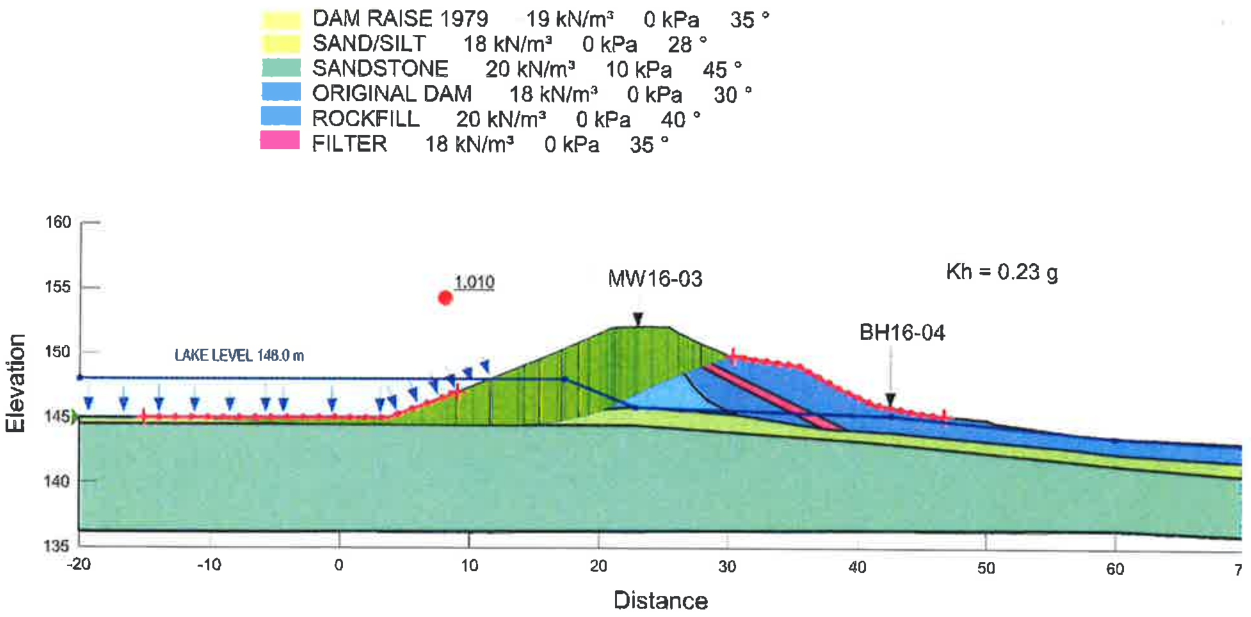
MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
PSEUDO-STATIC UPSTREAM

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	October 12, 2016

E7



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Money Lake Dam Section B_seepage at 148.0 m_UPSTREAM.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
PSEUDO-STATIC UPSTREAM

ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	October 12, 2016

E8

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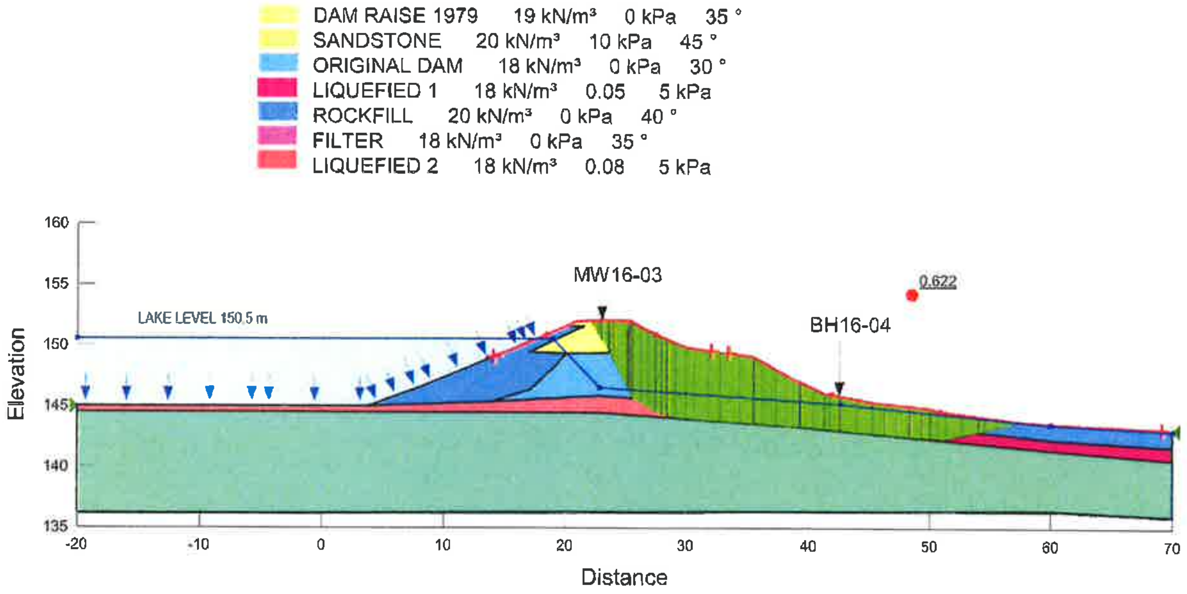

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Money Lake Dam Section B_seepage at 150.5 m_DOWNSTREAM.gsz

CLIENT

CRD

TETRA TECH EBA

ISSUED FOR USE

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
POST EARTHQUAKE DOWNSTREAM

PROJECT NO	DWN	CKD	REV
V13103344-02	CC	BP	0

OFFICE	DATE
Nanaimo	September 2, 2016

E9

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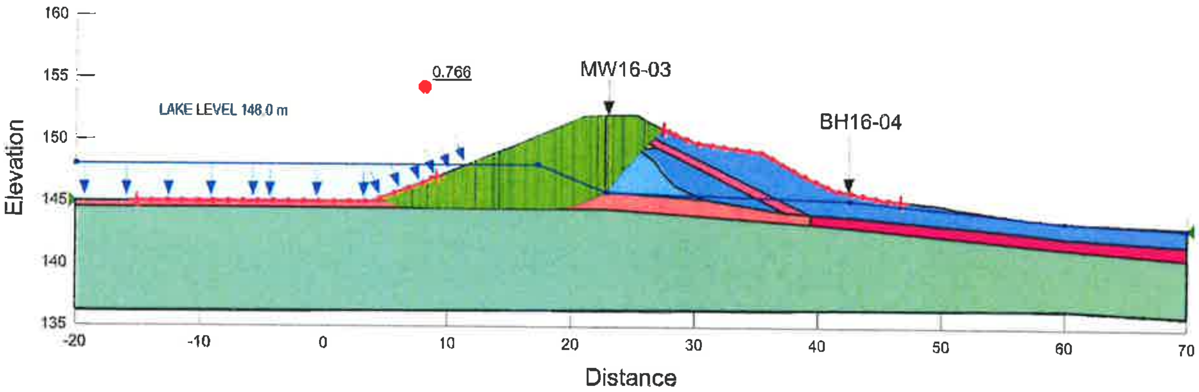
🟨	DAM RAISE 1979	19 kN/m³	0 kPa	35 °	
🟨	SANDSTONE	20 kN/m³	10 kPa	45 °	
🟦	ORIGINAL DAM	18 kN/m³	0 kPa	30 °	
🟥	LIQUEFIED 1	18 kN/m³	0.05	5 kPa	
🟦	ROCKFILL	20 kN/m³	0 kPa	40 °	
🟪	FILTER	18 kN/m³	0 kPa	35 °	
🟥	LIQUEFIED 2	18 kN/m³	0.08	5 kPa	



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Money Lake Dam Section B_seepage at 148.0 m_UPSTREAM.gsz

CLIENT

CRD

MONEY LAKE DAM ENGINEERING ASSESSMENT
SATURNA ISLAND, BC

SLOPE STABILITY ANALYSIS
POST EARTHQUAKE UPSTREAM

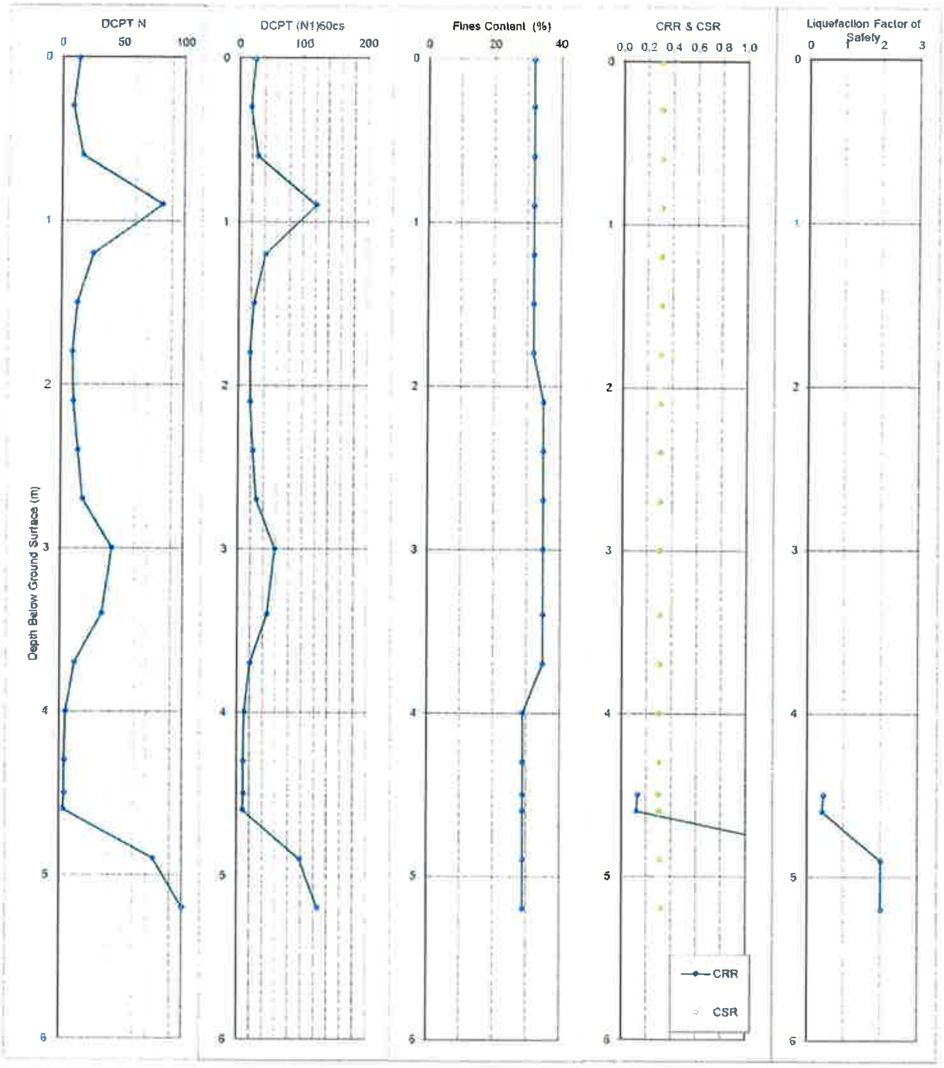
ISSUED FOR USE

TETRA TECH EBA

PROJECT NO	DWN	CKD	REV	
V13103344-02	CC	BP	0	E10
OFFICE	DATE			
Nanaimo	October 12, 2016			

APPENDIX F

LIQUEFACTION ANALYSIS RESULTS



LEGEND

Input Parameters

Groundwater Level (m): 4.5
Soil Density above WT (kN/m^3): 19
Soil Density below WT (kN/m^3): 20
Earthquake Return Period: 1 in 2475 years
Peak Ground Acceleration: 0.48 g
Magnitude (M): 7.15

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes.*

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses.

2.) Breaks in FOS series represent non-liquefiable soils.

MONEY LAKE DAM
SATURNA ISLAND, BC

DCPT LIQUEFACTION ASSESSMENT
MW16-02 1 in 2475 YEARS

TETRA TECH EBA

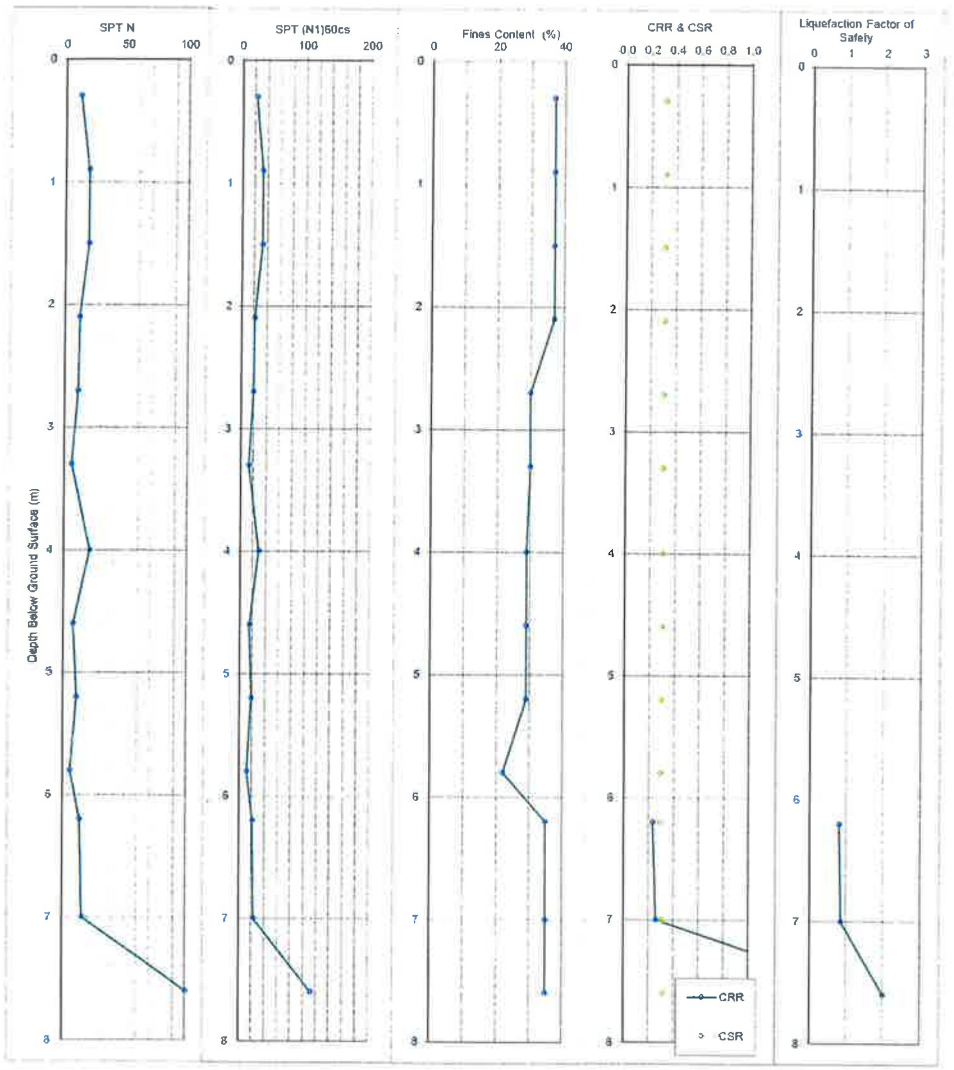
CLIENT

PROJECT NO.	BY	CKD	REV
V13103344-02	CC	AD	0

OFFICE
NANAIMO

DATE
September 9, 2016

F1



LEGEND

Input Parameters

Groundwater Level (m): 6.2

Soil Density above WT (kN/m^3): 19

Soil Density below WT (kN/m^3): 20

Earthquake Return Period: 1 in 2475 years

Peak Ground Acceleration: 0.48 g

Magnitude (M): 7.15

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes.*

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses

2.) Breaks in FOS series represent non-liquefiable soils.

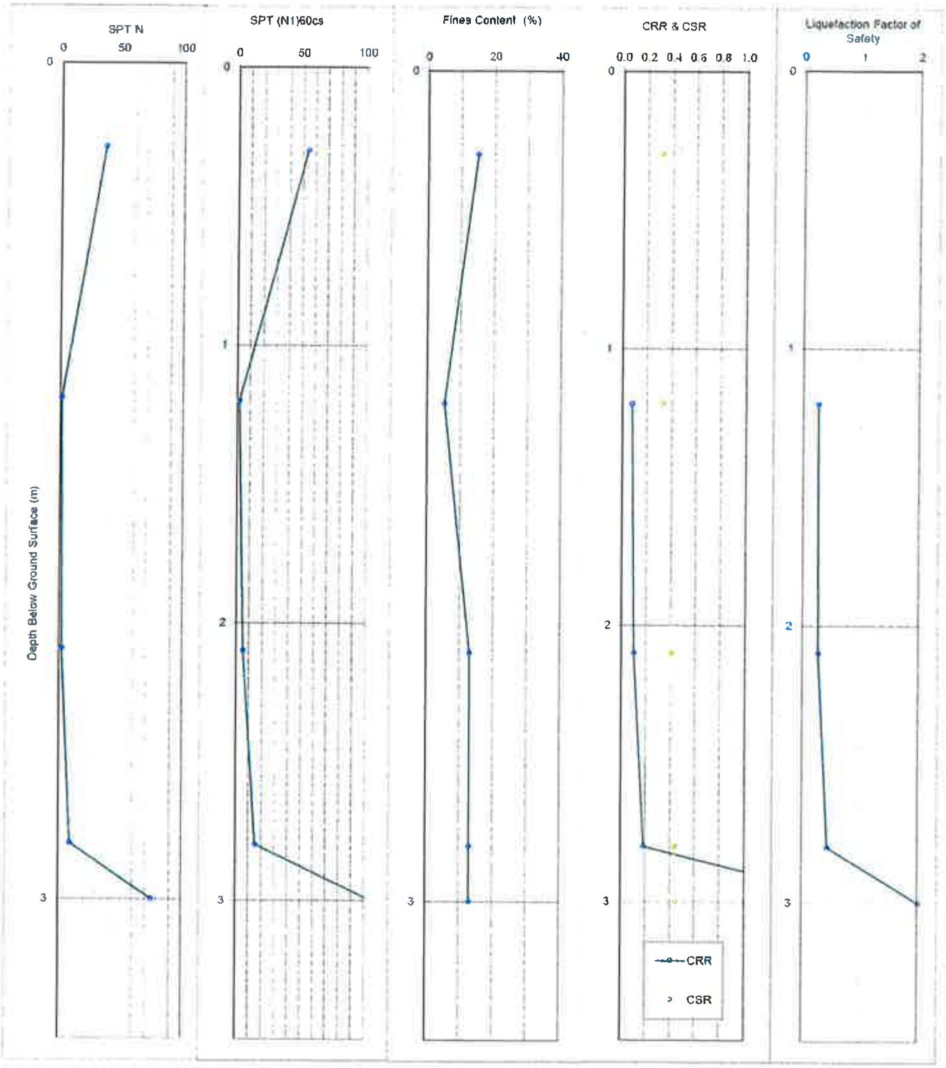
MONEY LAKE DAM
SATURNA ISLAND, BC

SPT LIQUEFACTION ASSESSMENT
MW16-03 1 in 2475 YEARS

TETRA TECH EBA

CLIENT
CRD

PROJECT NO.	BY	CKD	REV	
V13103344-02	CC	AD	0	F2
OFFICE NANAIMO	DATE September 9, 2016			



LEGEND

Input Parameters

Groundwater Level (m): 1.1
Soil Density above WT (kN/m^3): 19
Soil Density below WT (kN/m^3): 20
Earthquake Return Period: 1 in 2475 years
Peak Ground Acceleration: 0.48 g
Magnitude (M): 7.15

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes*.

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses.

2.) Breaks in FOS series represent non-liquefiable soils.

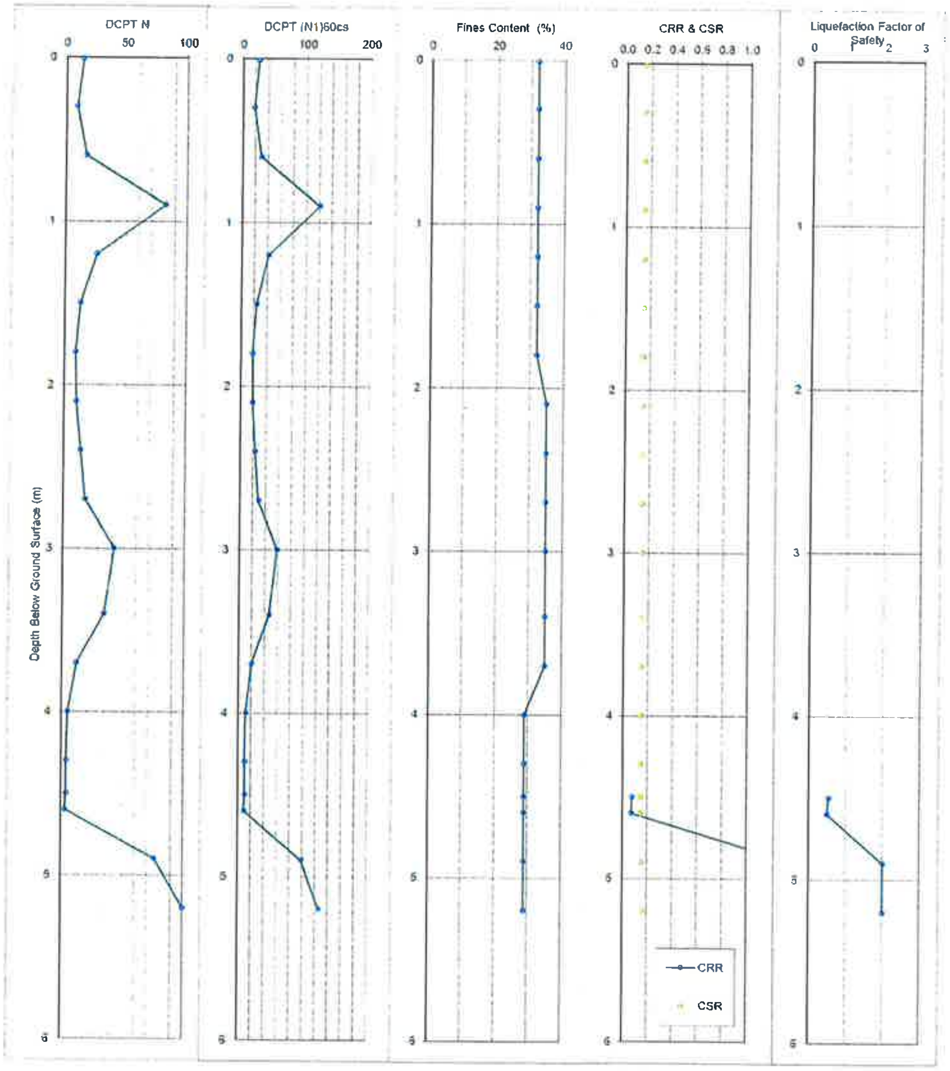
MONEY LAKE DAM
SATURNA ISLAND, BC

SPT LIQUEFACTION ASSESSMENT
BH16-04 1 in 2475 YEARS

TETRA TECH EBA

CLIENT
CRD

PROJECT NO.	BY	CKD	REV	
V13103344-02	CC	AD	0	F3
OFFICE	DATE			
NANAIMO	September 9, 2016			



LEGEND

Input Parameters

Groundwater Level (m): 4.5
Soil Density above WT (kN/m^3): 19
Soil Density below WT (kN/m^3): 20
Earthquake Return Period: SUBDUCTION
Peak Ground Acceleration: 0.23 g
Magnitude (M): 9

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes.*

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses.

2.) Breaks in FOS series represent non-liquefiable soils.

MONEY LAKE DAM
SATURNA ISLAND, BC

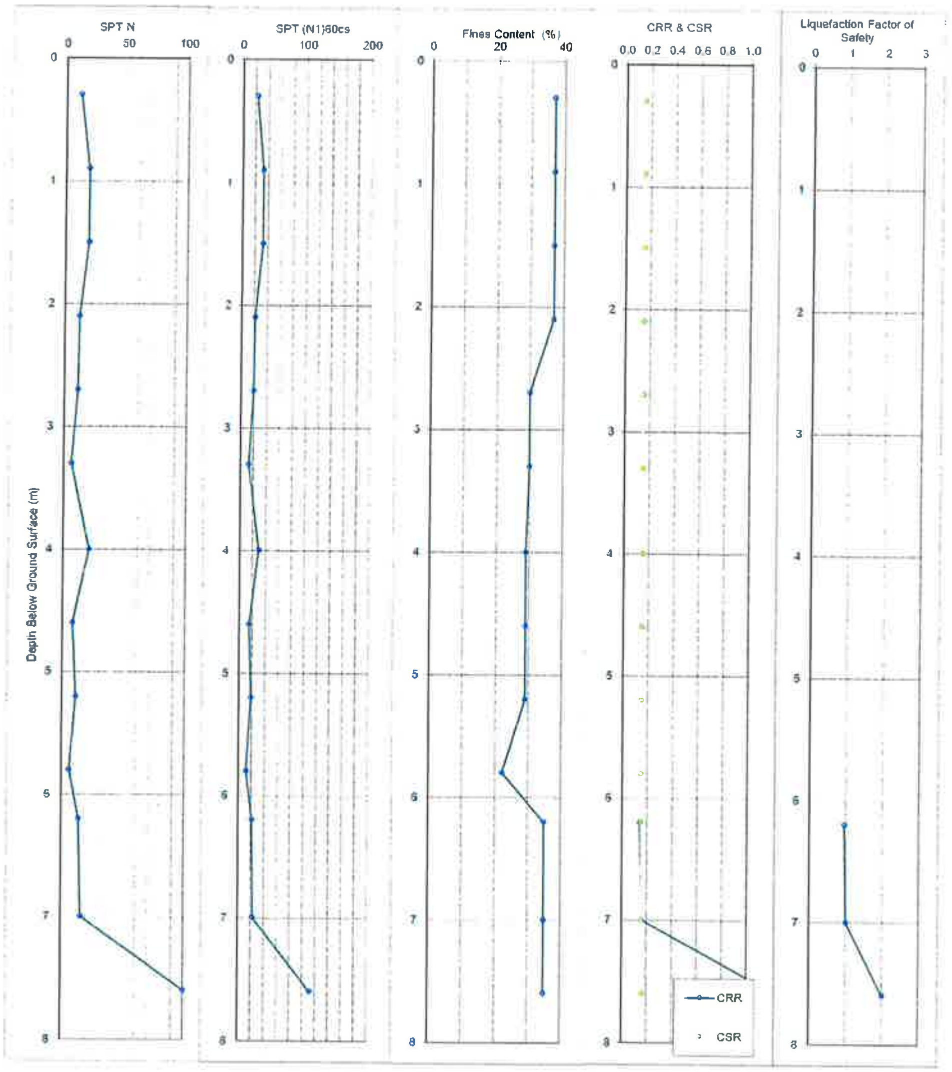
DCPT LIQUEFACTION ASSESSMENT
MW16-02 SUBDUCTION EVENT

TETRA TECH EBA

CLIENT
CRD

PROJECT NO. V13103344-02
BY CC
CKD AD
REV 0
OFFICE NANAIMO
DATE September 9, 2016

F4



LEGEND

Input Parameters

Groundwater Level (m): 6.2
Soil Density above WT (kN/m^3): 19
Soil Density below WT (kN/m^3): 20
Earthquake Return Period: SUBDUCTION
Peak Ground Acceleration: 0.23 g
Magnitude (M): 9

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes*.

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses.

2.) Breaks in FOS series represent non-liquefiable soils.

MONEY LAKE DAM
SATURNA ISLAND, BC

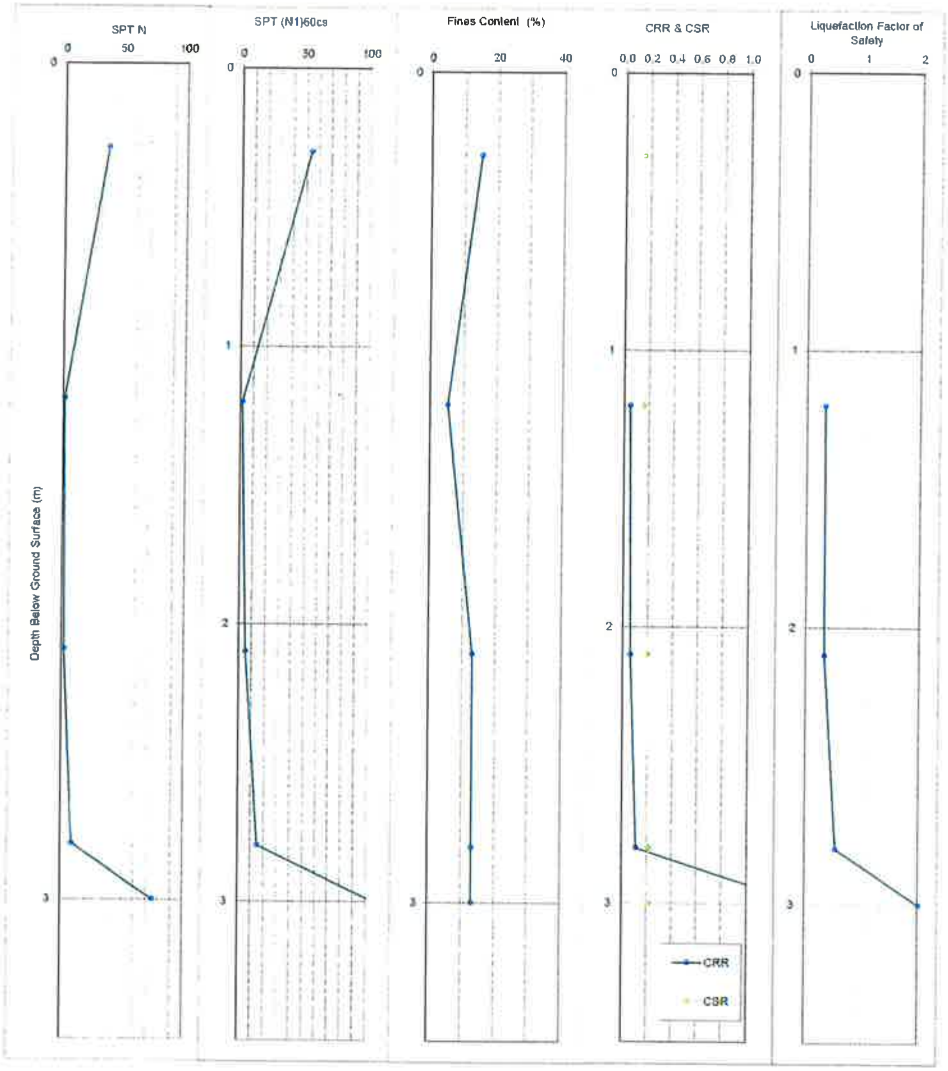
SPT LIQUEFACTION ASSESSMENT
MW16-03 SUBDUCTION EVENT

TETRA TECH EBA

CLIENT
CRD

PROJECT NO.: V13103344-02
BY: CC
CKD: AD
REV: 0
OFFICE: NANAIMO
DATE: September 9, 2016

F5



LEGEND

Input Parameters

Groundwater Level (m): 1.1
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Soil Density below WT (kN/m^3): 20
Earthquake Return Period: SUBDUCTION
Peak Ground Acceleration: 0.23 g
Magnitude (M): 9

References

1.) Idriss, I.M. and Boulanger, R.W. 2008. *Soil Liquefaction During Earthquakes.*

Notes

1.) CRR has been corrected for magnitude and effective overburden stresses.

2.) Breaks in FOS series represent non-liquefiable soils.

MONEY LAKE DAM
SATURNA ISLAND, BC

SPT LIQUEFACTION ASSESSMENT
BH16-04 SUBDUCTION EVENT

TETRA TECH EBA

CLIENT
CRD

PROJECT NO.	BY	CKD	REV
V13103344-02	CC	AD	0

OFFICE
NANAIMO

DATE
September 9, 2016

F6

Order of Magnitude Construction Cost Estimate

Table 1: Option 1 – Upgrade Dam, Order of Magnitude Construction Cost Estimate

Option 1 - Upgrade Dam						
	Major Element	**Description**	**Quantity**	**Unit**	**Unit Rate ($)**	**Amount ($)**
1.1	Site Preparation	Grubbing at buttress footprint and grading of downstream embankment for buttressing	1	L.S.	10,000	10,000
1.2	Bulk Earthworks	Supply, Hauling, placement, and compaction of fill for buttressing dam	1500	m^3	120	180,000
1.3	Erosion Protection	Supply and placement of rip rap to armour buttress	100	m^3	200	20,000
1.4	Other	Spillway improvements and upgrades to the existing buried pipe works	1	L.S.	25,000	25,000
					Subtotal	**235,000**
					Contingency (50%)	117,500
					Budget for Construction Cost	**352,500**
					Mobilization and Demobilization (5%)	17,500
					Engineering, Construction Monitoring, and Contract Administration Support (20%)	70,500
					Admin (10%)	35,000
					Operations Staff (5%)	17,500
					TOTAL	**493,000**
					Range Low (-30%)	**350,000**
					Range High (+30%)	**650,000**

APPENDIX B2

Order of Magnitude Construction Cost Estimate

Table 2: Option 2 – Construct New Dam, Order of Magnitude Construction Cost Estimate

Option 2 - Construct New Dam						
	Major Element	**Description**	**Quantity**	**Unit**	**Unit Cost ($)**	**Amount ($)**
1.1	Site Preparation	Grubbing	0.2	ha	12,000	3,000
1.2		Install and remove temporary cofferdam	1	L.S	150,000	150,000
1.3		Install and remove temporary water supply pipe	1	L.S	40,000	40,000
1.4	Bulk Earthworks	Excavation, hauling, and disposal of existing granular fill	9100	m^3	10	91,000
1.5		Supply, Hauling, placement, and compaction of fill and clay core	9500	m^3	120	1,140,000
1.6	Control Structure	Install spillway, low level outlet pipe and valves	1	L.S	100,000	100,000
1.7	Erosion Protection	Supply and placement of riprap to armour embankments	400	m^3	200	80,000
1.8	Instrumentation	SCADA and piezometers	1	L.S	20,000	20,000
Subtotal						**1,624,000**
Contingency (50%)						812,000
Budget for Construction Cost						**2,435,000**
Mobilization and Demobilization (5%)						122,000
Engineering, Construction Monitoring, and Contract Administration Support (20%)						487,000
Admin (10%)						244,000
Operations Staff (5%)						122,000
TOTAL						3,410,000
Range Low (-30%)						**2,400,000**
Range High (+30%)						**4,400,000**