Capital Regional District

Notice of Meeting and Meeting Agenda

Lyall Harbour Boot Cove Water Local Service Committee

Thursday, June 27, 2024 **9:30 AM** **Goldstream Conference Room, 479 Island Highway, Victoria, BC**

For members of the public who wish to listen to the meeting via telephone please call 1-833-353-8610 and enter the Participant Code 1911461 followed by #. You will not be heard in the meeting room but will be able to listen to the proceedings.

MEMBERS:
A. Olsen (Chair); J. Money (Vice Chair); P. Brent (EA Director); J. Crerar; I. Rowe; T. McLeod

1. Territorial Acknowledgement

2. Approval of Agenda

3. Adoption of Minutes

3.1. 24-663 Minutes of the March 7, 2024 Lyall Harbour/Boot Cove Water Local Service Committee

Recommendation: That the minutes of the March 7, 2024 meeting be adopted.

Attachments: Minutes - March 7, 2024

4. Chair's Remarks

5. Presentations/Delegations

Delegations will have the option to participate electronically. Please complete the online application for "Addressing the Board" on our website and staff will respond with details.

Alternatively, you may email your comments on an agenda item to the Lyall Harbour/Boot Cove Water Local Service Committee at iwsadministration@crd.bc.ca. Requests must be received no later than 4:30 p.m. two calendar days prior to the meeting.

6. Senior Manager's Report

6.1. Union of British Columbia Municipalities Grant for Disaster Risk Reduction - Climate Adaptation 2024

7. Commission Business

7.1. 24-640 2023 Annual Report

Recommendation: There is no recommendation. This report is for information only.

Attachments: Staff Report: 2023 Annual Report

Appendix A

7.2. 24-568 Capital Project Status Reports and Operational Updates - June 2024

Recommendation: There is no recommendation. This report is for information only.

Attachments: Staff Report: Project and Operations Update June 2024

Appendix A

8. Correspondence

9. New Business

10. Adjournment

Next Meeting: November 2024

Making a difference...together

MINUTES OF A MEETING OF THE Lyall Harbour Boot Cove Water Local Service Committee, held Thursday, March 7, 2024 at 9:30 a.m., In the Goldstream Conference Room, 479 Island Highway, Victoria, BC

PRESENT: **Commissioners:** A. Olsen (Chair); J. Money (Vice Chair); P. Brent (EA Director); J. Crerar; I. Rowe (EP)
Staff: D. Robson, Manager, Saanich Peninsula and Gulf Islands Operations; J. Dales, Senior Manager, Wastewater Infrastructure Operations; N. Tokgoz, Manager, Water Distribution Engineering and Planning; J. Kelly, Manager, Capital Projects; L. Hardiman, Manager, Asset Management; S. Henderson, Senior Manager, Real Estate and Southern Gulf Islands Administration; C. Moch, Manager, Water Quality; M. Risvold (Recorder)
REGRETS: T. McLeod

EP = Electronic Participation

The meeting was called to order at 9:30 am.

1. ELECTION OF CHAIR

The Senior Manager called for nominations for the position of Chair of the Lyall Harbour/Boot Cove Water Local Service Committee for the term ending December 31, 2024.

J. Crerar nominated A. Olsen. A. Olsen accepted the nomination.

The Senior Manager called for nominations a second time.

The Senior Manager called for nominations a third and final time.

Hearing no further nominations, the Senior Manager declared A. Olsen Chair of the Lyall Harbour/Boot Cove Water Local Service Committee for the term ending December 31, 2024, by acclamation.

2. ELECTION OF VICE CHAIR

The Chair called for nominations for the position of Vice Chair of the Lyall Harbour/Boot Cove Water Local Service Committee for the term ending December 31, 2024.

J. Crerar nominated J. Money. J. Money accepted the nomination.

The Chair called for nominations a second time.

The Chair called for nominations a third and final time.

Hearing no further nominations, the Chair declared J. Money Vice Chair of the Lyall Harbour/Boot Cove Water Local Service Committee for the term ending December 31, 2024, by acclamation.

3. APPROVAL OF AGENDA

MOVED by J. Money, **SECONDED** by J. Crerar,
That the agenda be approved.

CARRIED

The committee asked if members of the public can join and participate in committee meetings. Staff advised there are not currently any vacancies on the committee, however, when a vacancy comes available, the Capital Regional District (CRD) will accept nominations for a qualified person. Committee vacancies will be posted locally for 30 days. Staff noted that members of the public are welcome to attend and observe committee meetings but are unable to participate or ask questions.

4. ADOPTION OF MINUTES

MOVED by J. Money, **SECONDED** by J. Crerar,
That the minutes of the November 14, 2023 Lyall Harbour Boot Cove Water Local Service Committee meeting be adopted.

CARRIED

5. CHAIR'S REMARKS

The Chair thanked J. Crerar for her service and for her tenure as Chair.

The committee advised they attended an information session on dam safety which was very informative and well received by the community.

6. SENIOR MANAGER'S UPDATE

Groundwater well update: Progress is being made regarding entering an agreement with Natures Trust. Necessary parties have signed the required documents and CRD now has ownership of the well. A process will be established regarding the use of the well.

Money Lake road paving: Discussions are continuing with the Ministry of Transportation and Infrastructure (MoTI). MoTI has proposed potentially using a recycled asphalt instead of chip-sealing. CRD is working with MoTI to determine the impacts to Money Lake.

Culvert upgrade: CRD is working with MoTI for the culvert upgrade at the upper treatment plant. A design consultant has provided a quote and staff are looking at further negotiating the scope with MoTI.

Turbidity meter pilot project: The turbidity meter was installed in November 2023; data is being collected and monitored in parallel with the existing turbidity meter's data. Data will continue to be monitored throughout the wet season and the upcoming summer. A data comparison and recommendation will be provided to Island Health by the end of 2024.

Boil water advisory (BWA) update: The system is being monitored closely and turbidity has been consistently dropping. Staff have developed a BWA exit strategy for the service. Operational maintenance has been completed and includes flushing and cleaning of the intake, the surge tank, seepage pits and the main line from the upper treatment building to the lower treatment building. The exit strategy requires two bacteriological tests that are at least 24 hours apart and will be implemented next week.

Discussion ensued regarding:
- Separating well testing to complete it in phases
- Cost control and well monitoring
- Water quality testing
- Well study budget review and consideration
- Funding for paving near Money Lake
- Potential interference with turbidity readings

7. PRESENTATIONS/DELEGATIONS

There were none.

8. COMMITTEE BUSINESS

8.1. Project and Operations Update

Staff provided a capital projects and operational update.

Staff advised work on the Boot Cove pressure regulating valve (PRV) is planned to for March 19. The work will require a water interruption for a portion of the system. It is anticipated a water outage will occur for a couple of hours, but the notice will advise there will be an interruption for the entire day. Staff asked the committee to advise staff if there are any community conflicts with that scheduled date. The public will be notified through the CRD website, notifications placed on community boards, and through the committee.

Discussion ensued with staff responding to the following questions:
- Funding requested for the alternative approval process (AAP)
- Debt servicing
- The need for a hydrogeologist prior to conducting
- Costs for new connections being fully funded by the requestor

8.2. Asset Replacement Report Card

S. Henderson spoke to item 8.2.

Staff responded to a question from the committee regarding the life expectancy of the water meters. Staff noted that assets can go beyond their useful life, aging assets can still operate but will depend on level of service and expectations of the asset.

8.3. Water Usage Statistics

N. Tokgoz spoke to item 8.3.

Discussion ensued regarding:
- Having a potential tiered rate structure
- Moving to a fee based system
- The potential for zone meters
- Leak adjustment policy in place
- Emergency response process for system leaks

9. LYALL HARBOUR/BOOT COVE WATER LOCAL SERVICE COMMITTEE MEETING SCHEDULE

Regular meetings of the Lyall Harbour/Boot Cove Water Local Service Committee shall be held in the Goldstream Conference Room, 479 Island Highway, Victoria, BC in March, June, and November to approve the Operating and Capital Budget.

10. CORRESPONDENCE

There was no correspondence.

11. NEW BUSINESS

There was no new business.

12. ADJOURNMENT

MOVED by A. Olsen, **SECONDED** by P. Brent,
That the March 7, 2024 Lyall Harbour Boot Cove Water Local Service Committee meeting be adjourned at 10:30 am.

CARRIED

____
CHAIR

____
SECRETARY

Lyall Harbour/Boot Cove Water Service

2023 Annual Report

CRD | Drinking Water

Introduction

This report provides a summary of the Lyall Harbour/Boot Cove Water Service for 2023 and includes a description of the service, summary of the water supply, demand and production, drinking water quality, operations highlights, capital project updates and financial report.

Service Description

The community of Lyall Harbour/Boot Cove is primarily a rural residential development with community and commercial properties located on Saturna Island in the Southern Gulf Islands Electoral Area which was originally serviced by a private water utility and in 1978 the service converted to the Capital Regional District (CRD). The Lyall Harbour/Boot Cove water service is made up of 171 parcels (Figure 1) encompassing a total area of approximately 100 hectares. Of the 171 parcels, 155 properties (164 Single Family Equivalent's) are connected to the water system.

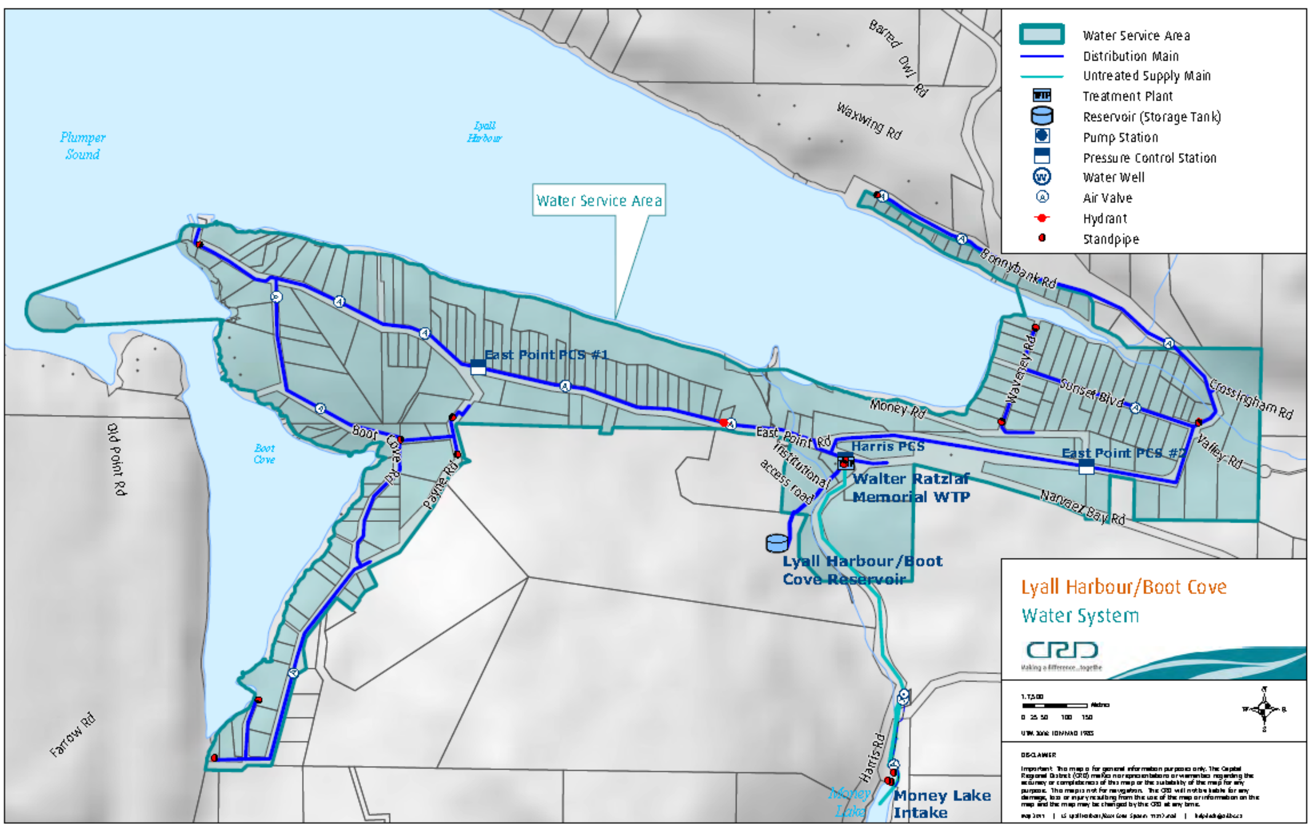


Figure 1: Map of Lyall Harbour/Boot Cove Water System

The Lyall Harbour/Boot Cove water system is primarily comprised of:

- Two raw water sources:
  - Money Lake, a small, impounded, surface water body that lies within a 94 hectare (230 acre) watershed on private and public lands.
  - Ground water spring (seepage pit) located near the base of Money Lake Dam.
- One earthen dam structure, Money Lake Dam No. 1.
- Treatment equipment including ozonation (currently offline), two stages of filtration (granular and absorption), ultraviolet light disinfection and chlorine disinfection.
- One steel storage tank (total volume 136 cubic meters or 36,000 US gallons).
- Supervisory Control and Data Acquisition (SCADA) system.
- Distribution system and supply pipe network (8,390 meters of water mains).
- Other water system assets: water service connections and meters, three pressure reducing valve stations, 50 gate valves, 12 standpipes and a small auxiliary generator.

Water Supply

Referring to Figure 2 below, Money Lake monthly water levels are highlighted for 2023. It is important to note that water supply levels in Money Lake, prior to 2008, were historically lower during the summer period. An upgrade to mitigate the low water levels involved the installation of a groundwater seepage spring recirculation pumping system. Excess water from the seepage spring is pumped back to Money Lake to keep the Lake as full as possible. The groundwater seepage spring water level is not monitored; however, the seepage spring weekly flow rate is monitored to confirm production rate. The seepage spring typically provides 100% of the winter water system demand for the community. Money Lake water is used periodically to supplement seepage spring flows, typically during the summer dry period.

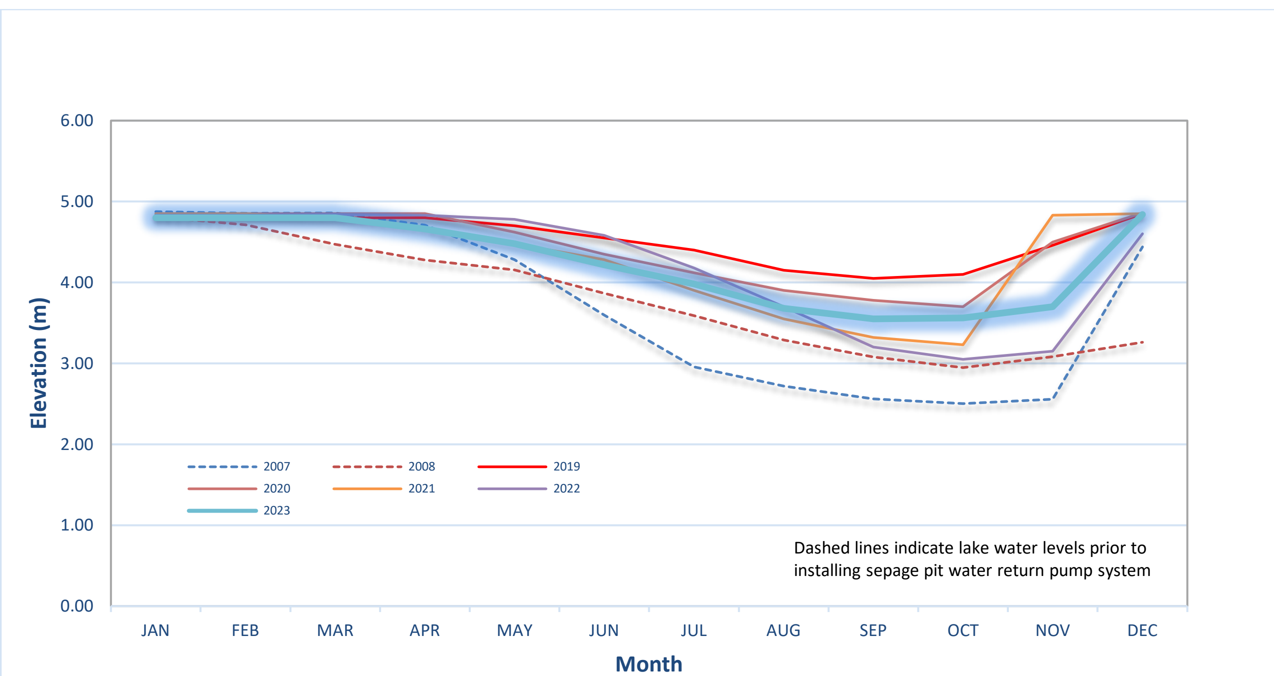


Figure 2: Money Lake Monthly Water Level

Water Production and Demand

Referring to Figure 3, 23,171 cubic meters of water was extracted (water production) from the seepage spring and Money Lake Reservoir in 2023; a 15% decrease from the previous year and a 7% decrease from the five-year average. Water demand (customer water billing) for the service totaled 19,534 cubic meters of water; 10% decrease from the previous year and an 1% increase from the five-year average.

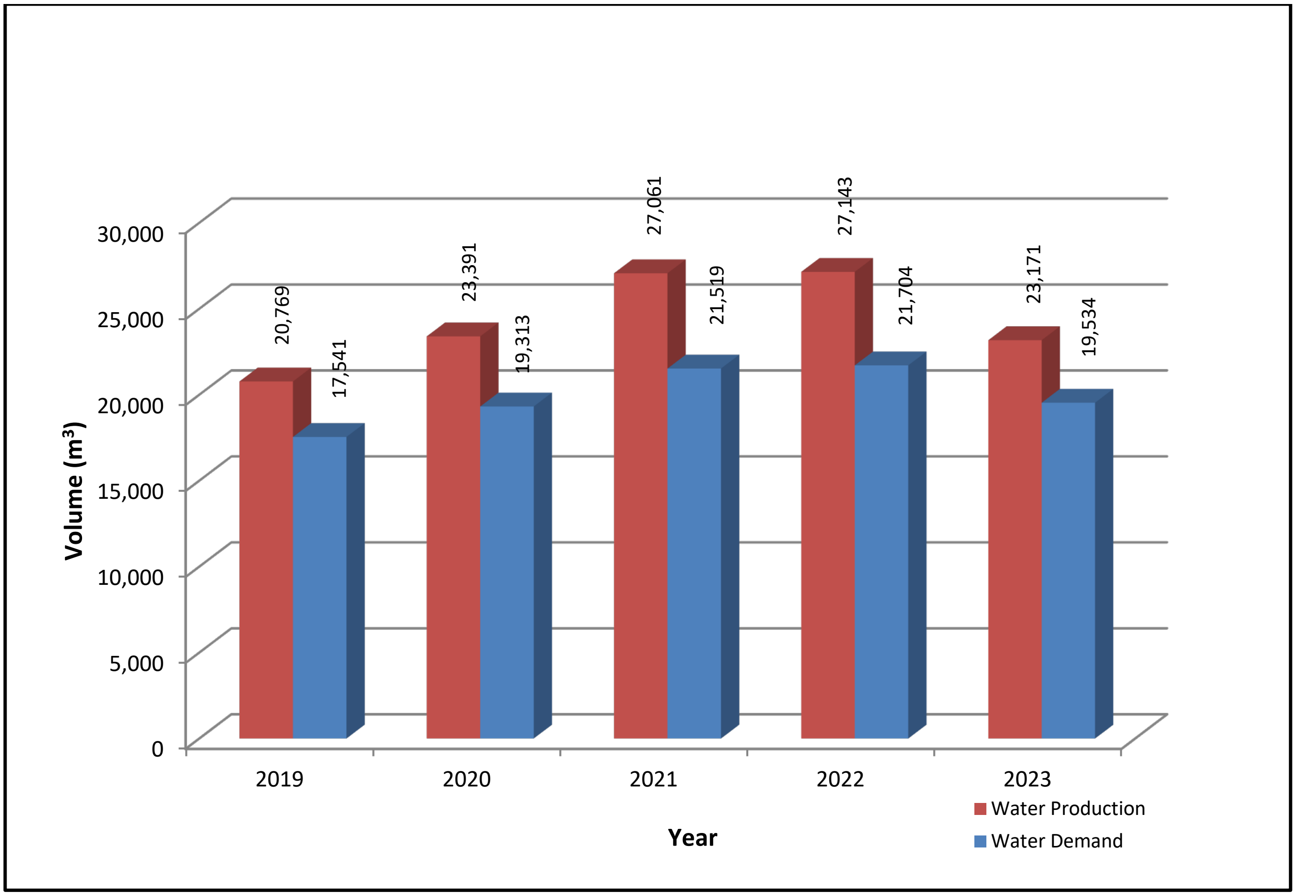


Figure 3: Lyall Harbour/Boot Cove Water System Annual Water Production and Demand

The difference between annual water production and annual customer demand is referred to as non-revenue water and can include water system leaks, water system maintenance and operational use (e.g. water main flushing, filter system backwashing), potential unauthorized use and fire-fighting use.

The 2023 non-revenue water (3,637 cubic meters) represents about 16% of the total water production for the service area. However, almost 14% of the non-revenue water can be attributed to operational use which includes water main flushing to keep chlorine residuals at acceptable levels at the extremities of the water system and water treatment filtration system backwashing activities. Therefore, the non-revenue water associated with system losses is approximately 2% which is considered acceptable for small water systems.

Figure 4 illustrates the monthly water production for 2023 along with the historical water production information. The monthly water production trends are typical for small water systems such as the Lyall Harbour/Boot Cove water system.

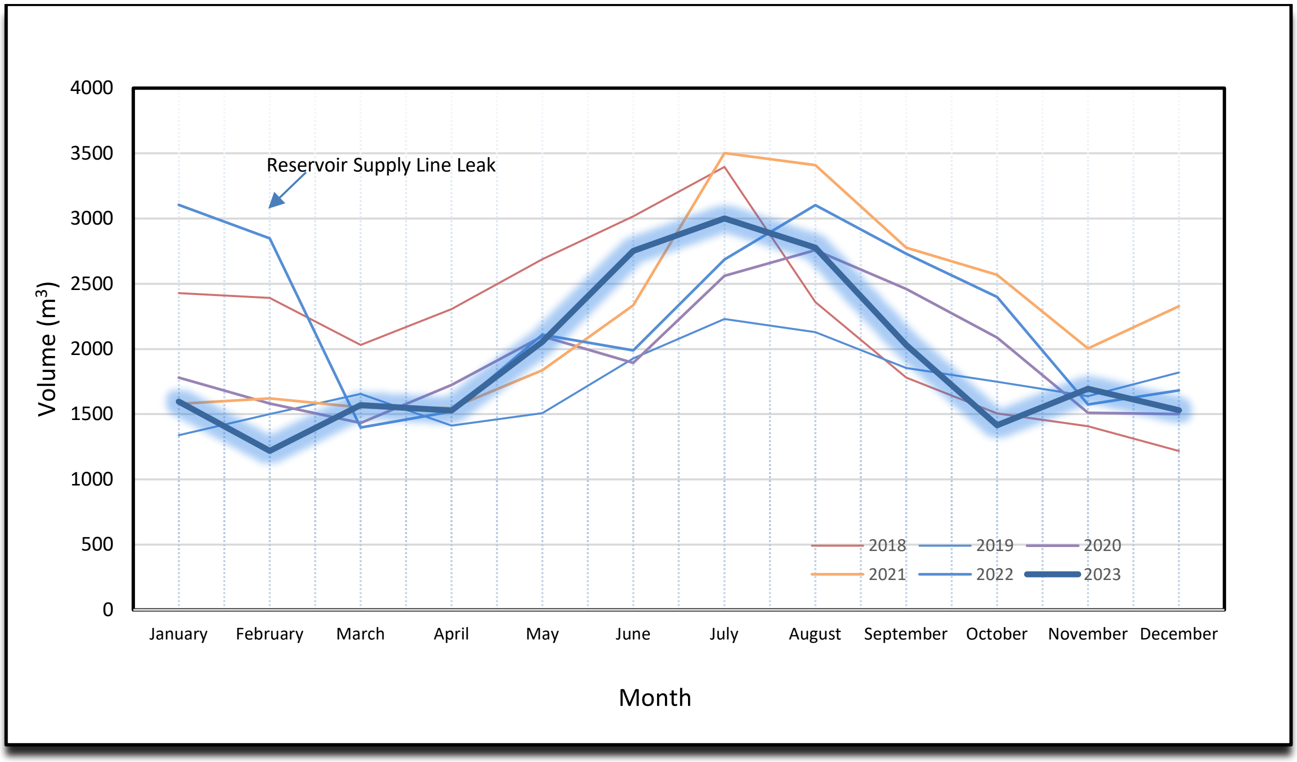


Figure 4: Lyall Harbour/Boot Cove Water Service Monthly Water Production

Drinking Water Quality

The Lyall Harbour/Boot Cove Water System uses predominantly seepage water collected from below the Money Lake dam as the primary raw water source. During the summer months this source is supplemented or completely replaced with flows from Money Lake. During summer and early fall 2023, all source water was supplied by Money Lake only, as the seepage water collection system ran dry. There is sufficient evidence to conclude that the seepage water is hydraulically connected to the lake source.

The Lyall Harbour/Boot Cove Water System experienced another challenging year in 2023. In total, it was under boil water advisories (BWA) for 179 days throughout the year. The first BWA was a continuation of a turbidity related event that has now developed into an annual pattern which sees the treated water turbidity starting to exceed one Nephelometric Turbidity Unit (NTU) in late fall and remaining above this threshold until the spring, typically until March. In 2023, this turbidity related BWA lasted even until April 21. On October 25, this annual winter turbidity pattern set in again and necessitated another BWA that lasted into 2024. CRD staff, in collaboration with scientists at the University of Victoria, concluded in a 2022 study that turbidity measurement interference likely contributes to this annual turbidity and BWA pattern. The study found evidence that dissolved organic matter interferes with the turbidity readings. CRD staff are working on a solution to this issue.

Between mid-June and mid-July, Money Lake experienced a strong cyanobacteria bloom. An even stronger cyanobacteria bloom occurred from early August to mid-October, with the peak in early September. Multiple cyanotoxin tests did not detect microcystin toxins in the raw water during these blooms.

These blooms did not pose a public health risk through the drinking water supplied. The annual average concentration for both regulated disinfection by-products, total Trihalomethanes (TTHM) and Haloacetic Acids (HAA), remained below the maximum acceptable concentration (MAC) in the Guidelines for Canadian Drinking Water Quality (GCDWQ).

The data below provides a summary of the water quality characteristics in 2023:

Raw Water:

- The raw water exhibited overall low concentrations of total coliform bacteria, with much higher concentrations during the summer and early fall months when lake water was the primary water source and water temperatures were high. Throughout most of the year, the raw water entering the treatment plant contained either none or only very low concentrations of *E. coli* bacteria.
- The raw water turbidity ranged from 0.9 to 18.2 NTU. The highest raw water turbidity period was recorded during a strong cyanobacteria bloom from mid-June to mid-July. The median annual raw water turbidity was 2.25 NTU.
- No *Giardia* cysts and no *Cryptosporidium* oocysts were detected in two sample sets in 2023.
- The raw water had naturally high concentrations of iron and manganese especially during the fall season. Elevated iron and manganese concentrations are typically released during the fall turnover event in Money Lake and can be compounded by the ground passage of the seepage water. Iron concentrations were especially high on November 15, likely because of the lake turnover event and in the wake of the first significant post-summer rainfalls in early November.
- The raw water was slightly hard (median hardness 40.1 mg/L $CaCO_3$).
- The natural total organic carbon (TOC) in the source water was moderately high (median 5.6 mg/L).
- The water had high colour, above the aesthetic objective in the GCDWQ in the fall and winter periods.

Treated Water:

- Outside the periods with a BWA, the treated water was safe to drink. No treated water sample from the distribution system tested positive for *E. coli* bacteria. Two distribution samples from July and September tested positive for total coliform bacteria. Immediate resamples from the same locations did not confirm an actual drinking water contamination.
- The treated water turbidity was regularly > 1 NTU from January to March and November/December and caused the two periods with BWAs. Investigations are underway to determine if the turbidity measurements could be affected by dissolved organic matter and whether such effect constitutes a risk to the safety of the drinking water or not. For this, a secondary turbidity analyzer with less interference from colour was installed in November 2023. Conclusions will be drawn after 1 year test period.
- The treated water TOC was periodically high within a range from 3.5 to 7.6 mg/L. The annual mean was 4.9 mg/L. There is currently no guideline in the GCDWQ for TOC levels, however TOC levels > 2 mg/L indicate a potential for disinfection by-product exceedances. TOC levels > 4 mg/L are usually a precursor for high disinfection by-product concentrations.
- As a result of a chlorination optimization process, the disinfection by-product (DBP) concentrations remained below the GCDWQ health limits. The annual average TTHM and HAA concentrations were 89.8 µg/L and 70.7 µg/L respectively and therefore below the MAC (100 µg/L and 80 µg/L respectively).

- Iron concentrations in exceedance of the aesthetic objective were found in distribution system samples from November and February. This was a result of high iron concentrations in the raw water and the lack of adequate treatment for metals. Manganese concentrations, while elevated in the raw water, were consistently low in the treated water. Elevated iron concentrations are not a health concern but can lead to discolouration of the drinking water which can be a nuisance for the customers. The newly established GCDWQ MAC for aluminum was not exceeded in 2023.
- The treated water had colour concentrations above the aesthetic objective throughout the fall and winter season.
- The annual median pH of the treated water was 6.2. This is well below the Health Canada recommended range of 7 - 10.5. Drinking water with low pH can cause corrosion issues on metallic pipes and fittings and potentially leach toxic metals such as lead into the drinking water. Lead in drinking water is typically not found in samples from distribution systems but in samples from building taps and faucets.

Table 1 and 2 below provide a summary of the 2023 raw and treated water test results.

Water quality data collected from this drinking water system can be also reviewed on the CRD website:

https://www.crd.bc.ca/about/data/drinking-water-quality-reports

Operational Highlights

The following is a summary of the major operational issues that were addressed by CRD Integrated Water Services staff:

- Operational effort due to the boil water advisory issued on October 18, 2022, and rescinded on April 21, 2023.
- System leak detection activities performed in January, April, May, and June because of low reservoir alarms due to high water demands. As a result, several leaks were identified to be on the private side of the system.
- Installed physical hand off auto switch (HOA) switch at Water Treatment Plant (WTP) to allow for operator control without use of SCADA.
- Replaced 2" isolation valve for standpipe at WTP.
- Installed and configured VPN connection and internet communications connection at WTP.
- Communications failure at WTP due to challenges with remote communications connection.
- Money Lake Line Leak Repair on Mill connection. Excavate, expose, and replace corroded fittings.
- Installation of second turbidimeter within WTP.
- Replacement of Chlorine Contact Tank isolation valves in March to allow for tank inspection that was completed November.
- Planned storage tank drain, clean and inspect completed in October.

Capital Project Updates

The Capital Projects that were in progress or completed in 2023 included:

1. Money Lake Dam - Dam Safety Review (Audit) Report - finalized. This report is a regulatory requirement and was funded by Community Works Funds.
2. Money Lake Dam Seismic Stability Assessment – finalized. The detailed 3D assessment was completed following the DSR Report to better understand the seismic hazards of the dam.
3. Dam Improvements – Geotechnical analysis was completed by Thurber Engineering including a draft toe filter design. Based on original design assessments, available funding is believed to be insufficient with the remaining Community Works Funds. CRD will continue to pursue grant funding opportunities but have discussed with the commission that options to secure debt will need to start being considered in 2024.

Financial Report

Please refer to the attached 2023 Statement of Operations and Reserve Balances.

Revenue includes parcel taxes (Transfers from Government), fixed user fees (User Charges), interest on savings Interest earnings), transfer from Operating Reserve Fund and miscellaneous revenue such as late payment charges (Other revenue).

Expenses include all costs of providing the service. General Government Services include budget preparation, financial management, utility billing and risk management services. CRD Labour and Operating Costs include CRD staff time as well as the cost of equipment, tools, and vehicles. Debt servicing costs are interest and principal payments on long term debt. Other Expenses include all other costs to administer and operate the water system, including insurance, supplies, water testing and electricity.

The difference between Revenue and Expenses is reported as Net revenue (expenses). Any transfers to or from capital or reserve funds for the service (Transfers to Own Funds) are deducted from this amount and are added to any surplus or deficit carry forward from the prior year, yielding an Accumulated Surplus (or deficit) that is carried forward to the following year.

Submitted by:	Jason Dales, B.Sc., WD IV, Senior Manager, Wastewater Infrastructure Operations
	Joseph Marr, P.Eng., Senior Manager, Infrastructure Engineering
	Glenn Harris, Ph.D., R.P.Bio., Senior Manager, Environmental Protection
	Angela Linwood, CPA, CMA, Controller, Financial Services
Concurrence:	Alicia Fraser, P.Eng., General Manager, Integrated Water Services
	Luisa Jones, MBA, General Manager, Parks, Recreation & Environmental Services

Attachments: Table 1
Table 2
2023 Statement of Operations and Reserve Balances

For questions related to this Annual Report please email IWSAdministration@crd.bc.ca

Table 1

Table 1: 2023 Summary of Raw Water Test Results, Lyall Harbour / Boot Cove Water System										
PARAMETER		2023 ANALYTICAL RESULTS				CANADIAN GUIDELINES	2013-2022 ANALYTICAL RESULTS			
Parameter Name	Units of Measure	Annual Median	Samples Analyzed	Range Minimum	Range Maximum	≤ = Less than or equal to	Median	Samples Analyzed	Range Minimum	Range Maximum
ND means Not Detected by analytical method used										
Physical/Biological Parameters										
Carbon, Total Organic	mg/L as C	**5.6**	12	3.5	7		5.03	114	3.2	18
Colour, True	TCU	**27.5**	12	10	88		19	65	9	RC 71
Hardness as $CaCO_3$	mg/L	**40.05**	4	36.8	43.3	No Guideline Required	43	71	34.7	52.2
pH	pH units	**6.35**	2	5.7	7	7.0 - 10.5 AO	6.81	27	6.2	7.52
Turbidity, Field Tests	NTU	**2.535**	68	1.22	18.2		3.125	352	0.67	36.1
Turbidity, Grab Samples	NTU	**2.25**	12	0.9	5		1.9	124	0.2	20.3
Water Temperature	Degrees C	**13.9**	102	1.3	22.3	15°C AO	10.8	472	-0.1	25.5
Metals										
Aluminum	ug/L as Al	**36.45**	4	10.4	145	2900 MAC / 100 OG	73.1	71	8.7	739
Antimony	ug/L as Sb	**< 0.5**	4	< 0.5	< 0.5	6 MAC	< 0.5	71	0.042	< 0.5
Arsenic	ug/L as As	**0.49**	4	0.34	0.6	10 MAC	0.4	71	0.22	1.06
Barium	ug/L as Ba	**3**	4	2.5	4.9	1000 MAC	3.3	71	1.47	40.4
Beryllium	ug/L as Be	**< 0.1**	4	< 0.1	< 0.1		< 0.1	71	< 0.01	< 3
Bismuth	ug/L as Bi	**< 1**	4	< 1	< 1		< 1	67	0.017	< 1
Boron	ug/L as B	**< 50**	4	< 50	< 50	5000 MAC	< 50	71	11	74
Cadmium	ug/L as Cd	**< 0.01**	4	< 0.01	< 0.01	7 MAC	< 0.01	71	< 0.01	< 0.1
Calcium	mg/L as Ca	**10.2**	4	9.32	11.3	No Guideline Required	10.8	71	8.65	13.2
Chromium	ug/L as Cr	**< 1**	4	< 1	< 1	50 MAC	< 1	71	0.15	< 10
Cobalt	ug/L as Co	**< 0.2**	4	< 0.2	< 0.2		< 0.2	71	0.022	< 20
Copper	ug/L as Cu	**2.33**	4	2.16	3.14	2000 MAC / ≤ 1000 AO	3.82	71	1.34	285
Iron	ug/L as Fe	**452.5**	4	188	1610	≤ 300 AO	273	73	25.6	1960
Lead	ug/L as Pb	**0.29**	4	< 0.2	0.46	5 MAC	0.24	71	<0.2	105
Lithium	ug/L as Li	**< 2**	4	< 2	< 2		2.13	39	< 2	20.1
Magnesium	mg/L as Mg	**3.525**	4	3.28	3.67	No Guideline Required	3.82	71	2.98	4.67
Manganese	ug/L as Mn	**45.5**	4	9.5	61.9	120 MAC / ≤ 20 AO	27.5	72	< 1	1370
Molybdenum	ug/L as Mo	**< 1**	4	< 1	< 1		< 1	71	0.065	< 20
Nickel	ug/L as Ni	**< 1**	4	< 1	< 1		< 1	71	0.353	< 50
Potassium	mg/L as K	**0.639**	4	0.509	0.889		0.659	71	0.387	1.36
Selenium	ug/L as Se	**< 0.1**	4	< 0.1	< 0.1	50 MAC	< 0.1	71	< 0.04	< 0.5
Silicon	mg/L as Si	**7270**	4	5840	8660		7310	71	2750	10100
Silver	ug/L as Ag	**< 0.02**	4	< 0.02	< 0.02	No Guideline Required	< 0.02	71	< 0.005	< 40
Sodium	mg/L as Na	**8.715**	4	7.77	9	≤ 200 AO	9.11	71	6.44	13.2
Strontium	ug/L as Sr	**93.75**	4	80.2	99.4	7000 MAC	95.8	71	70	120
Sulfur	mg/L as S	**< 3**	4	< 3	< 3		< 3	67	< 3	6.1
Tin	ug/L as Sn	**< 5**	4	< 5	< 5		< 5	71	0.46	65
Titanium	ug/L as Ti	**< 5**	4	< 5	7.5		< 5	71	1.44	65
Thallium	ug/L as Tl	**< 0.01**	4	< 0.01	< 0.01		< 0.01	67	0.008	< 0.05
Uranium	ug/L as U	**< 0.1**	4	< 0.1	< 0.1	20 MAC	< 0.1	67	0.007	< 0.1
Vanadium	ug/L as V	**< 5**	4	< 5	< 5		< 5	71	0.5	< 10
Zinc	ug/L as Zn	**6.55**	4	5.8	8.1	≤ 5000 AO	9.2	71	< 1	258
Zirconium	ug/L as Zr	**0.11**	4	< 0.1	0.25		0.17	67	< 0.1	0.57
Microbial Parameters										
Indicator Bacteria										
Coliform, Total	CFU/100 mL	**170**	11	10	7300		105	119	<1	9200
E. coli	CFU/100 mL	**< 1**	11	< 1	15		< 1	121	<1	29
Hetero. Plate Count, 35C (2 day)	CFU/1 mL	Not tested in 2023					2200	2	1100	3300
Parasites										
Cryptosporidium , Total oocysts	oocysts/100 L	**< 1**	2	< 1	< 1	Zero detection desirable	< 1	19	< 1	2.8
Giardia , Total cysts	cysts/100 L	**< 1**	2	< 1	< 1	Zero detection desirable	< 1	19	< 1	< 1
Algal Toxins										
Microcystin	ug/L	<1	10	<1	<1	1.5 ug/L MAC	<1	27	<1	<1

Table 2

Table 2: 2023 Summary of Treated Water Test Results, Lyall Harbour / Boot Cove Water System										
PARAMETER		2023 ANALYTICAL RESULTS				CANADIAN GUIDELINES	2013-2022 ANALYTICAL RESULTS			
Parameter Name	Units of Measure	Annual Median	Samples Analyzed	Range Min.	Range Max.	≤ = Less than or equal to	Median	Samples Analyzed	Range Minimum	Range Maximum
ND means Not Detected by analytical method used										
Physical Parameters										
Carbon, Total Organic	mg/L as C	**4.9**	16	3.5	7.6		4.395	152	1.1	66.9
Colour, True	TCU	**16**	24	2	> 50		7	60	< 2	40
pH	No units	**6.2**	2	5.9	6.5	7.0 - 10.5 AO	6.795	20	6.3	8
Hardness	mg/L as CaCO3	**40.2**	8	37.2	43.6		43.2	63	37.2	50.1
Turbidity	NTU	**0.85**	24	0.3	3.4	1 MAC and ≤ 5 AO	0.955	206	0.18	5.3
Turbidity, Field Tests	NTU	**0.79**	39	0.32	3.8		0.81	340	0.09	4
Water Temperature	Degrees C	**9.4**	209	4.5	19.4	≤ 15 AO	11.3	1780	0	RES 20.8
Microbial Parameters										
Indicator Bacteria										
Coliform, Total	CFU/100 mL	**< 1**	99	< 1	65	0 MAC	< 1	815	0	A 460
E. coli	CFU/100 mL	**< 1**	99	< 1	< 1	0 MAC	< 1	817	<1	1
Hetero. Plate Count, 7 day	CFU/1 mL	**1950**	40	< 10	15,000	No Guideline Required	610	119	< 10	A 24000
Algal Toxins										
Algal Toxins										
Microcystin	ug/L	Not tested in 2023				1.5 ug/L MAC	<1	3	<1	<1
Disinfectants										
Disinfectants										
Chlorine, Free Residual	mg/L as Cl2	**0.18**	189	0.02	5.7	No Guideline Required	0.35	1802	0.01	8.8
Chlorine, Total Residual	mg/L as Cl_2	Not tested in 2023				No Guideline Required	0.51	1394	0.01	8.8
Disinfection By-Products										
Haloacetic Acids										
HAA5	ug/L	**60**	3	12	140	80 MAC	52	29	< 0.1	160
Trihalomethanes (THMs)										
Bromodichloromethane	ug/L	**14**	4	12	15		15	44	0.643	40.6
Bromoform	ug/L	**< 1**	4	< 1	< 1		< 1	44	< 0.1	< 1
Chloroform	ug/L	**66.5**	4	52	110		80	44	7.26	250
Chlorodibromomethane	ug/L	**1.2**	4	< 1	1.6		1.6	44	<0.1	31
Total Trihalomethanes	ug/L	**82**	4	65	130	100 MAC	99	44	7.9	EXG 280
Metals										
Aluminum	ug/L as Al	**21.35**	8	6.7	115	2900 MAC / 100 OG	18.1	63	7.3	138
Antimony	ug/L as Sb	**< 0.5**	8	< 0.5	< 0.5	6 MAC	< 0.5	63	0.035	< 50
Arsenic	ug/L as As	**0.385**	8	0.28	0.49	10 MAC	0.34	63	0.2	0.8
Barium	ug/L as Ba	**2.75**	8	2.4	3.5	1000 MAC	2.5	63	1.5	16.1
Beryllium	ug/L as Be	**< 0.1**	8	< 0.1	< 0.1		< 0.1	63	< 0.01	< 0.1
Bismuth	ug/L as Bi	**< 1**	8	< 1	< 1		< 1	63	0.005	< 1
Boron	ug/L as B	**< 50**	8	< 50	< 50	5000 MAC	< 50	63	13	< 50
Cadmium	ug/L as Cd	**< 0.01**	8	< 0.01	< 0.01	7 MAC	< 0.01	63	< 0.005	0.087
Calcium	mg/L as Ca	**10.15**	8	9.44	11.3	No Guideline Required	10.9	63	9.55	13.2
Chromium	ug/L as Cr	**< 1**	8	< 1	< 1	50 MAC	< 1	63	< 0.1	< 10
Cobalt	ug/L as Co	**< 0.2**	8	< 0.2	< 0.2		< 0.2	63	0.01	< 0.5
Copper	ug/L as Cu	**26.4**	8	9.74	71.1	2000 MAC / ≤ 1000 AO	31.7	63	2.14	595
Iron	ug/L as Fe	**297**	8	68.2	1290	≤ 300 AO	118	65	28.8	EXG 1670
Lead	ug/L as Pb	**0.96**	8	0.47	2.29	5 MAC	0.915	63	<0.2	25.8
Lithium	ug/L as Li	**< 2**	8	< 2	< 2		< 2	34	1.74	< 5
Magnesium	mg/L as Mg	**3.585**	8	3.29	3.72	No Guideline Required	3.87	63	3.2	4.53
Manganese	ug/L as Mn	**3.75**	8	1.4	12.4	120 MAC / ≤ 20 AO	1.7	65	< 1	26.3
Molybdenum	ug/L as Mo	**< 1**	8	< 1	< 1		< 1	63	0.076	< 1
Nickel	ug/L as Ni	**1.05**	8	< 1	2.7		1.5	63	0.288	80.9
Potassium	mg/L as K	**0.6575**	8	0.514	0.868		0.681	63	0.479	0.956
Selenium	ug/L as Se	**< 0.1**	8	< 0.1	< 0.1	50 MAC	< 0.1	63	< 0.04	0.12
Silicon	mg/L as Si	**7135**	8	5940	8800		7220	63	2970	8850
Silver	ug/L as Ag	**< 0.02**	8	< 0.02	< 0.02	No Guideline Required	< 0.02	63	< 0.005	< 0.02
Sodium	mg/L as Na	**11.05**	8	10.1	14.4	≤ 200 AO	11.6	63	9.26	15.6
Strontium	ug/L as Sr	**95.9**	8	80.5	99.4	7000 MAC	96.2	63	81.5	121
Sulfur	mg/L as S	**< 3**	8	< 3	< 3		< 3	63	< 3	5.6
Tin	ug/L as Sn	**< 5**	8	< 5	< 5		< 5	63	< 0.2	47.8
Titanium	ug/L as Ti	**< 5**	8	< 5	6.1		< 5	63	0.79	9.3
Thallium	ug/L as Tl	**< 0.01**	8	< 0.01	< 0.01		< 0.01	63	< 0.002	< 0.05
Uranium	ug/L as U	**< 0.1**	8	< 0.1	< 0.1	20 MAC	< 0.1	63	0.008	< 0.1
Vanadium	ug/L as V	**< 5**	8	< 5	< 5		< 5	63	0.48	< 5
Zinc	ug/L as Zn	**26.05**	8	16.3	39.4	≤ 5000 AO	26.6	63	< 5	102
Zirconium	ug/L as Zr	**< 0.1**	8	< 0.1	0.46		0.12	63	< 0.1	0.66

CAPITAL REGIONAL DISTRICT

LYALL HARBOUR BOOT COVE WATER
Statement of Operations (Unaudited)
For the Year Ended December 31, 2023

		2023	2022
Revenue			
Transfers from government		133,030	131,060
User Charges		122,312	112,637
Other revenue from own sources:			
Interest earnings		147	415
Transfer from Operating Reserve		25,000	-
Insurance Claim Reimbursement		-	2,463
Other revenue		1,385	4,084
Total Revenue		281,874	250,659
Expenses			
General government services		8,676	8,301
CRD Labour and Operating costs		164,563	153,774
Contract for Services		9,421	1,902
Debt Servicing Costs		30,266	30,210
Other expenses		40,078	34,308
Total Expenses		253,004	228,495
Net revenue (expenses)		28,870	22,164
Transfers to own funds:			
Capital Reserve Fund		8,870	7,427
Operating Reserve Fund		20,000	10,000
Annual surplus/(deficit)		-	4,737
Accumulated surplus/(deficit), beginning of year		-	(4,737)
Accumulated surplus/(deficit), end of year	$	-	-

CAPITAL REGIONAL DISTRICT

LYALL HARBOUR BOOT COVE WATER
Statement of Reserve Balances (Unaudited)
For the Year Ended December 31, 2023

	Capital Reserve	
	2023	**2022**
Beginning Balance	32,171	23,956
Transfer from Operating Budget	8,870	7,427
Transfer from Completed Capital Projects	-	-
Transfer to Capital Projects	(8,000)	-
Interest Income	1,767	788
Ending Balance	34,808	32,171

	Operating Reserve	
	2023	**2022**
Beginning Balance	10,931	815
Transfer from Operating Budget	20,000	10,000
Transfer to Operating Budget	(25,000)	-
Interest Income	566	116
Ending Balance	6,497	10,931

Making a difference...together

REPORT TO LYALL HARBOUR/BOOT COVE WATER LOCAL SERVICE COMMITTEE
MEETING OF THURSDAY, JUNE 27, 2024

SUBJECT **Capital Project Status Reports and Operational Updates**

ISSUE SUMMARY

To provide the Lyall Harbour/Boot Cove Water Local Service Committee with capital project status reports and operational updates.

BACKGROUND

The Lyall Harbour/Boot Cove Water System is located on the west side of Saturna Island in the Southern Gulf Islands Electoral Area and provides drinking water to approximately 166 single family equivalents. Capital Regional District (CRD) Integrated Water Services is responsible for the overall operation of the water system with day-to-day operation, maintenance, design, and construction of water system facilities provided by the CRD Infrastructure Engineering and Operations Divisions. The quality of drinking water provided to customers in the Lyall Harbour/ Boot Cove Water System is overseen by the CRD Water Quality Section.

CAPITAL PROJECT UPDATE

19-02 | Pressure Reducing Valve (PRV) Bypass Assembly Replacement (Complete)

Project Description: Construct bypasses on the East Point, Narvaez, and Boot Cove PRV stations to maintain system operation while the PRV's undergo maintenance.

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

Project Update and Milestones:

- Operations to undertake the works.
- East Point, Narvaez and Boot Cove PRV work is all complete.

19-04 | Alternative Approval Process

Project Description: Conduct public consultation and carry out an Alternative Approval Process (AAP) to assess public willingness to utilize debt to fund necessary capital upgrades for the water service.

Project Rationale: Multiple projects including the dam improvements and the future ground well suitability study are deemed necessary for the water service and Capital Reserves are insufficient to cover the capital costs.

With several unsuccessful grant funding attempts, an AAP is proposed to obtain approval to take on debt to fund projects that are critical for the water service.

Project Update and Milestones:

- The AAP process has not yet been progressed but following the November 20, 2023, budget meeting, it was agreed that staff would initiate the process in 2024 once some certainty around obtaining use of a well on private land was clear so that this potential water source could be factored into the future planning.
- Progress has been made in 2024 regarding access to the private well. CRD hope to consolidate information to be able to start compiling information for an AAP in Q3/Q4 of 2024.

22-02 | Dam Improvements & Regulatory Requirements

Project Description: Seismic reinforcement of Money Lake Dam based upon the 2016 Dam Safety Review (DSR). Includes seepage pit construction and Dam Safety Review.

Project Rationale: This is a continuation of project 18-03, where seismic reinforcement of the Money Lake Dam will commence. Funds are required to retain a contractor to undertake the works and retain a consultant to conduct the dam safety review.

Project Update and Milestones:

- The Community Works Funds (CWF) were approved in 2021 for design work to start in 2022.
- Staff are currently engaging consultants to provide quotes for design and construction services.
- Geotechnical Engineer (Thurber) has conducted more detailed 3D analysis of the dam to better assess seismic risks and are reviewing the results and recommendations with CRD.
- Geotechnical Engineer (Thurber) has drafted a downstream toe filter design memo and are reviewing the results and recommendations with CRD.
- Assessment of constructability of recommendations resulted in concerns over funding availability to carry out the complete works. CRD submitted an internal Growing Communities Fund (GCF) grant application for additional funding (in combination with works to develop a future well) but this was determined to be unsuccessful at the September 13, 2023 CRD Board Meeting.
- CRD will continue to pursue other grant opportunities but in the absence of grant funding, debt will need to be secured to carry out this work, as well as future additional work identified within the DSR.
- CRD's 2024 Action Planning memo has been attached to this Report for reference.

Milestone	Completion Date
CWF Approval	October 10, 2021
Consultant Contract Award	July 27, 2022
Consultant field investigation	August 31, 2022
Draft Dam Safety Review submission and CRD review meeting	Jan 27, 2023
Dam Safety Review Report - Final	March 15, 2023
Toe Filter Design Memo	March 27, 2023
Seismic Stability Assessment	April 21, 2023
Growing Communities Fund Grant Application – Not Approved	September 13, 2023
Action Planning Memo to address DSR items	Q1 2024

OPERATIONAL UPDATE

This is an operational update reporting period from February through May 2024.

- Boil Water Advisory (BWA) issued on October 25, 2023, for the service due to elevated treated water turbidity was discontinued on March 15, 2024. Water quality sampling and testing results were discussed with Island Health and confirmed the water was safe and boiling was no longer required before consumption.
- Water Treatment Plant (WTP) Ultraviolet Light (UV) treatment system operational control improvements. The improvements are intended to extend the operating life of the UV system equipment.
- WTP plant occupational health and safety investigation and corrective actions. Corrective actions included replacement and rerouting of the sodium hypochlorite chemical feed lines. Operations office relocated from the WTP to remote site for operator to perform administrative duties. Implement chlorine gas monitoring procedure for operator. Other corrective actions are pending that include facility extraction fan improvement and implementation of additional emergency tempered shower system.
- Surge tank and raw water supply line flushed and cleaned in advance of BWA discontinuance.
- Emergency response to water treatment plant SCADA communications failure event.
- Continued response and effort during this reporting period related to leak detection due to high daily water production. Several properties were identified having leaks. Water was turned off and residents were notified.
- Money Lake Dam corrective maintenance that included pressure washing the concrete spillway and repairing damaged concrete joint sealant.
- Boot Cove PRV Station bypass capital work completed by Operations. All PRV station bypass capital work is now complete.
- Narvaez PRV damaged hatch replaced.
- Annual regulatory formal dam inspection completed on May 29.
- Replacement of the WTP filtration media operational project initiated. This preventative maintenance work involves the procurement of specified anthracite, granular activate carbon and sand/gravel filtration media. Operations is currently working with a consultant to assist in the review and procurement of the filtration media products. This work is funded by the Operating Reserve Funds (ORF) that is included in the 2024 operating budget in the amount of $20,000.

RECOMMENDATION

There is no recommendation. This report is for information only.

Submitted by:	Jared Kelly, P.Eng., Manager, Capital Projects
Submitted by:	Dan Robson, A.Sc.T., Manager, Saanich Peninsula and Gulf Islands Operations
Concurrence:	Joseph Marr, P.Eng., Senior Manager, Infrastructure Engineering
Concurrence:	Jason Dales, B.Sc., WD IV., Senior Manager, Wastewater Infrastructure Operations
Concurrence:	Alicia Fraser, P.Eng., General Manager, Integrated Water Services

Appendix A: Money Lake Dam No. 1 – 2022 Dam Safety Review Audit – Action Plan

Memorandum

Making a difference...together

TO: FILE

FROM: Jared Kelly, P.Eng., Manager, Capital Project

DATE: April 10, 2024 FILE: 5220-20

SUBJECT: Lyall Harbour Boot Cove (LHBC) – Money Lake Dam No. 1 – 2022 Dam Safety Review Audit – Action Plan

Introduction

Money Lake Dam No. 1 is located on Saturna Island as part of the Lyall Harbour Boot Cove water service ("LHBC"), which provides drinking water to more than 160 properties. Due to the remote location and small user base of this water service, financial and human resources are limited. This adds to the challenge in delivering significant capital projects. The Capital Regional District ("CRD") hired Thurber Engineering Ltd. ("Thurber") to complete the Money Lake Dam No. 1 – 2022 Dam Safety Review Audit ("DSR") as part of LHBC Capital Project Number 22-02. The DSR is a legislated obligation to the BC Dam Safety Regulation, (BC Reg 40/2016), and the Water Sustainability Act. Thurber finalized the DSR on March 15, 2023. The report was submitted to the BC Dam Safety Officer (David Johnson) by email on May 11, 2023 and followed up by a phone call on the same day. In alignment with the regulations, this memo has been prepared to outline CRD's plan to address the items listed in the DSR.

Key findings

At the completion of the DSR, the dam consequence classification of "High" was deemed to remain appropriate. While the DSR concluded that the owner (CRD) has complied with all applicable regulations, several recommended actions were identified, which include 8 non-conformances, 2 deficiencies and 1 potential deficiency. A detailed list of these items can be found in Table G-1, located in Appendix G of the DSR. A summary of recommendations from the DSR has also been further expanded upon to include preliminary budget estimates for the various items in Table 1, below.

Table 1 - DSR Recommendations and Budget Breakdown

No.	Recommendation	Priority / Effort	Proposed CAPEX *	Proposed OPEX *
1	Recommendations related to the DSR site visit include the following: a) Repair and reseal the exposed foam water stops within the concrete joints of the spillway. b) Remove the excess vegetation from the stilling basin area. c) Re-establish the rock stilling basin by installing new rock or reshaping the existing rock to provide adequate erosion protection where the spillway chute discharges into the creek channel. Also restore armouring in the channel immediately downstream of the dam where the pedestrian bridge abutment is undermined. d) Clean or replace the primary staff gauge, which is difficult to read. The adjacent broken gauge should be removed. e) An information sign should be posted at the dam to follow best practices described by the CDA and meet the intent of the BC Dam Safety Regulation	High/Low to Moderate	a) $12,000 c) $15,000	b) $1,000 d) Complete e) Complete

2	An updated dam break analysis and inundation study should be completed that considers both sunny day and flood induced failure scenarios.	High / Moderate	$60,000	
3	Evaluations should be carried out to assess the condition of the HDPE water supply pipe and whether any leaks are present, particularly the section extending from the upstream face of the dam to the vicinity of MH1 beyond the downstream toe.	Moderate/Moderate	$15,000	
4	The CRD should continue planning to install a downstream toe filter. However, given the observed groundwater conditions at the toe of the dam, alternate toe filter design concepts should be prepared.	High/Moderate	$375,000 (design underway)	
5	The following recommendations relate to instrumentation: a) When collecting water level readings, surveillance staff should review the readings collected during the previous visit. If the reading is beyond the typical data range, repeated readings should be completed to improve confidence in the data. b) Surveillance staff should be mindful of the sediment level within MW16-02, which may still be accumulating. A water level within several centimeters of the sediment may not be an accurate indication of the phreatic surface within the dam. If a well is noted to be dry, this be noted in the record. c) Surveillance staff should sound the monitoring wells and well point installations to full depth at least annually to check for the accumulation of material within the wells. This information should be noted in the data spreadsheet. d) The seepage database should also include daily precipitation data from a nearby weather station. This practice is done for other CRD dams and including this information in the plot can provide added context when evaluating elevated seepage measurements. e) The CRD should retain an engineering consultant familiar with earth dams to review and interpret the piezometric data on an annual basis.	High/Low		Within existing budget Within existing budget Within existing budget Within existing budget $10,000/yr
6	The CRD should confirm that local operations and surveillance personnel receive adequate dam inspection and emergency response training, and that refresher sessions be offered on a regular basis to support new and existing personnel. Training activities should be recorded.	High/Low		Within existing budget
7	The following recommendations pertain to the OMS Manual: a) Additional operational details should be included in the manual, including the pipework schematic plan, along with function of the five noted valves. A copy of this drawing is included in Appendix B. b) Details regarding instrumentation and data recording/management should be included in the surveillance section of the manual (rather than maintenance). The frequency of data collection at installed monitoring instruments should be specified. c) A comment should be included to sound the three standpipes (MW16-01, -02, and -03) to the bottom at least once a year to check for the development of sediment. If sediment builds up above the length of the well screen, the functionality of the instrument will be compromised, and it may be necessary to flush the well out to improve instrument performance.	High / Low	$5,000	Within existing budget Within existing budget Within existing budget

	d) Additional detail should be provided in the surveillance section regarding what observations could trigger increased levels of surveillance, including how significant an increase in measured seepage rate would justify increased surveillance. Increasing water levels at the standpipe piezometer installations should also be listed as a trigger for increased levels of surveillance or the detection of cloudy seepage. The CRD should retain a consultant to assist in the development of alarm levels.			Within existing budget
8	The following recommendations pertain to the DEP: a) The description of the 5-step DEP process, including how to determine the appropriate emergency level, should be presented before discussion on the general roles and responsibilities during an emergency, since these actions depend on the emergency level. b) The drawings included in Appendix C should represent current conditions. c) Simplify/consolidate the presentation of information to make it easier to find. For example, delete Appendix I and include the information in Table 1 of the plan, where most of the information is already presented. Also consolidate Appendix D and Appendix G, as similar information is presented in both appendices. d) An assessment should be completed to evaluate the approximate drawdown rates associated with available rental equipment (i.e., pumps) and add this information to the emergency reservoir drawdown SOP included in Appendix J of the new DEP. This would assist with emergency planning.	High / Low	$5,000	Within existing budget Within existing budget Within existing budget Within existing budget
9	It is recommended that a training exercise be carried out to test the DEP once it is updated to allow local operations staff to become more familiar with their roles and responsibilities during an emergency (Section 11.4).	Moderate/Moderate	$5,000	Within existing budget

**Costs in this table are considered preliminary and should be further developed in the capital planning process.*
Updates to EGBC requirements for DSR Reviews and High-Risk Professional Activities or Work may result in the need for further independent engineering reviews in the future, which would result in additional time and costs for completing some works.

In parallel with the DSR process, CRD requested that Thurber conduct a 3D finite element analysis to assess the seismic risk of Money Lake Dam No. 1 (see attachment). This assessment was done based on Thurber's recommendation that a 3D analysis would more accurately reflect the field conditions beyond what could have been shown on previous 2D analyses. The analysis predicted that following the 1/2475yr design earthquake, complete dam failure is not predicted, and deformations of the dam would be more localized than predicted in previous modelling scenarios. It is important to note however, that some permanent deformations would still occur and require assessment and likely repairs, following the design seismic event. Based on this, the recommendation for buttressing has been deferred at this time but may be reassessed following subsequent DSR's.

Additionally, it is worth noting that a leak along the water supply line, downstream of the dam, was identified by operations staff in early 2023 and flagged for review by CRD engineering staff. This quick identification highlights that the dam visual surveillance process is working. CRD informed the Dam Safety Officer as a courtesy but given the work was not within the dam structure and was necessary for maintaining the water service, no formal Leave to Commence process was necessary. The water line was isolated until a subsequent repair could be completed by CRD Operations staff, under direct supervision of a geotechnical engineer from Thurber. Oversight of this work verified that this was in fact a leak in the water pipeline and not an issue resulting from the dam structure itself.

Progress and Next Steps

Items 1b, 1d, 1e, 5 and 6 are either already complete, or already planned to be addressed in the near term as part of CRD's Dam Safety Program. Items 7, 8 and 9 will require some capital investment but CRD believe that funding can be secured and these works completed within the 2-3 years.

Items with more significant capital investment requirements (1a, 1c, 2, 3 and 4) present an additional challenge due to the limited funding and resource availability within the LHBC water service. LHBC has a small user base and limited Capital Reserves. Other critical works outside of Money Lake Dam No. 1 are also being restricted due to funding limitations. In the absence of available capital reserves, CRD and the LHBC Committee must seek additional funding sources, typically in the form of grants or debt. A Community Work Fund grant was obtained in 2022 which has funded this DSR as well as a seismic stability assessment and preliminary toe filter design. Following the preliminary toe filter design, CRD solicited local contractor input in June 2023 and assessed that the remaining funding was insufficient to carry out the extent of the toe filter works. With this knowledge, CRD applied for a Growing Communities Fund grant in June 2023 but were informed in September 2023 that this was unsuccessful. With this knowledge, CRD raised the funding limitations with the LHBC Committee during the 2024 budget meeting on November 20, 2023 and expressed concerns on waiting further for grant opportunities. The LHBC Committee generally agreed with CRD's recommendation to proceed with an Alternate Approvals Process ("AAP") in hopes of obtaining approval from the water service users to secure debt to carry out these works, in addition to other critical projects required for the water service. The agreement to proceed with the AAP was under the conditions that:

1) CRD continue to pursue grant opportunities in the interim; and

2) CRD wait to proceed with the AAP until other critical projects can be included – in particular, the development of a potential ground water well that CRD is expecting to be granted access to.

CRD will continue with planning work to support the AAP process. Of the items 1a, 1c, 2, 3 and 4 that require additional funding, item 4 is considered the most critical and the most expensive and so it will be prioritized above the other items, subject to funding availability. This toe filter work has been recommended by Thurber to be completed in the dry season so if an AAP is conducted and successful in 2024 (other projects and resourcing factors could delay this) then there is potential to proceed with this work in 2025. Any delays limiting the ability to obtain additional funding would further delay these improvements.

In addition to the specific action planning items above, the Dam Safety Regulation mandates that Dam Safety Reviews for "High" Consequence Classifications must be completed every 10 years and as such, funding must be made available to complete the next DSR by 2032 to comply with the regulation.

Attachments (3): -Money Lake Dam No. 1 – 2022 Dam Safety Review (Audit) – Lyall Harbour Boot Cove Water Service
-2024 Lyall Harbour Boot Cove Capital Budget
-Money Lake Dam No. 1 Seismic Performance Assessment

Cc: Joseph Marr, P. Eng., Senior Manager, Infrastructure Engineering
Jason Dales, B.Sc., WD I, Senior Manager, Wastewater Infrastructure Operations
Scott Mason, P.Eng., Manager, Water Supply Engineering and Planning
Dan Robson, Manager, Saanich Peninsula and Gulf Island Operations
Scott Hawthorne, CWP, Field Supervisor, Saanich Peninsula and Southern Gulf Islands Operations
Damon Gosper, P.Eng., Project Engineer
Fraser Hall, A.Sc.T., Senior Technologist

Attachment 1

Money Lake Dam No. 1 – 2022 Dam Safety Review (Audit) – Lyall Harbour Boot Cove Water Service

THURBER ENGINEERING LTD.

MONEY LAKE DAM NO. 1
2022 DAM SAFETY REVIEW (AUDIT)

LYALL HARBOUR / BOOT COVER WATER SERVICE

Report
to
CRD Integrated Water Services

Thurber Engineering Ltd.
Permit to Practice #1001319

PROFESSIONAL PROVINCE OF J. D. McINTYRE BRITISH COLUMBIA ENGINEER

2023-03-15

Jay McIntyre, P.Eng.
Senior Geotechnical Engineer

Date: March 15, 2023
File: 21566

Stephen Bean, P.Eng.
Review Engineer

THURBER

EXECUTIVE SUMMARY

Per the requirements of the BC Dam Safety Regulation (B.C. Reg 40/2016), a dam safety review (DSR) has been completed for Money Lake Dam No. 1, located on Saturna Island, BC. The dam is owned and operated by the Capital Regional District (CRD) and provides drinking water to approximately 150 local properties within the Lyall Harbour / Boot Cove service area. This is the second DSR to be completed for the dam - the first being undertaken in 2011 by EBA (now Tetra Tech).

A thorough review of background information was carried out as part of the DSR process, including notes and correspondence from the 1970s and 1980s not previously available. The dam was originally constructed prior to 1978 and was last raised in 1979/80. Leakage has been a significant operational concern for the facility and the CRD has made efforts to capture seepage downstream of the dam and incorporate it into their water supply system. Recognizing the previous seepage performance concerns, an inclined granular filter was incorporated into the 1979/80 dam raising design, but in some areas this zone was placed against gradationally incompatible material. Nor was it extended to sufficient depth to filter seepage through natural channel deposits that remain under the central portion of the dam.

Key recommendations from the 2011 DSR included completing a minor dam raising to prevent the predicted overtopping of the dam during the inflow design flood (IDF), completing geotechnical investigations and a stability assessment to evaluate seismic performance of the dam, and installing a downstream toe filter/drain to reduce the potential of a piping failure, which was considered a credible failure mode. Since the last DSR was completed, geotechnical studies have been carried out by Tetra Tech and Thurber to characterize the dam fill and underlying foundation materials, and to evaluate the dam stability under using limit equilibrium methods. These studies concluded that both the upstream and downstream dam slopes have an adequate factor of safety (FS) during static loading conditions, but do not meet the Canadian Dam Association's (CDA) recommended minimum safety factors for the pseudo-seismic and post-earthquake loading conditions. This indicated that significant permanent deformations may occur during a design level earthquake, which could potentially result in a sudden release of the reservoir.

To address the seepage performance concerns raised by the 2011 DSR, the CRD made preparations in 2019 to install a downstream toe filter that followed the preliminary design concept developed by Tetra Tech. However, additional geotechnical investigations completed prior to construction concluded that groundwater control using either local sumps or newly installed screened wells would likely be inadequate to safely control groundwater during construction. It was recommended that an alternate toe filter design be developed, and it was noted that such a

THURBER

system would likely be incompatible with the existing downstream seepage collection infrastructure. Given these findings it was recommended that an alternate toe filter configuration be developed, and this design work is currently underway.

Following the 2011 DSR, a preliminary design for a seismic buttress was proposed to improve the embankment's seismic performance. However, given the narrowing downstream valley and shallow sandstone bedrock, Thurber recommended that more sophisticated seismic deformation analyses be completed to evaluate the anticipated seismic performance benefits from three-dimensional effects. This work has been undertaken as a parallel study by Thurber and the analysis results indicate that earthquake-induced deformations will be considerably smaller than previously estimated using simpler methods. As a result, a sudden uncontrolled release of the reservoir is not anticipated following a design level (1/2475) earthquake.

Based on the available information, the facility's previously determined dam failure consequence classification (High) appears to be appropriate. However, an updated and more sophisticated dam break and inundation study is recommended and would provide an improved understanding of inundation areas, water depths and flow velocities. This information would help with emergency planning and would also inform future decision-making regarding dam safety management.

An independent review of the inflow design flood (IDF) was completed for Money Lake and resulted in an estimated flow rate of 6.0 m^3/s which is approximately 17% lower than the IDF flow rate calculated previously. Hydrotechnical calculations confirmed that the IDF could be safely routed through the existing spillway and that the minimum freeboard requirements identified in the CDA guidelines (2007) would be achieved. Based on these updated findings, the previously recommended minor dam raising is not required.

The recently released 6^{th} generation seismic model prepared by the Geological Survey of Canada indicates an overall increase in the seismic hazard for the Money Lake Dam No. 1 site compared to the 5^{th} generation (2015) model. This results in an approximate 24% increase in site-adjusted peak ground acceleration assuming Site Class B conditions (shallow bedrock).

Both the facility's latest Operations, Maintenance and Surveillance Manual and Dam Emergency Plan were reviewed and were generally found to provide the necessary information and level of detail. Minor recommendations were provided on how to improve the documents, primarily in terms of their layout and ease of use.

A review of the owner's compliance with the regulatory requirements specified in B.C. Reg 40/2016 was completed and the CRD was found to have complied with all applicable regulations.

THURBER

A dam safety expectations assessment was completed to identify and document deficiencies and non-conformances in the dam's overall safety management. The assessment identified 8 non-conformances, 2 actual deficiencies and one potential deficiency. Recommendations are provided to address the noted deficiencies and non-conformances.

THURBER

TABLE OF CONTENTS

THURBER

TEXT FIGURES

TABLES

THURBER

APPENDICES

THURBER

LIST OF ACRONYMS AND ABBREVIATIONS

AEP	Annual Exceedance Probability
CDA	Canadian Dam Association
CRD	Capital Regional District
DEP	Dam Emergency Plan
DFCC	Dam Failure Consequence Classification
DSO	Dam Safety Officer
DSR	Dam Safety Review
EBA	EBA Engineering Consultants Ltd.
FS	Factor of Safety
GSC	Geological Survey of Canada
HDPE	High Density Polyethylene
ICOLD	International Congress on Large Dams
IDF	Inflow Design Flood
IWS	Integrated Water Services
LHBC	Lyall Harbour / Boot Cover
KWL	Kerr Wood Liedal Associates Ltd.
MCE	Maximum Credible Earthquake
NBCC	National Building Code of Canada
OMS	Operation, Maintenance and Surveillance
PGA	Peak Ground Acceleration
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PVC	Polyvinyl Chloride
QPE	Qualified Professional Engineer
WCT	Willis Cunliffe Tait

THURBER

1. INTRODUCTION

This report presents the results of the 2022 Dam Safety Review (DSR) of Money Lake Dam No. 1 conducted by Thurber Engineering Ltd. (Thurber) and its sub-consultant Kerr Wood Leidal Associates Ltd. (KWL) for the Capital Regional District (CRD).

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions. With reference to Clause 4 of the Statement (Use of the Report) the CRD and the Dam Safety Office of the BC Ministry of Forests are considered approved users of this report.

2. PROJECT UNDERSTANDING

Per the requirements of the BC Dam Safety Regulation (B.C. Reg 40/2016), it is the responsibility of dam owners to ensure that their facilities comply with acceptable safety standards. Under the regulation, owners of a dam with a failure consequence classification of High, Very High or Extreme must complete a DSR, no less frequently than every 7 to 10 years (depending on the dam's failure consequence rating) and submit it to a dam safety officer for acceptance.

Thurber's scope of work for this assignment was outlined in our letter dated July 27, 2022. It was proposed that the 2022 DSR be generally conducted as an audit type assessment in general accordance with the Engineers and Geoscientists B.C. (EGBC) Professional Practice Guidelines for Legislated Dam Safety Reviews in B.C. (version 3.0) and the 2007 Canadian Dam Association Dam Safety Guidelines (CDA, updated 2013). The following summarizes the various tasks to be completed:

- Review of relevant background information,
- Site visit,
- Review of dam failure consequence classification,
- Assess hazards and failure modes,
- Dam safety assessment including geotechnical and hydrotechnical aspects of the facility's design and performance,
- Review the Operations Maintenance and Surveillance Manual and Dam Emergency Plan,
- Review of dam safety management system, and
- Preparation of the DSR report.

Approval to proceed with this scope was received in the form of Purchase Order No. 4500100457 signed August 8, 2022.

THURBER

This is the second formal DSR completed for Money Lake Dam No. 1. The first was undertaken by EBA Engineering Consultants Ltd. (EBA) in 2011. Since that time, professional practice guidelines have been developed by EGBC for conducting DSRs. Under the current practice, the DSR Engineer is to prepare a Dam Safety Assurance Statement that provides an opinion of the safety of the dam.

3. FACILITY DESCRIPTION

Money Lake Dam No. 1 (the dam) is located on Saturna Island, BC, within the CRD's Lyall Harbour/Boot Cove local service area and provides drinking water for approximately 150 local properties. The dam is located about 2 km southeast of the BC Ferries terminal at Lyall Harbour (see Figure A-1 in Appendix A). The dam can be accessed by means of a gated gravel driveway located near the intersection of Harris Road and Staples Road, approximately 700 m south of Narvaez Bay Road. Table 1 below provides a summary of key features of the dam and impoundment.

TABLE 1 – KEY ATTRIBUTES OF MONEY LAKE DAM No. 1 AND RESERVOIR

Dam Location	48.7862 N, 123.1790 W
Reservoir Surface Area	23,000 m^2 (approx.)
Approximate Storage Capacity	72,000 m^3 (approx.)
Spillway Sill / Full Pool Elevation	150.55 m (top of weir, concrete slab elevation 150.4 m)
Spillway Width at control	4.3 m (Aluminum Weir)
Spillway Width	2.44 m (at crest); 1.22 m (chute)
Dam Crest Elevation	~152.0 m
Normal Freeboard (Full Pool Level)	~1.4 m
Dam Crest Length	~46 m
Dam Crest Width	4.5 m
Original Construction Date	Unknown (prior to May 1978)
Dam Upgrades	Dam Raised (1979/1980); Spillway replaced (1986); Intake Modified (2004); Piezometers Installed (2016)
Dam Construction Type	Zoned earth fill (following 1979 raising)
Upstream Embankment Slope	~2H:1V
Downstream Embankment Slope	~2H:1V
Embankment Height	~7 m
Low-Level Outlet Pipe	none
Water Supply Intake Pipe	150 mm diameter (HDPE)

THURBER

The dam is located near the west end of Saturna Island in a narrow fault valley that trends in the north-south direction and runs between Mt. Fisher on the west and Mt. Warburton Peak on the east. The dam is located at the north end of the reservoir. Bedrock exposures indicate the local bedrock is primarily sandstone of the Late Cretaceous Nanaimo Group. Including the lake, the reservoir catchment area was estimated to be about 1.17 km^2, and the median basin elevation of the Money Lake Dam No. 1 watershed is approximately 230 m (EBA, 2011).

A concrete spillway is located near the dam's right abutment and empties into a rock stilling basin prior to flowing into Money Creek downstream. The stilling basin was constructed approximately 5 m in diameter, 1 m deep, and lined with nominal 0.5 m diameter rock fill (EBA, 2011). A 150 mm diameter water intake pipe is located in the lake, suspended from a raft some distance upstream. Available drawings indicate the intake is a high-density polyethylene (HDPE) pipe that passes through the dam near the spillway and then curves to the northwest immediately downstream of the dam, ultimately crossing to the ditch running along the west side of the downstream access road (see record drawings in Appendix B). Additional infrastructure is located downstream of the dam and was originally installed to collect seepage emanating below the dam. Further details are provided in Section 4 of this report.

4. REVIEW OF BACKGROUND INFORMATION

Table 2 below summarizes the background information that was reviewed while completing the current DSR.

TABLE 2 – SUMMARY OF BACKGROUND INFORMATION REVIEWED

Document Name	Date	Prepared By
Internal Thurber project correspondence	1978 - 1982	Thurber
Money Lake Dam, Saturna Island; Seepage Concerns	Aug. 23, 2007	Thurber
Money Lake Dam, Saturna Island; Test Trench Excavation and Backfilling – Completion Report	Oct. 15, 2007	Thurber
Money Lake Dam, Saturna Island; Site Inspection of January 16, 2008	Jan. 18, 2008	Thurber
Money Lake Dam, Saturna Island; Site Inspection of February 10, 2009	Feb. 17, 2009	Thurber
Money Lake Dam, Saturna Island; Site Inspection of August 12, 2010	Oct. 6, 2010	Thurber
Money Lake No.1 - Dam Safety Review 2011 (Report)	Apr. 2012	EBA
Lyall Harbour / Boot Cove; Collection System Record Drawing	Apr. 9, 2013	Genivar
Lyall Harbour / Boot Cove; Money Lake Dam Pipework Schematic	Apr. 2014	CRD

THURBER

Money Lake Dam #1 Engineering Assessment; Lyall Harbour/Boot Cove, Saturna Island	Oct. 13, 2016	Tetra Tech EBA
Annual Dam Inspection Reports – Lyall Harbour Boot Cove	2017 - 2022	CRD
Preliminary Design Technical Memorandum; Money Lake Dam Upgrade – Downstream Filter	Sep. 14, 2017	Tetra Tech Canada Inc.
Money Lake Dam, Saturna Island, BC; Conceptual Design of Seismic Buttress	Nov. 7, 2018	Thurber
Money Lake Dam, Saturna Island, BC; Geotechnical Investigation Preliminary Summary of Findings	Oct. 11, 2019	Thurber
Money Lake Dam, Saturna Island, BC; Geotechnical Investigation Report	Dec. 18, 2019	Thurber
2021 Formal Annual Dam Inspection – Lyall Harbour Boot Cove	Oct. 7, 2021	CRD
Dam Emergency Plan and Operation, Maintenance and Surveillance Manual; Money Lake Dam No. 1	Jan. 2022	CRD Integrated Water Services
Monitoring data (i.e., piezometric readings, seepage observations and reservoir levels) up to December 2022	-	CRD
Dam Safety Risk Register (spreadsheet)	-	CRD

The following is a summary of the dam's history based on available drawings and reports, archived correspondence in Thurber's project files and verbal information obtained during the site reconnaissance visit.

<u>Original Dam Configuration (1978)</u>

The original dam was constructed prior to 1978 by Mr. John Money, who operated a small sawmill nearby. The dam reportedly incorporated a homogenous earth fill section constructed using weathered sandstone obtained from the east (right) abutment area. This material was reportedly placed and compacted using a dozer. Based on archived information in Thurber's files, the original dam was approximately 27.4 m long and 3.6 m high and was constructed over an even smaller dam that was built previously by Mr. Money's father. The original dam reportedly had a 50 mm diameter PVC intake pipe that supplied water to the sawmill.

Willis Cunliffe Tait (WCT) was retained by the CRD to complete a water supply feasibility study in 1978 and subsequently prepared the design of dam upgrades. At the request of WCT, Thurber completed a site visit in May 1978 with the objective of providing recommendations to reduce seepage losses through the original dam (at that time a dam raising was not proposed). The dam had apparently already been in operation for some time as it was observed to have trees growing on the downstream slope. Thurber provided preliminary recommendations for improving the dam, including the installation of a low permeability blanket on the upstream face of the dam and also extending beyond the upstream dam toe into the reservoir. However, it was subsequently

THURBER

determined that draining the reservoir to conduct these upgrades would not be permitted and that a dam raising would be carried out to increase reservoir capacity.

Dam Raising (1979/80)

A dam raising was undertaken in 1979 and extended into early 1980. The work was completed by Mr. Money with engineering supervision provided by WCT. Based on the available record drawings, the embankment was raised by up to 3.5 m in some areas. At the request of WCT, Thurber completed three site visits in relation to the dam upgrade, as discussed below:

- The first site visit was completed in July 1979 prior to the dam raising to evaluate potential fill sources and review the conditions at the left abutment area, where leakage was already occurring. This left abutment area was described as consisting of talus material over weathered bedrock. It was recommended that a cut-off trench be excavated through the talus material to bedrock and backfilled with compacted clay.
- A second site visit occurred in late November 1979 while the dam raising was underway. Thurber completed field density testing of dam fill, which determined that the specified compaction level of 98% of Standard Proctor Density was not being achieved and that increased compaction was needed. These results were shared with WCT. Thurber also reviewed the cut-off trench excavation at the left abutment which had extended to the point where any further trenching into the talus slope was considered impracticable and dangerous because of overhanging conditions.
- Thurber was asked to complete a final site visit in January 1980, by which time the dam had been raised to the new design elevation and the reservoir had already filled to the new design operating level. During the visit, significant amounts of seepage was observed through the talus material / bedrock that forms the left abutment of the dam. The seepage emerged from the slope along the roadway downstream of the dam and all seepage was observed to be clear. Thurber's project files indicate that the new water distribution system was not yet in operation although the original 50 mm diameter PVC water supply pipe was operating.

Two record drawings (Dwg No.: VI6553-1-18 and VI6553-1-19) marked "As Constructed" and dated February 12, 1980 are attached in Appendix B. The drawings provide details regarding the raised embankment, the new 150 mm diameter water intake pipe and the seepage collection infrastructure installed beyond the central downstream toe of the dam. Details are not provided regarding where the original 50 mm water supply pipe was located and how it was to be decommissioned. Section 1 shown on Drawing No.: VI6553-1-18 indicates that the 150 mm diameter water intake pipe would be installed at considerable depth (approx. 4 m) below the crest

THURBER

of the original dam and would incorporate two concrete seepage collars, spaced 16 m apart. Subsequent correspondence with the CRD has confirmed that the depth to the top of the valve assembly is approximately 3.6 m, suggesting the installation depth noted on the as constructed drawing is likely accurate and that the reservoir was likely lowered during the dam raising to facilitate installation of the pipe to this depth.

Based on record drawings, the 1979/80 dam upgrade included the installation of a 1.8 m diameter manhole downstream of the dam. This manhole (MH1) was connected to a 150 mm diameter perforated drainpipe located on the upstream side of the manhole and oriented perpendicular to the dam crest. The objective of this system was to collect the anticipated seepage from the downstream toe area such that it could be added into the water supply system. The water intake line from the reservoir was routed to MH1, which was fitted with a float valve that would automatically close when the water level in the chamber became too high. The manhole was to include an overflow culvert that would direct excess water to the channel downstream of the spillway. The water supply system also included a 100 mm diameter PVC bypass pipe around the seepage collection manhole.

<u>Subsequent Dam Modifications</u>

The downstream seepage collection system installed as part of the 1979/80 dam upgrade was reportedly not very effective and a second manhole (MH2) was subsequently installed (likely in 1980) upstream of the MH1 and was connected to lateral perforated drainpipes oriented roughly parallel to the dam crest. A schematic of the updated water supply system provided by the CRD is attached in Appendix B.

The 1979 dam raising included the installation of a 900 mm x 700 mm corrugated metal pipe arch as an overflow spillway, which was located nearer to the midpoint of the dam. This pipe was later replaced in 1986 when the current concrete spillway was constructed near the dam's right abutment. Drawings marked "as-constructed" that show the new spillway geometry and construction details are attached in Appendix B.

An upgrade to the water supply pipe intake was carried out in 2004 and involved the installation of a new screened intake assembly suspended from a raft and connected to the existing 150 mm water supply pipe by a flexible hose. A record drawing providing as-constructed details of the modified water intake system is attached in Appendix B.

THURBER

Second Seepage Cut-off

In August 2007, Thurber was retained by the CRD to provide geotechnical input related to addressing ongoing seepage losses from the reservoir. Following a review of background information and discussions with the CRD and input from Mr. Money, it was decided to install a new seepage cut-off trench along the dam crest centerline extending from the left abutment slope a distance of approximately 15 m. The trench was excavated in October 2007 and backfilled in lifts with compacted clay. The trench extended through the dam raising fill and into the underlying dam fill used to construct the original dam. Seepage was only observed at the contact between the dam fill and the natural slope forming the west abutment, which comprised highly fractured/weathered bedrock. It appears that installation of the second seepage cut-off trench has not had a discernable effect on overall seepage rates.

Leakage Collection Upgrades

Since the late 1990s the CRD has incorporated collected seepage water into their domestic water supply system by pumping seepage collected downstream of the dam back into the reservoir using an exposed 75 mm diameter PVC return pipe. In about 2012 the CRD installed a series of infiltrator chambers in the ditch downstream of the dam's left (west) abutment where seepage has historically been observed, to integrate this seepage into the drinking water system as raw water. Details are provided on a drawing in Appendix B.

5. SUMMARY OF 2011 DAM SAFETY REVIEW FINDINGS

EBA was retained by the CRD to complete the only previous formal dam safety review for Money Lake Dam No. 1 in 2011. The key findings from that review were as follows:

- Based on a simplified dam break analysis and the incremental loss of life that could occur in the event of a failure, it was judged that the dam failure consequence classification (DFCC) for the dam should be High.
- The inflow design flood (IDF) was determined to have a peak inflow of 7.2 m^3/s. Routing the IDF through the reservoir and spillway was predicted to result in the dam crest being overtopped by 0.02 m assuming no waves, and by 0.30 m with the recommended allowance for waves.
- A level survey conducted during the 2011 DSR site visit indicated that the actual dam crest elevation was higher than the recorded as-constructed elevation.

THURBER

- Although no stability analyses were completed, EBA concluded that embankment failure under static loading conditions was unlikely; however, due to the severity of ground shaking anticipated during a design seismic event, the seismic stability of the embankment slopes may not meet the minimum requirements outlined in the CDA guidelines.
- The turbidity associated with the seepage water at the central manhole area suggest internal erosion / piping is occurring within the dam.

A summary of recommendations from the 2011 DSR report is presented below in Table 3, including comments on the status of the recommendations.

TABLE 3 – LIST OF RECOMMENDATIONS FROM THE 2011 DSR REPORT

Recommendation	Status Prior to 2022 DSR
The dam crest should be raised to at least Elevation 151.6 m to prevent overtopping during the IDF.	The dam crest has not been raised. A 2018 survey by CRD indicates the dam crest elevation is generally about 152.0 m. The typical freeboard is ~1.4 m.
A gravel toe drain/filter should be installed to reduce the potential for a piping failure. In the interim, the frequency of documented inspections should be increased to daily.	Not yet installed. A preliminary toe filter design was prepared by EBA Tetra Tech in 2017. Thurber completed additional investigations to evaluate the feasibility of installing the toe filter in 2019 which indicated that installation would not be possible without lowering the reservoir.
The inoperative intake valve should be resolved	Valve is reportedly operable and exercised annually.
The log boom should be replaced and securely fastened	Replaced in 2015.
The CRD should commission a site investigation and simple seismic stability assessment to evaluate the stability of the dam slopes to confirm they are stable during a design seismic event.	Completed in 2016. The investigation predicted a factor of safety (FS) below 1.0 for both the upstream and downstream slopes during the design earthquake (assuming full PGA). Additionally, a FS lower than 1.0 was predicted for the post-earthquake scenario, suggesting a potential flow slide and sudden release of the reservoir could occur.
The Operations, Maintenance and Surveillance (OMS) Manual should be updated	Latest version is dated 2022
The Emergency Response Plan should be updated.	Now referred to as Dam Emergency Plan. The 2022 version was reviewed as part of the current DSR.

THURBER

6. ENGINEERING ASSESSMENTS SINCE 2011 DSR

Following the 2011 DSR, several engineering assessments were completed for Money Lake Dam No. 1, and details are provided below.

6.1 2016 Tetra Tech EBA Engineering Assessment

Following up on one of the recommendations from the 2011 DSR, the CRD retained Tetra Tech EBA Inc. (Tetra Tech) in 2016 to complete a geotechnical investigation and slope stability analysis. The primary objectives of the assessment were as follows:

- to characterize the geotechnical properties of the dam fill and foundation by drilling test holes and collecting material samples,
- to install standpipe piezometers to permit the monitoring of water levels within the dam,
- to complete geotechnical analyses to verify dam performance related to embankment stability, liquefaction triggering potential, and residual strength.

The following is a summary of the key findings from Tetra Tech's 2016 assessment:

- A factor of safety, FS > 1.5 was calculated for both the upstream and downstream slopes of the dam under static conditions, indicating the stability of the embankment meets the minimum CDA requirement for static conditions.
- An FS of less than 1.0 was calculated for both the upstream and downstream pseudo-seismic analyses considering the full PGA of 0.48 g for the 1/2,475 seismic event. This finding means the dam does not meet the minimum CDA recommendations (CDA recommend FS ≥ 1.0) and that permanent deformations would be expected to occur under a design level earthquake. Using a simplistic deformation analysis method, permanent embankment displacements up to 0.65 m were estimated, which are generally assumed to occur along a critical slip surface.
- FS values of 0.8 and 0.6 were calculated for the post-earthquake slope stability analysis case for the upstream and downstream slopes (recommended minimum is FS ≥ 1.2), indicating the embankment does not meet the minimum CDA requirements. An FS < 1.0 for the post-earthquake condition also indicates the potential for a flow slide to occur, which may cause a sudden release of the reservoir.
- Given the predicted results, repair of the dam would be required following the design seismic event.

THURBER

- The embankment and foundation soils are susceptible to internal erosion. Although a downstream filter was incorporated into the 1979 dam upgrade, it is believed the filter zone was not extended to the underlying bedrock. Installing a toe filter/drain downstream of the existing filter (i.e., extending to bedrock) would limit the potential for continued internal erosion.

Tetra Tech recommended that dam upgrades be carried out to improve seismic performance and reduce the risk of internal erosion. They also recommended that the CRD begin collecting monthly water levels at the newly installed piezometers, which is being done by CRD staff. Additionally, they recommended that the design of new dam upgrades consider the effects of a longer duration earthquake (i.e., consistent with a subduction event). To meet dam safety expectations, Tetra Tech identified two options:

Option 1 – complete dam removal and replacement, or

Option 2 – adding a downstream buttress and toe filter/drain.

Tetra Tech characterized Option 2 as a "risk management" approach, as even with the addition of a seismic buttress at the downstream toe, this approach would not mitigate against failure of the upstream slope into the reservoir during a design level earthquake. The intent of the buttress would be to limit the deformation such that a breach of the dam would not occur during or immediately after the earthquake. Depending on the level of damage, the dam may leak significantly following the earthquake and may require repairs.

6.2 2017 Tetra Tech Engineering Assessment

Tetra Tech Canada Inc. (Tetra Tech) was retained by the CRD in 2017 to prepare the preliminary design for a downstream filter for Money Lake Dam No. 1. As outlined in Section 5, installation of a toe filter that extended vertically to bedrock was one of the recommendations included in the 2011 DSR report and was intended to reduce the risk of a dam failure as a result of internal erosion / piping.

The preliminary design for the toe filter was presented in a technical memorandum submitted by Tetra Tech to the CRD on September 14, 2017. The following are key components of the proposed design:

- The toe filter would be constructed by trenching along the downstream toe of the dam from the existing access road near the left abutment across to the location of the 150 mm diameter supply pipe near the spillway. The trench was to extend to bedrock as directed

THURBER

by the engineer (estimated depth ~3 m) and have a minimum base width of 1.0 m and side slopes of 1.5H to 1V.

- Tetra Tech's design required that most of the existing infrastructure beyond the dam toe be decommissioned or removed, including MH2 and the adjacent pipes.
- Tetra Tech's memo provided preliminary design recommendations for both a granular filter option and a synthetic filter (i.e., geotextile).

Given the local dependence on the reservoir as a water supply, lowering of the reservoir to facilitate construction was to be avoided. Construction of the filter was recommended to occur in September when reservoir levels are at a seasonal low and following the higher summer demand period.

Tetra Tech's memo stated that "sump and pump" techniques are generally used to dewater excavations, but that overall dewatering requirements are typically determined by the contractor. Given uncertainty about the potential seepage rates, it was proposed that a test trench be excavated prior to construction to evaluate seepage rates. To mitigate the potential for erosion and sloughing of the excavation during construction, it was proposed that the trench be excavated and backfilled promptly and in increments no longer than 10 m. This would reduce dewatering requirements such as the requirement to run pumps through the night.

6.3 2018 Thurber Conceptual Design for Seismic Buttress

Thurber was retained by the CRD in 2018 to advance the design concepts proposed by Tetra Tech in 2016 and 2017. The first task was to complete an independent stability analysis to assess the seismic buttress dimensions necessary to sufficiently improve seismic performance such that the minimum factors of safety recommended by the CDA would be achieved. Table 4 below summarizes the minimum factors of safety (FS) recommended by the CDA for different loading conditions. The assessment utilized limit equilibrium analysis software to evaluate slope stability and used the interpreted dam cross-section developed by Tetra Tech, as well as the same seismic design ground motions.

TABLE 4 – MINIMUM FACTORS OF SAFETY (CDA, 2013)

Loading Condition	CDA Recommended Minimum Factor of Safety
Static Loading (Drained)	1.5
Pseudo-Seismic (Undrained)	1.0
Post-Seismic	1.2

Thurber's analysis indicated the following approximate downstream buttress dimensions were necessary to achieve the CDA recommended factors of safety for the above noted loading conditions:

- Approximate buttress height: 3.5 m (top of buttress ~ El.147.0 m)
- Approximate buttress top width: 10 m (perpendicular to dam centerline)
- Downstream slope: 3H to 1V

Additionally, to achieve the desired results, the buttress design required that the ground below the buttress would undergo improvement to improve its strength. It was envisioned that this would involve sub-excavating potentially liquefiable soils from below the buttress and replacing them with compacted granular fill. It was anticipated that this could be done as part of the toe filter installation proposed by Tetra Tech. Thus, the toe filter excavation and backfilling would be done first and then the seismic buttress would be constructed overtop.

One of the limitations noted in Thurber's 2018 seismic buttress assessment letter is that the CDA does not provide a recommended performance criteria for the scenario where liquefaction occurs within or below an embankment during the seismic event (rather than afterwards following the cessation of shaking). This is considered a credible scenario for this site given the regional seismicity and potential for longer duration earthquakes. Tetra Tech's 2016 geotechnical assessment had indicated that liquefaction would be triggered in the foundation soil under the dam during a design level earthquake. Tetra Tech had recommended that the 'liquefaction during earthquake' scenario be considered during the buttress design.

Given the likelihood of localized pockets of liquefied soil under the dam, it is not expected that the FS will remain above 1.0 during a larger earthquake, and in these circumstances an assessment of permanent deformation is required to assess the level of damage to the dam. The presence of liquefiable zones under the dam complicates the assessment, as simplified analysis methods are generally not reliable for estimating permanent ground deformations for sites with significant amounts of liquefied soil. Using a semi-empirical statistical analysis method, permanent deformations larger than 1 m were predicted and indicate the dam could experience significant damage as a result of earthquake even if the proposed seismic buttress were constructed. Thurber recommended that sophisticated analysis software incorporating complex soil models that can accommodate large strains be used to better evaluate buttress performance and whether additional changes to the buttress configuration could reduce the deformations.

THURBER

Thurber's 2018 report also recommended that geotechnical investigations be completed to confirm the depth to sandstone bedrock to inform toe-filter and seismic stabilization design, to observe the feasibility of excavations in these ground conditions by observing sidewall stability and groundwater seepage conditions, and to obtain representative samples of encountered fill and foundation soil materials to support an assessment of reusability. This work is described further in the following report section.

6.4 2019 Thurber Geotechnical Investigations

6.4.1 Test Pits

Geotechnical investigations were undertaken in 2019 as had been recommended in Thurber's 2018 conceptual design report for the seismic buttress. On August 21, 2019, four test pits (TP19-1 to TP19-4) were excavated near the downstream toe of the dam by Mr. Andrew Money. At TP19-2, near the middle of the proposed toe filter excavation, rapid groundwater infiltration and unstable test pit sidewalls were encountered, resulting in termination of the test pit before bedrock was reached. The instability was due to a zone of loose wet sand that extended below the dam fill. Given these conditions, Thurber recommended installing several screened dewatering wells to investigate the feasibility of temporarily dewatering this sand layer to facilitate the proposed toe filter excavation. Thurber returned to the site approximately 3 weeks later to install a temporary dewatering well with a stainless-steel screen in a test pit (WP19-1) excavated several meters upstream of TP19-2. The test pit encountered similar challenges with groundwater seepage and instability of the sand layer, resulting in a well installation that did not extend to the base of this layer.

Relatively shallow bedrock and manageable seepage rates were encountered at TP19-1 and TP19-5 (completed the same day as WP19-1) which were approximately 4 m to 6 m east of TP19-2 and WP19-1, respectively. This indicated that the challenging groundwater conditions were relatively localized.

6.4.2 Sonic Drilling

Thurber and the CRD discussed the implications of the initial investigation findings on the proposed toe filter and seismic upgrades. Potential alternative design options were identified but all required additional investigation to confirm their feasibility. A sonic drill rig was therefore mobilized to the site in October 2019 and completed 7 test holes including TH19-1 to TH19-5 and WP19-2 and WP19-3. All the sonic holes were advanced to bedrock. A geotechnical engineer logged the drill holes and representative soil samples were collected from the sonic core barrel

THURBER

for subsequent laboratory assessment. Dynamic cone penetration tests were completed at each location to evaluate the relative density of the soils encountered.

The test holes were backfilled either with cement-bentonite grout or bentonite chips. Several attempts were made to fully grout TH19-1 which was located at the dam crest. The level of grout in the casing could not be maintained above the approximate static groundwater level due to seepage of the grout into the surrounding foundation soil. As a result, bentonite chips were used to establish a seal near the groundwater level before continuing to grout.

Temporary dewatering wells were installed at WP19-2 and WP19-3 with screened intervals extending to bedrock. Pumping was carried out by the drilling contractor at the two new drilled wells, as well as at WP19-1 which was installed using an backhoe. Pumping was carried out at each well individually for between 1 hour and 3 hours to develop the wells.

Despite being throttled down to its lowest setting, the small dewatering pump (25 mm diameter suction line) quickly pumped the water level inside the wells down to within the screened interval. The rate of pumping was found to be limited to approximately 5 L/min to 10 L/min by the rate of inflow into the well screens which were designed to limit migration of the sand formation. The rate of pumping was also constrained by the relatively limited well penetration below the static groundwater level, due to the presence of bedrock. This limited the drawdown potential within each pumping well.

6.4.3 Investigation Findings

A plan and interpreted cross sections of the dam are presented in Figures A-2 to A-4 in Appendix A and illustrate the findings of the 2019 geotechnical investigations. As shown in the figures, the bedrock surface dips gradually towards the downstream direction and more steeply towards the left abutment. Bedrock outcrops are visible in some areas on the left abutment slope at higher elevations, therefore we infer there is an old fault in the bedrock near the left abutment. This interpretation is consistent with the Geologic Survey of Canada Map 1553A which shows a north-south trending fault in this area, parallel to the valley bottom. There is no evidence that this fault is active.

Buried stream channel deposits were generally found to fill the depression in the bedrock surface and are interpreted to be intermixed with colluvium deposits below the toe of the left abutment slope. The buried channel deposits are generally located below the groundwater table and vary in penetration resistance from very loose to compact. The colluvium was also very loose in some zones.

The three de-watering well points installed in the buried channel deposits were pumped individually at approximately 10L/min, which was found to be the maximum sustainable rate. The maximum drawdown achieved during pumping in the adjacent wells (located approximately 3 m away) was approximately 0.4 m. This indicates that solely using the three installed screened dewatering wells will likely not adequately control groundwater levels to permit the safe construction of the toe filter concept proposed by Tetra Tech. Proceeding without effective dewatering was not recommended due to worker and dam safety concerns. Thurber's October 11, 2019 report stated that consideration should be given to an alternative toe filter arrangement; however, such an arrangement would have implications for the existing infrastructure. An alternate toe filter design is currently being prepared by Thurber.

7. 2022 DSR FIELD VISIT

A field visit to Money Lake Dam No. 1 and the downstream area was completed by Mr. Jay McIntyre, P.Eng. of Thurber and Mr. Dwayne Meredith, P.Eng. of KWL on August 31, 2022 following a period of extended dry weather. Present were Mr. Ian Jesney, P.Eng. and Mr. Jared Kelly, P.Eng. of the CRD Integrated Water Services (IWS) Department. Also present for a portion of the site visit was Mr. John Money, who was involved with the original dam construction and its subsequent upgrades. The following is a summary of site observations and discussions during the visit.

- The dam site is accessed from Harris Road. A gravel driveway extends from the road to the dam along the west side of the narrow valley. Vehicles must pass through a locked gate to access the dam. There is no fence restricting pedestrian traffic.
- As identified in the 2021 formal annual inspection, a small sinkhole is present approximately 15 m to 20 m upstream of the dam's left abutment. The sinkhole is roughly circular in shape, with a diameter of approximately 0.7 m and a depth of 0.4 m. The sinkhole is located at the base of a relatively steep bedrock-controlled slope and signs of previous rockfall events were observed, including several isolated boulders along the slope toe adjacent to the reservoir.
- Two adjacent staff gauges are installed within the reservoir close to the left abutment. Both gauges were difficult to read, especially near the water level. The reservoir level was estimated to be ~3.65 m.
- A log boom was present and was deployed diagonally across the narrow reservoir, with the closest end located just upstream of the spillway entrance. We understand that the log boom was installed in 2015. Although the boom appears to be functioning adequately, it was noted that several of the logs appear to sit low in the water. A secondary float boom

is deployed much further upstream, closer to the southern end of the reservoir. According to the 2022 OMS Manual, it was installed prior to October 2021. The secondary float boom was not visually reviewed.

- The community water system intake is suspended from a small floating raft that is anchored upstream of the log boom. The control valve for the intake (valve #1) is located just downstream of the dam crest near the spillway but was not exercised during the visit. CRD personnel subsequently confirmed the valve is exercised at least yearly and requires an ~3.6 m long rod to actuate the valve. Additionally, CRD personnel confirmed they prefer to utilize the water obtained from the infiltration gallery installed downstream of the dam; however, the lake intake is also routinely used to augment the flow as required.
- The concrete spillway was found to be in good condition and was clear of debris and vegetation. A sealing compound was observed at the joints in the spillway, including along the length of the chute (reportedly installed prior to 2018). This compound appears to generally be in good condition; however, the sealant appeared to be locally split at the two upstream joints, exposing the foam water stops on the right hand side.
- There is considerable vegetation beyond the downstream end of the spillway chute, including several small cedar trees which make it difficult to visualize the stilling basin. It appears that some of the original riprap armour within the stilling basin has been displaced. To provide safe access to the right abutment area for maintenance and surveillance activities, a small pedestrian bridge is located in the channel a short distance downstream of the spillway outlet. The banks of the channel in this area are not well armoured, particularly the west bank.
- A visual inspection of the embankment did not reveal any obvious evidence of movement or distress (e.g., cracking or bulging). However, relatively high grass was noted over portions of the ground surface, including the dam crest and the upstream slope, which obscured the ground surface.
- Rip rap armouring was noted across the majority of the upstream slope near the water line but does not extend all the way across to the left abutment.
- The dam crest is accessible by means of a ramp that crosses diagonally up the dam from the downstream toe near the left abutment. A sign is posted on the downstream side of the crest identifying it as a drinking water reservoir. No emergency contact information is provided on the sign.
- The downstream slope was measured at approximately 2H to 1V; however, the slope is irregular given the access ramp that travels diagonally up the slope from the dam toe near

THURBER

the left abutment. There are other fluctuations on the ground surface beyond the downstream toe related to the previously installed infrastructure as well as re-grading work completed to facilitate past geotechnical investigations. This has resulted in generally uneven ground along the downstream toe making it difficult to perceive where the embankment ends.

- Despite the dry conditions leading up to the site visit, the ground vegetation across portions of the downstream slope, as well as the area beyond the dam toe, was particularly lush and green, suggesting seepage is occurring in these areas.
- The covers to MH1 and MH2 were removed so that the interior of the chambers could be observed. MH1 was essentially full of water, which is typical. Using an electric pump and generator, the water level was slowly lowered to about the midway point. The water pumped out was noted to have a brown, turbid appearance. MH2 had approximately 25 cm of saturated rusty brown sediment at the bottom of the chamber (no standing water).
- Small mounds of clean gravel were observed in the ditch adjacent to the access road downstream of the dam. These mounds cover a series of arched seepage infiltrators that were installed following the 2011 DSR to collect seepage in the ditch and convey it into a 100 mm diameter PVC collection pipe. No water was observed in the ditch between the mounds.

Following the DSR field visit, the downstream area was briefly reviewed to better understand the likely flow path should a dam breach occur. Further details are discussed in Section 8. Selected photographs from the site visit are attached in Appendix C.

Recommendations:

The following is a list of items requiring maintenance or repair based on the DSR field visit:

- *Repair and reseal the exposed foam water stops within the concrete joints of the spillway.*
- *Remove the excess vegetation from the stilling basin area.*
- *Re-establish the rock stilling basin by installing new rock fill or reshaping the existing rock fill to provide adequate erosion protection where the spillway chute discharges into the creek channel. Also restore armouring in the channel immediately downstream of the dam where the access bridge abutment is undermined.*
- *The primary staff gauge should be cleaned and the adjacent broken gauge should be removed as it is preferable to have only one gauge to reduce potential mis-reads.*

THURBER

- *An information sign should be posted at the dam to follow best practices described by the CDA and meet the intent of the BC Dam Safety Regulation.*

8. DAM FAILURE CONSEQUENCE CLASSIFICATION (DFCC)

8.1 General Commentary and Previous Findings

The DFCC is a means of establishing an adequate overall level of care related to the operations, maintenance, and surveillance of the structure. The rating is also used to select appropriate design and performance criteria for the facility. In general, the higher the DFCC, the higher the level of care that must be exercised.

Dam breach and inundation studies are typically required to help establish the DFCC. These studies estimate the impacts of a hypothetical breach of the structure and should consider both "sunny day" and "flood-induced" failure situations. Mapping the estimated areas of inundation is the basis for determining the DFCC. Key to the classification assessment is the incremental consequence of failure, which is defined as the total damage or loss from an event that involves a dam breach minus the damage that would have resulted from the same event had the dam not failed.

The DFCC is determined through consideration of the effects of a dam failure on three primary consequence categories:

- Loss of Life
- Environmental and Cultural Values
- Infrastructure and Economics.

The DFCC is to be reviewed on an annual basis per the BC Dam Safety Regulation and should also be reviewed as part of a DSR.

EBA completed a dam break analysis as part of their 2011 DSR scope and used the simplified assessment method (SMPDBK) to simulate the failure. Only the flood-induced failure scenario was considered. EBA concluded that three structures (the fire station, general store and restaurant) located near the intersection of Narvaez Bay Road and Harris Road could be at risk during a flood-induced dam breach. They concluded the appropriate classification for the dam was High based on the anticipated incremental loss under both the "loss of life" criteria and the "infrastructure and economics" criteria. Less extensive losses (Significant rating) were predicted under the "environmental and cultural values" criteria.

THURBER

During the 2017 annual inspection the CRD completed a reconnaissance of the downstream area, and this resulted in an update to the inundation map. This updated map appears to indicate the inundation zone could extend further west down Narvaez Bay Road, where a culvert crosses under the road (see Figure A-5 in Appendix A)

8.2 DFCC Review

Completing an updated dam break analysis and inundation map was excluded from the current DSR audit work scope; however, a brief review of the area downstream of the dam was completed during the site visit and available mapping was reviewed afterwards. Based on the available information, the current DFCC of High is considered appropriate.

Were a dam breach to occur, the released water would flow in a northerly direction approximately 200 m within the dam valley, dropping approximately 10 m in elevation over this distance. The water would then cross over Harris Road and continue down the valley in a northwesterly direction before entering the small Money Diversion Dam impoundment. Important infrastructure along this portion of the flow route includes Harris Road (which would be washed out following a dam breach) and drinking water supply infrastructure, including piping and the primary water treatment plant.

Along this second leg of the flow route, the valley is steep and narrow, dropping approximately 40 m over a horizontal distance of 180 m. The released water would overwhelm the second impoundment and would continue flowing in a northwesterly direction, dropping another 25 m in elevation over approximately 200 m before reaching flatter ground, where the nearest buildings within the inundation zone are located. At the location where the ground flattens, the valley widens and Harris Road makes a sharp curve to the northeast.

Prominent structures in this area include a community centre, the fire station, a general store and an attached restaurant. EBA's previous dam break analysis indicates that the berm located on the south and east sides of the community centre would protect this structure during a breach event and deflect all flow towards the intersection of Narvaez Bay Road and Harris Road, where the fire hall and other buildings are located. Downstream of the general store and restaurant, the breach waters would flow over East Point Road and down a steep slope into the ocean.

Based on a subsequent reconnaissance by the CRD in 2017, it was concluded that the inundation zone could extend further west and that some of the released water could enter a treed area and cross under East Point Road at a low point located approximately 200 m west of Harris Road. In this case, flood water could potentially impact several residential properties located on the north side of East Point Road. Although there was not sufficient time to walk the flow route, the

THURBER

observations made from Harris Road suggest it may be plausible for some of the released water to flow to the west of the community centre, and this could potentially result in more flow heading towards residences.

Recommendation:

An updated dam break analysis should be completed that considers both "sunny day" and flood induced failure scenarios. This study should use a more sophisticated model that incorporates a digital elevation model derived from LiDAR data, augmented by manual survey pickup at discrete locations if necessary. The updated analysis would provide an improved understanding of potential inundation extents, water depths and flow velocities, which would help with emergency planning and would also inform future decision-making regarding dam safety management.

8.3 Required Performance Criteria

The CDA guidelines (2013) recommend criteria for the inflow design flood (IDF) and design earthquake based on consequence of failure criteria. These are summarized in Table 5.

TABLE 5 FLOOD AND EARTHQUAKE PERFORMANCE CRITERIA

Dam Class(1)	Annual Exceedance Probability (AEP)	
	Design Flood(2)	Earthquakes(3)
Low	1/100	1/100
Significant	Between 1/100 and 1/1000 (4)	Between 1/100 and 1/1,000
High	1/3 between 1/1000 and PMF(5)	1/2,475(6)
Very High	2/3 between 1/1000 and PMF(5)	½ between 1/2475(6) and 1/10,000 or MCE(5)
Extreme	PMF(5)	1/10,000 or MCE(5)

Acronyms:

MCE – Maximum Credible Earthquake
PMF – Probable Maximum Flood

Notes:

1. Per Table 2-1, CDA Dam Safety Guidelines (2013),
2. Extrapolation of flood statistics beyond 1/1000 AEP is not acceptable
3. Mean values of the estimated range in AEP levels for earthquakes should be used.
4. Selected on basis of incremental flood analysis, exposure and consequences of the hazard
5. PMF and MCE have no associated AEP.
6. This level has been selected for consistency with seismic design levels given in the National Building Code of Canada.

The dam must safely pass the appropriate IDF and withstand the design earthquake without catastrophic failure.

THURBER

9. HYDROTECHNICAL REVIEW

9.1 Inflow Design Flood (IDF)

An independent review of the IDF for Money Lake was completed by KWL and details are provided in their technical memorandum attached in Appendix E. As noted in Table 5 above, the annual exceedance probability for a dam with a High DFCC is 1/3 between the 0.001% AEP (1:1000-year peak instantaneous flood) and the Probable Maximum Flood (PMF).

The following is a summary of the hydrotechnical review findings:

- The 1000-year flood was estimated to be 2.6 m^3/s, which is below the peak flow estimate of 3.7 m^3/s that was produced in 2011 by EBA.
- The probable maximum precipitation (PMP) was checked using the methodology described in the British Columbia Extreme Flood Project PMP guideline, published in July 2021. Accounting for the smaller catchment area of the Money Lake watershed, the 24hr PMP was determined to be 276 mm. For the 2011 DSR, EBA calculated the PMP to be 322 mm using the Hershfield Method. As noted in KWL's hydrotechnical assessment attached in Appendix E, both methods are considered appropriate for evaluating the PMP. However, the Hershfield Method suits larger watersheds and applying this method to the small Money Lake No. 1 watershed can result in an overestimation of the PMP.
- The probable maximum flood (PMF) is theoretically the largest flood that could occur based on the meteorologic and hydrologic conditions for a given location. KWL created a HEC-HMS model to estimate the PMF using the derived PMP and the calculated watershed size (1.02 km^2). The analysis, which considered the Spring PMP as well as a 100-year snow accumulation, resulted in a PMF flow rate of 12.8 m^3/s. This is slightly lower than the 14.1 m^3/s determined by EBA in 2011.

The IDF was calculated to be 6.0 m^3/s using the following equation (CDA, 2007):

$$Q_{IDF} = \boldsymbol{Q_{1,000}} + \boldsymbol{C}(\boldsymbol{Q_{PMF}} - \boldsymbol{Q_{1,000}})$$

Where:

Q_{IDF} = Inflow design flood (m^3/s),
$Q_{1,000}$ = 1,000-year flood (m^3/s),
C = Coefficient (1/3 for High DFCC dams).

THURBER

9.2 Outflow Determination

KWL's hydrotechnical assessment included an estimation of the outflow from the reservoir during a storm event. Apart from the 150 mm diameter water supply intake pipe, there is no other outlet pipe. The outflow assessment ignored the minor contribution from the water supply pipe and evaluated only the hydraulic capacity of the concrete overflow spillway. KWL concluded that the spillway capacity is governed by the cross-section at the weir crest rather than the narrower, more steeply graded spillway chute, and that the IDF would be safely routed through the spillway.

9.3 Wind-Wave and Freeboard Analysis

The dam must have adequate freeboard to provide an allowance for wave action and other variables that could result in an overtopping. The CDA guidelines (2007) identify the following two performance requirements to be considered as part of a freeboard assessment:

1. Normal Freeboard – No overtopping by 95% of the waves caused by the 0.001% AEP wind wave when the reservoir is at its full supply level.
2. Minimum Freeboard – No overtopping by 95% of the waves caused by the 0.5% AEP wind wave when the reservoir is at its maximum extreme level during the passage of the IDF.

Specific details of KWL's assessment are presented in Appendix E. KWL's analysis concluded that there is adequate freeboard under both the normal freeboard and minimum freeboard scenarios.

10. GEOTECHNICAL ASSESSMENT

10.1 Seismic Hazard

Money Lake Dam No. 1 is located on Saturna Island in southwestern British Columbia where oceanic tectonic plates are sliding (subducting) under the North American continental plate. This tectonic setting results in three sources of earthquake shaking:

Crustal events: earthquakes that are within the crust of the North American plate,

Inslab events: deeper earthquakes beneath the Strait of Georgia and Puget Sound that are within the subducted plate,

Subduction zone events: giant "megathrust" earthquakes that occur off the west coast of Vancouver Island.

THURBER

Each of these earthquake sources contributes to the seismic hazard in different proportions depending on the location of the site and on the period of ground motion considered. Each of the three seismic sources can produce damaging earthquakes (Rogers et al., 2015).

In the absence of a site-specific data, seismic hazard across Canada can be estimated using the National Building Code of Canada (NBCC) online seismic hazard calculator. The calculator uses seismic hazard maps prepared by the Geological Survey of Canada (GSC) which are derived from statistical analysis of past earthquakes and from the advancing knowledge of Canada's tectonic and geological structure. Ground motion probability values are provided in terms of an annual exceedance probability (AEP) which is the likelihood of a given ground motion being exceeded within a particular time duration. As noted in Table 5, the design earthquake for a dam having a High DFCC has an AEP of 1/2475, which is equivalent to a 2% chance of occurrence over a 50-year period.

The 6th generation seismic hazard maps were recently released in preparation for the 2020 NBCC, along with an updated version of the online hazard calculator. In terms of local hazard, the principal changes to the new seismicity model are: 1) changes to the recurrence of the Cascadia subduction earthquake from an inter-event period of 532 years to 432 years, 2) breaking up the Strait of Georgia source zone into 3 smaller zones with varying depths to reflect the dip of the inslab source, and 3) inclusion of the Leech River Valley and Devil's Mountain Faults near Victoria. Considering the stiffer site response reflective of shallow bedrock (i.e., Site Class B) this would result in a peak ground acceleration (PGA) of approximately 0.51g for the Money Lake Dam No. 1 site using the 6th generation seismic hazard model, compared to a site adjusted PGA of 0.41g using the 5th generation model (i.e., an approximate 24% increase).

In 2007 the CDA cautioned against using the NBCC seismic hazard data for dam safety evaluations, especially for higher consequence structures that must withstand severe, low-probability earthquakes. However, given the incremental updates to the GSC seismic hazard model since 2007 including the recent changes to the 6th generation hazard model in southwestern BC described above, it is considered reasonable to use the hazard obtained from the online calculator for evaluating the structure's seismic performance. It is noted that if the DFCC for Money Lake Dam No. 1 were to increase beyond a High rating (i.e., due to additional downstream development or based on the results of an updated dam break analysis), then a site-specific seismic hazard assessment would be required since the NBCC online calculator does not provide seismic hazard data that is applicable for the very low-probability events associated with these consequence classifications.

THURBER

10.2 Slope Stability and Anticipated Seismic Performance

10.2.1 Previous Stability Assessments

Previous stability assessments indicate that both the dam's upstream and downstream slopes meet the minimum recommended factors of safety for normal (static) loading conditions. Under seismic loading conditions, however, the embankment is not predicted to meet minimum recommended performance criteria both in terms of factors of safety during and after the earthquake. The primary contributors to the poor seismic performance include the high regional seismic hazard, the relatively steep embankment slopes (2H:1V), and the presence of liquefiable zones in the relatively shallow overburden materials under the dam.

When the initial screening level or simplistic analysis methods for evaluating seismic stability yield unsatisfactory or indeterminate results, the recommended approach is to utilize more sophisticated analysis procedures. With regard to seismic performance, the primary consideration is assessing the magnitude and distribution of the earthquake-induced deformations, which can be significant if liquefiable zones are present within or below the dam.

10.2.2 Parallel Seismic Assessment

As noted in Section 6.3, following Tetra Tech EBA's 2016 geotechnical assessment, Thurber was retained by the CRD to advance the seismic buttress design concept, intended to reduce earthquake deformations to reduce the likelihood of a sudden dam failure. Based on the findings of the subsequent analysis, Thurber recommended that more sophisticated analysis software incorporating complex soil models be used to better evaluate buttress performance and to determine if additional changes to the buttress configuration could reduce the deformations.

Thurber was retained by the CRD to carry out seismic deformation analyses as a parallel exercise, and this work is to be reported separately. One of the objectives of this work is to evaluate the potential benefits of 3-dimensional effects related to the location and orientation of the dam within the narrowing, bedrock-controlled valley. Preliminary results previously shared with the CRD indicate that earthquake-induced deformations (even without a downstream buttress) are significantly less than those predicted using simpler analysis methods. Although these analyses indicate that post-earthquake repairs may be required, a sudden collapse of the structure is not predicted. Detailed analysis results are to be reported separately.

THURBER

10.3 Seepage Performance and Internal Erosion Potential

10.3.1 General

Foster et al. (2000a) reviewed a large database of worldwide dam failures prepared by the International Congress on Large Dams (ICOLD). Based on their review of data for earth fill dams, piping through the embankment contributed to 30% of the dam failures and 15% of the failures were attributed to piping through the foundation.

Piping is the progressive internal erosion of fill materials within an embankment along a preferential seepage path. This could include seepage along conduits that pass through the dam. As water seeps through the dam, the seepage forces can begin to erode finer soil particles in the fill matrix, either at the toe of the dam or at an interface between two materials with incompatible gradations. Over time, pipes or voids can form within the dam that generally advance in an upstream direction (towards the reservoir). Eventually this process can lead to a relatively sudden release of water through the piped zone, causing a breach to form and the rapid discharge of the reservoir.

Mitigating risks associated with internal erosion is accomplished by incorporating suitably designed filter zones within dams and maintaining a comprehensive dam surveillance program that includes regular monitoring visits to check for changes in seepage patterns and flow rates.

10.3.2 Past Seepage Performance

Even before Money Lake Dam No. 1 was raised in 1979, leakage had been a significant operational concern. This was previously thought to be a factor of material used to construct the dam (i.e., weathered sandstone), the poor compaction of the original dam fill, and possibly a result of seepage along the original water intake pipe. Once the dam was raised in 1979, seepage began exiting the left abutment slope downstream of the dam. The area downstream of the central portion of the dam also continued to be wet and at least some of this water is likely related to foundation underseepage through buried granular channel deposits.

10.3.3 Internal Erosion Potential

The design for the 1979 dam raising included a gravel filter zone and the granular filter specifications were included on the drawings. Tetra Tech EBA (2016) compared the gradation of the embankment fill materials sampled in their drill holes with the gravel filter zone specifications included on the 1980 “as-constructed” drawings. They concluded that if the filter material installed as part of the 1979 raising met the specified gradation limits, then it would meet typical filter criteria and would allow the flow of water while holding back erodible material within the embankment.

However, the available as-built information indicates the filter zone was not placed directly against the original dam fill, but rather was placed as an inclined layer against a zone of rockfill that was placed against the downstream face of the previous dam (see Figure 1 below). This means that fines from the pre-1979 embankment could be migrating into the unfiltered rockfill zone; however, this internal erosion would not necessarily be apparent. Additionally, there is no evidence that the new filter zone was extended to sufficient depth to filter seepage through natural channel deposits that remain under the central portion of the dam.

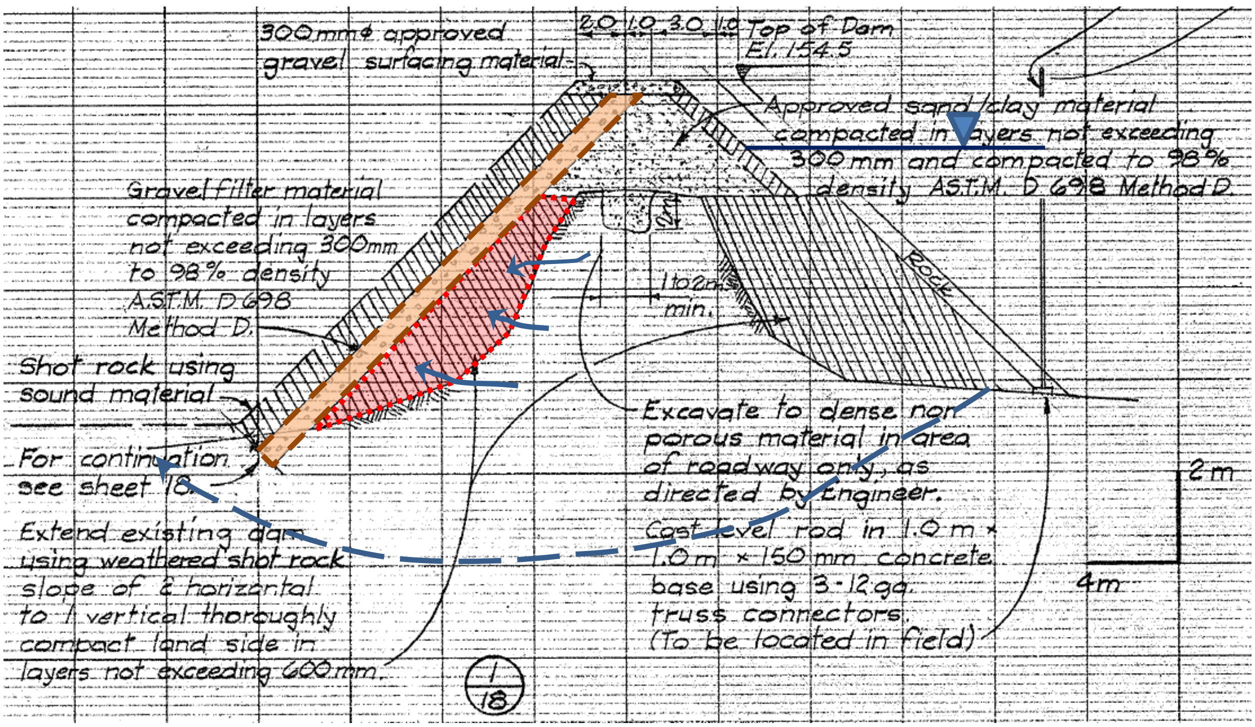


Figure 1: Illustrating unfiltered rockfill zone (red) upgradient of inclined filter (orange) as well as unfiltered foundation soils (From 1980 As-Built Drawing)

Another important consideration related to the internal erosion of dams is the presence of conduits that pass through the water barrier. As described previously, the available records show that a 150 mm diameter HDPE water intake pipe passes through the embankment at significant depth (approx. 4 m) to the east of the spillway. Two concrete seepage collars, spaced 16 m apart, are also shown on this drawing. Internal erosion can be the result of preferential seepage along the pipe or due to flow through leaks in the pipe.

The 2011 DSR report identified apparent turbidity in the water at the central manhole area, which was taken as a possible indication of internal erosion / piping. During the 2022 DSR field visit, the water observed in MH1 was also observed to be turbid, and approximately 0.25 m of fine

THURBER

sediment was observed at the base of MH2. These observations suggest that internal erosion is likely occurring, with fine material migrating through/under the dam as a result of seepage forces. Internal erosion through the dam foundation is considered a credible phenomenon given the seepage gradients and since the inclined filter zone from the 1979 raising would not have been extended sufficiently deep to cut-off seepage through the buried channel deposits, which have been encountered to depths of about 3 m below the dam toe. Some of the fines observed in MH1 and MH2 could be related to the deterioration of associated water supply infrastructure including the degradation and possible collapse of the 150 mm diameter perforated pipes connected to MH2.

10.3.4 Implications for Dam Safety

Although the dam upgrade/raising conducted in 1979 included granular filter, this filter zone was not constructed directly against the original dam fill and it wasn't extended to sufficient depth to mitigate particle migration / internal erosion through the buried channel deposits, the extents of which are now better understood given the recent phased investigation programs.

The preliminary design for a granular toe filter was prepared by Tetra Tech EBA in 2017 and is discussed in Section 6.2 of this report. As discussed in Section 6.4.3, recent investigations completed by Thurber, including pumping from newly installed screened wells, indicate that it may be difficult to adequately dewater the buried channel deposits such that the toe filter design proposed by Tetra Tech can be safely installed. Installing the toe filter as near to the existing dam toe as practical is preferred, but a significant lowering of the reservoir would be required to reduce the seepage gradients.

Recommendations:

- *Given the prevailing groundwater conditions at the downstream toe of the dam and anticipated risks/challenges associated with installing the toe filter arrangement proposed by Tetra Tech, alternative toe filter configurations should be developed.*
- *Evaluations should be carried out to assess the condition of the HDPE water supply pipe and whether any leaks are present, particularly the section extending from the upstream face of the dam to the vicinity of MH1 beyond the downstream toe.*

Given the embankment deformations associated with a seismic event, there will be an increased risk of internal erosion following an earthquake. As outlined in the OMS Manual (discussed further in Section 11.3) an inspection of the dam should be carried out as soon as possible following a significant earthquake to confirm the post-earthquake operating freeboard and evaluate the level

THURBER

of cracking. Depending on the observed conditions, operations personnel should be prepared to begin immediately lowering the reservoir per the procedures identified in the DEP to reduce seepage pressures on the damaged structure.

10.4 Review of Monitoring Instrumentation

The instrumentation at Money Lake Dam No. 1 includes the staff gauge, three standpipe piezometers installed in 2016 and three additional screened wells installed near the downstream toe in 2019. Additionally, there is a seepage monitoring location approximately 50 m downstream of the dam where a PVC pipe passes under the access road. The bucket and stopwatch method is used at this location to provide a relative measure of dam seepage, particularly the seepage emanating from the ditch downstream of the dam's left abutment. Surveillance staff visit the dam twice weekly to make seepage observations, whereas the water levels in the three 2016 monitoring wells are generally recorded monthly.

Table 6 below provides a summary of the standpipe and well point installations at the dam. The installed depths and screen lengths shown for the 2016 installations are based on the test hole logs provided in Tetra Tech EBA's report.

TABLE 6 – MONEY LAKE DAM No. 1 STANDPIPE AND WELL POINT INSTALLATIONS

Instrument ID	Location	Approx. Surface Elev. (m)	Installed Depth (m)	Screen Length (m)	Comments
MW16-01	D/S toe	145.7	1.8	1.2	PVC well screen, monitored monthly
MW16-02	Crest	152.0	5.1	1.4	PVC well screen, monitored monthly
MW16-03	Crest	152.0	7.6	3.0	PVC well screen, monitored monthly
WP19-1	D/S toe	146.0	2.3	1.3	125 mm diam. #12 slot SS well screen
WP19-2	D/S toe	146.0	3.3	1.5	75 mm diam. #20 slot SS well screen
WP19-3	Ramp	147.5	5.5	1.5	75 mm diam. #20 slot SS well screen

During the August 2022 DSR site visit it was noted that MW16-02 was dry to 4.59 m below the dam crest. When the water level probe was recovered, it was caked with a grey clayey sediment. Assuming the details provided on the original test hole log are accurate, this indicates that approximately 0.5 m of material has collected within the screened section of the monitoring well. A similar observation was made at MW06-3, also located on the dam crest. For this monitoring well, a water level was recorded, but when the probe was lowered further it could not advance to the full well depth noted on the test hole log. Based on the reading collected on August 31, 2022, approximately 0.9 m of material has collected within the well screen. Sediment can accumulate within a monitoring well for a number of reasons, including the well screen not being fully surrounded by filter sand, or if particularly fine particles can be conveyed by the adjacent formation through the filter sand (e.g., as a result of seepage through the dam).

A graph of the water level readings collected by the CRD for the six-year period from November 2016 to November 2022 is presented in Figure A-6 in Appendix A. The following observations are provided:

- Overall, the water level fluctuations at the monitoring wells correlate with seasonal changes in the reservoir level; but the fluctuations at the monitoring wells are relatively muted, particularly at MW16-01 and MW16-03.
- MW16-02 was found to be dry to approximately El. 174.41 m on August 31, 2022, where sediment was encountered and prevented the water level sensor from advancing any further. CRD's data spreadsheet reports water levels ranging between El. 147.41 m and 147.45 m between August and December 2022, indicating this monitoring well was likely dry, or very close to it, during this period. A review of the data collected at this instrument shows the water level has not been recorded below El. 174.4 m since 2017.
- Occasional anomalous water levels are evident in the data set, with some readings plotting above and below the normal water level range. These are generally single events, not repeated in readings collected in the preceding or following data collection visit and are likely the result of "mis-reads".

Recommendations:

- *When collecting water level readings, surveillance staff should review previous readings and be aware of the typical data range for the instrument. If the current reading is outside the typical data range, repeated readings should be taken to confirm the water level.*
- *Surveillance staff should be mindful of the sediment level within MW16-02, which may still be accumulating. A water level within several centimeters of the sediment may not be an accurate indication of the phreatic surface within the dam. If a well is noted to be dry, this should be noted in the record.*
- *Surveillance staff should sound the monitoring wells and well point installations to full depth at least annually to check for the accumulation of material within the wells. This information should be noted in the data spreadsheet.*

Seepage observations include reviewing the toe of the dam for seepage (historically, seepage and standing water has been observed in the vicinity of MH1) as well as measuring the flow rate in a PVC pipe that passes under the dam access road downstream of the infiltrator units. The CRD records and plots this flow data against reservoir level (see Figure A-7 in Appendix A). The data suggests there is a strong correlation between reservoir level and flow rate, but that the monitoring pipe discharges from a ditch that runs along the base of a slope, it is suspected that a component of the flow is related to both surface run-off during storms as well as local groundwater flow out of the west slope.

Recommendation: The seepage database should also include daily precipitation data from a nearby weather station. This practice is done for other CRD dams and including this information in the plot will provide added context when evaluating elevated seepage measurements.

11. CDA DAM SAFETY PRINCIPLES

11.1 General

The CDA Dam Safety Guidelines outline processes and criteria for the management of dam safety in accordance with defined principles. Table 7 below summarizes the dam safety principles that are applicable to all dams and should be understood by dam owners, managers, regulators and other interested parties.

TABLE 7 – DAM SAFETY PRINCIPLES (CDA, 2007)

Principle	Description
Dam Safety Management	
1a	The public and the environment shall be protected from the effects of dam failure, as well as release of any or all of the retained fluids behind a dam, such that the risks are kept as low as reasonably practicable.
1b	The standard of care to be exercised in the management of dam safety shall be commensurate with the consequences of dam failure.
1c	Due diligence shall be exercised at all stages of a dam's life cycle.
1d	A dam safety management system, incorporating policies, responsibilities, plans and procedures, documentation, training, and review and correction of deficiencies and nonconformances, shall be in place.
Operation, Maintenance and Surveillance	
2a	Requirements for the safe operation, maintenance, and surveillance of the dam shall be developed and documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure.
2b	Documented operating procedures for the dam and flow control equipment under normal, unusual, and emergency conditions shall be followed.
2c	Documented maintenance procedures shall be followed to ensure that the dam remains in a safe and operational condition.

THURBER

2d	Documented surveillance procedures shall be followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety.
2e	Flow control equipment shall be tested and be capable of operating as required.
Emergency Preparedness	
3a	An effective emergency management process shall be in place for the dam.
3b	The emergency management process shall include emergency response procedures to guide the dam operator and site staff through the process of responding to an emergency at a dam.
3c	The emergency management process shall ensure that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain.
3d	The emergency management process shall ensure that adequate staff training, plan testing, and plan updating are carried out.
Dam Safety Review	
4a	A safety review of the dam (“Dam Safety Review”) shall be carried out periodically.
4b	A qualified registered professional engineer shall be responsible for the technical content, findings, and recommendations of the Dam Safety Review and report.
Analysis and Assessment	
5a	The dam system and components under analysis shall be defined.
5b	Hazards external and internal to the dam shall be defined.
5c	Failure modes, sequences, and combinations shall be identified for the dam.
5d	The dam shall safely retain the reservoir and any stored solids, and it shall pass flows as required for all applicable loading conditions.

Key aspects of the principles summarized in Table 8 are discussed further in the following report sections. An assessment of the CRD’s compliance with the safety principles listed above is presented in Table G-1 in Appendix G.

11.2 Dam Safety Management System

As stated in the CDA Dam Safety Guidelines (2013), dam owners are accountable for the safe management of their dams throughout the dam’s life cycle. The primary objective of dam safety management is preventing dam failure. The key elements of an owner’s dam safety management system include the following:

- Developing a policy that formalizes the owner’s commitment to dam safety (e.g., assigning budget, responsibilities and duties for dam safety tasks),
- Carrying out planning to ensure the various components of the dam safety program are implemented (e.g., scheduling for routine inspections, maintenance, etc.),

THURBER

- Implementing the dam safety program (i.e., the ongoing activities associated with the operation, maintenance and surveillance of the dam),
- Checking and reviewing dam performance, including routine inspections, formal DSRs, and investigating significant dam safety incidents to determine whether improvements can be made,
- Taking corrective actions to address deficiencies and non-conformances identified by routine inspections, formal dam safety reviews, emergency preparedness tests, etc.
- Reporting the status of the issues and findings to senior management on a regular basis.

Many of the elements of the CRD's dam safety management system are captured in a comprehensive Dam Safety Risk Register that exists in the form of an Excel spreadsheet, that is updated regularly for all the dams managed by the IWS department. A copy of the register was provided to Thurber for review. The file includes information for all CRD dams but is organized such that details for a specific facility can be found readily. The spreadsheet has individual tabs dedicated to various components of the system including current DFCC, dam attributes, and water licence information. With respect to dam safety management components, the register also includes tabs for the following functions:

- Identifying which individuals within the CRD are responsible for various OMS activities for each facility.
- Recording and tracking identified dam safety issues, including how and when the issue was identified and when it was resolved.
- Routine and formal inspection schedules, including the status of regulatory documents such as the OMS Manual and DEP.

Recommendation: *Staff training is one of the supporting processes that is required for the successful implementation of a Dam Safety Management System. On-going dam safety training related to OMS and emergency preparedness activities is encouraged and can take many forms including self-study modules, workshops, and on-going work. In particular, the CRD should confirm that local operations and surveillance personnel receive adequate dam safety training targeted to their position, and that refresher sessions be offered on a regular basis to support new and existing personnel.*

THURBER

11.3 Operations, Maintenance and Surveillance Manual

The CRD provided a copy of their OMS Manual for Money Lake Dam No. 1, dated January 2022. The following comments are provided:

- The OMS Manual provides a summary of key attributes of the facility including a physical description, its assigned DFCC, and details on site access.
- A description of the hydraulic works and procedures for dam operation is provided. No discussion is included on seepage recycling.
- A description of maintenance requirements is provided, including both routine items and less frequent activities such as exercising the outlet valve for the lake supply system.
- A description of the instrumentation, data recording and management is provided in the maintenance section of the manual, but arguably should be included in the surveillance section of the manual.
- The surveillance section provides a good summary of surveillance requirements including routine inspections and annual formal inspections. Discussion is also provided about the potential requirement for special inspections and increased levels of surveillance, which could be triggered depending on events.
- A copy of the 2021 Formal Annual Dam Inspection is included in the manual. The annual inspections are carried out by experienced personnel from the CRD's Infrastructure Engineering (IE) Department and provide an excellent level of detail. The inspection report conveniently summarizes required action items, including identifying which items are new for the current inspection cycle. Such items are added to the CRD's risk register.

Recommendation: *The following recommendations are provided regarding the OMS Manual:*

- *Additional operational details should be included in the manual. It is recommended that the pipework schematic plan be included in the manual, along with function of the 5 noted valves. A copy of this drawing is included in Appendix B.*
- *Details regarding instrumentation and data recording/management should be included in the surveillance section of the manual (rather than maintenance). The manual should identify the frequency for the collection of instrumentation readings.*
- *A comment should be included to sound the three standpipes (MW16-01, -02, and -03) to the bottom at least once a year to check for the development of sediment. If sediment builds up above the length of the well screen, the functionality of the instrument will be*

THURBER

compromised, and it may be necessary to flush the well out to improve instrument performance.

- *Additional detail should be provided in the surveillance section regarding what observations would trigger increased levels of surveillance, including how significant an increase in measured seepage rate would justify increased surveillance. Increasing water levels at the standpipe piezometer installations should also be listed as a trigger for increased levels of surveillance or the detection of cloudy seepage. The CRD should retain a consultant to assist in the development of alarm levels.*

11.4 Emergency Planning and Simulations

The BC Dam Safety Regulation stipulates that a dam emergency plan (DEP) be prepared for all dams with a DFCC of High, Very High or Extreme. The CRD updates the DEP for the dam on a yearly basis. A draft version of the 2023 DEP was provided in December 2022 for review. Unlike previous versions of the DEP, the 2023 version adopts a new "standalone" format to better align with the template provided by the BC Dam Safety Office.. The plan provides a useful "Quick Reference Guide" at the beginning of the document to better direct plan users during an emergency situation. The document also describes the 5-step DEP process that is used to determine the level of the emergency, which dictates emergency response activities. Like the provincial template document, the DEP also includes sample messages to be used to describe the emergency situation to the local emergency authority.

Recommendation: The following comments and recommendations are provided regarding the draft 2023 DEP for Money Lake Dam No. 1:

- *The description of the 5-step DEP process, including how to determine the appropriate emergency level, should be presented before discussion on the general roles and responsibilities during an emergency, since these actions depend on the emergency level.*
- *The drawings included in Appendix C should represent current conditions. The February 1984 drawing titled "General Plan of Dam" does not show the current embankment and spillway configuration. Additionally, Appendix C includes a drawing showing proposed modifications to the dam crest and spillway (page 50), which have not been carried out.*
- *Simplify/consolidate the presentation of information to make it easier to find and use in an emergency. For example, delete Appendix I and include the information in Table 1 of the plan, where most of the information is already presented. Also consolidate Appendix D and Appendix G, as similar information is presented in both appendices.*

THURBER

- *An assessment should be completed to evaluate the approximate drawdown rates associated with available rental equipment (i.e., pumps) and add this information to the emergency reservoir drawdown SOP included in Appendix J of the new DEP. This would assist with emergency planning.*

One of the CDA's dam safety principles is that the emergency management process shall ensure that adequate staff training, plan testing, and plan updating are carried out. Exercising emergency plans is an important part of an effective dam safety program. The CRD carried out a large-scale emergency planning exercise on October 28, 2022, that was jointly carried out by dam safety staff of the IWS department, as well as staff from CRD Protective Services and other groups. The scenario involved a dam emergency at Sooke Lake Dam that required planning for an evacuation of people living and working downstream of the dam. Such planning exercises are expected to benefit the CRD on an institutional scale, but it is noted these benefits are not likely translatable to the individuals at the bottom end of the internal notification chart including in the DEP for Money Lake Dam No. 1 (i.e., the LHBC operator and field supervisor as well as the operations manager they report to).

Recommendation: It is recommended that a training exercise be carried out to test the DEP and to allow local operations staff to become more familiar with their roles and responsibilities during an emergency.

12. REGULATORY COMPLIANCE

Table 8 below provides a summary of the CRD's compliance with the BC Dam Safety Regulation for Money Lake Dam No. 1 in relation to the frequency of dam safety activities.

TABLE 8 – SUMMARY OF DAM OWNER'S COMPLIANCE WITH BC DAM SAFETY REGULATION (*)

Regulation	Requirement for High Classification Dam	CRD Compliance
Requirements under Part 2		
1. Redetermine the classification of the dam and submit to the DSO written notice of the proposed new classification	Annually	Yes - inundation area is reviewed annually during formal inspection.
Requirements under Part 3		
2. Conduct site surveillance	Weekly unless otherwise specified in OMS Manual	Yes
3. Conduct formal inspections	Annually	Yes

THURBER

4. Test operation of mechanical components of the dam (there are not electrical components)	Annually unless otherwise specified in the OMS Manual	Yes – supply line valve exercised at least one each year (during formal inspection).
5. Collect readings from instrumentation and analyze & interpret the readings	Annually	Yes – the collected data is plotted and reviewed by CRD personnel on a quarterly basis.
6. Review contact information in DEP, revise if necessary and report to DSO	Annually	Yes
7. Review emergency contact information and, if necessary, revise and submit revision to DSO	Not applicable	This requirement only applies to Low consequence dams.
8. Review OMS manual and DEP, revise if necessary and report to DSO	Every 10 years	Yes
9. Ensure DSR carried out and submit report to DSO	Every 10 years	Yes

* From Schedule 2 of B.C. Reg. 40/2016 (Minimum frequency of safety activities).

13. HAZARDS AND FAILURE MODES ASSESSMENT

13.1 Introduction

A hazards and failure modes assessment is a key part of the overall dam safety analysis process. The objective of this process is to determine the capability of the dam and systems to retain the stored volume and to pass flows around and through the dam in a controlled manner *(CDA Technical Bulletin, Dam Safety Analysis and Assessment, 2007)*.

The hazards are broadly categorized as either external or internal hazards. External hazards, defined as those hazards beyond the control of the dam owner and originating outside the boundary of the dam and immediate reservoir system, include the following:

- Meteorological events (rain, snow, floods caused by extreme runoff, temperature extremes, ice, etc.)
- Seismic events (either natural or man-made such as from blasting)
- The reservoir environment (including foreshore areas, upslope areas, burrowing animals)
- Vandalism or terrorist activities.

Internal hazards are errors or omissions in the design, operation and maintenance of the dam and water conveyance structures, including the following:

THURBER

- Construction errors or design compromises to accommodate natural or imposed deviations from the design assumptions,
- Errors due to poor definition of maintenance requirements at the design stage,
- Errors and omissions in the development of standard operating procedures and rules, and
- Inadequate consideration of the performance of the reservoir rim and upstream dams.

A failure mode is a means of describing how a specific element or component of the dam must fail in order for a part of the system to lose its functionality. For a water supply dam, failure modes are classified into two general categories: dam overtopping or dam collapse.

The overtopping failure mode generally relates to inadequate freeboard leading to the flow of water over the crest of the dam in a matter not intended or provided for in the design, construction or operation of the dam. Examples of functional failures associated with overtopping include the exceedance of the dam's discharge capacity, inadequate operation, inadequate maintenance, wave overtopping, etc.

The collapse failure mode relates to inadequate internal resistance to forces applied to the dam, foundations and abutments while being hydraulically operated in accordance with the design intent. Examples of functional failures associated with collapse include liquefaction, internal erosion, structural weakening and deformations.

13.2 Failure Modes Analysis and Matrix

The interactions between hazards and failure modes can be related through a matrix representation, known as a hazards and failure modes matrix. The matrix (developed originally by BC Hydro) is typically represented in tabular format with the various external and internal hazards listed across the top of the table (in columns), and the global failure modes arranged along the left side of the table (in rows). The global failure modes (e.g., overtopping) are further divided into more specific functions, such as "durability" or "watertightness".

The procedure involves considering the various hazard and failure mode "pairs" that exist where the hazard columns and failure mode rows intercept, and then eliminating those pairs that don't exist and assessing the remainder. For example, one of the failure mode rows deals with the potential for dam overtopping due to the reservoir "operation rules" not being followed. These might apply if spillway gates must be opened to lower the reservoir. However, since the Money Lake No. 1 reservoir incorporates an overflow spillway, this failure mode pair is not applicable.

THURBER

This procedure was carried out for the facility and the results are tabulated on Figure A-8 in Appendix A. Five basic outcomes were obtained when evaluating the hazard and failure mode pairs:

- Not possible (grey shading),
- Not applicable (green shading),
- Assessed - satisfactory outcome or remote chance of occurring (green shading),
- Assessed - potential to develop into a concern (yellow shading), and
- Assessed – considered a critical safety issue (red shading)

As noted by the shading of the cells in the Figure A-8, most of the hazard and failure mode pairs resulted in either the “not applicable” or “satisfactory/remote chance of occurring” outcomes. However, less favourable yellow and red shaded outcomes were also obtained, particularly for the lower half of the matrix table. Additional discussion is provided below.

13.2.1 Meteorological Hazards (External)

The primary failure mode of note for external meteorological events is dam overtopping as a result of wind-wave effects during the IDF event (see Section 9.3). This is identified as a critical dam safety issue.

Less severe (i.e., potential) failure modes include the inability of CRD personnel to access the dam during a major flood because of a road washout. Such a washout occurred following the atmospheric river event of November 2021. The inability to access the dam in a timely fashion would delay/prevent the detection of poor dam performance and the completion of necessary maintenance including the removal of spillway blockages or repairing displaced rip rap, etc.

Elevated reservoir levels during a major storm (e.g., approaching the dam crest elevation) would also increase seepage pressures, which could increase the likelihood of triggering and internal erosion/piping failure.

13.2.2 Seismic Hazards (External)

The primary failure modes of note for seismic hazards include reduced freeboard and seismic displacements during or immediately after an earthquake. These displacements would be exacerbated by liquefaction of loose foundation layers, which were encountered in the buried channel deposits under the dam. Liquefaction of these pockets would result in temporary loss of support within the foundation.

THURBER

Secondary concerns include the potential for increased leakage and internal erosion following a significant earthquake. Damage to the concrete overflow spillway at the dam crest could also lead to increased seepage around this interface and at the construction joints.

13.2.3 Water Barrier (Interior)

The dam's water barrier consists of the embankment, which has been raised several times, and the underlying foundation. The primary failure mode for this system is internal erosion, which includes piping through the dam fill zones and the foundation soils and fractured bedrock. As described in Section 10, although the 1979 dam raising design included a granular filter zone, this filter does not protect all of the embankment and nor was it extended to filter the buried channel deposits that pass under the dam. Unfiltered seepage through the foundation is the primary failure mode of concern for the water barrier. Loss of support (i.e., sinkholes) and internal erosion within the unfiltered dam zones is also a potential concern.

13.2.4 Hydraulic Structures (Interior)

For the purposes of the hazards and failure modes assessment, the hydraulic structures at Money Lake Dam No. 1 include the water intake pipe as well as the seepage collection infrastructure installed beyond the toe of the dam following the 1979 dam raising. This includes the various buried valve assemblies, both manholes and connected piping.

Although the 1979 dam raising did specify the use of filter gravels in some locations, it is considered unlikely that the subsequently installed hydraulic structures were adequately filtered to prevent the migration of fines into the cavities provided by these pipes and manhole structures. Furthermore, given the intervening time, it is considered likely that much of the original metal piping has rusted and collapsed. This situation, combined with the historic leakage at the dam, increases the likelihood for quick seepage paths to develop through and under the structure, which could threaten the dam's safety.

Given the above, three hazard and failure mode pairs were identified on Figure A-8 when considering the hydraulic structures in relation to watertightness and durability.

THURBER

14. DAM SAFETY EXPECTATIONS

Per the former BC Dam Safety Review Guidelines (2012), one of the requirements of a DSR is to identify and document deficiencies and non-conformances in the dam or the dam's safety management. This can be accomplished by using the dam safety expectations check sheet that was included in Appendix 2 of the 2012 DSR Guidelines. This practice continues even though the dam safety expectations check sheet is not specifically referenced in more recent guidance documents for DSRs, including the EGBC professional practice guidelines prepared for Legislated Dam Safety Review in BC (2018). The check sheet lists the safety expectations for a facility in relation to the CDA's dam safety principles, and is divided into five sections:

- Dam Safety Analysis
- Operations, Maintenance and Surveillance
- Emergency Preparedness
- Dam Safety Review
- Dam Safety Management System

During a DSR, the Qualified Professional Engineer (QPE) is expected to determine which expectations are applicable for the dam being reviewed, and then determine if the expectation has been met or not. If the expectation has not been met, the QPE is expected to determine whether this is a deficiency or a non-conformance, and what the priority is to meet this expectation.

A dam safety expectations assessment has been completed for Money Lake Dam No. 1 and the summary table is attached in Appendix G. The assessment has identified 8 non-conformances, 2 actual deficiencies and 1 potential deficiency. The reader should refer to Table G-1 for further details. The recommended priority for addressing non-conformances and deficiencies is shown in Table 9.

THURBER

15. RECOMMENDATIONS

Table 9 below provides a summary of key recommendations from the 2022 DSR for Money Lake Dam No. 1.

TABLE 9 - SUMMARY OF 2022 DSR RECOMMENDATIONS

No.	Recommendation	Priority / Effort
1	Recommendations related to the DSR site visit (Section 7) include the following: a) Repair and reseal the exposed foam water stops within the concrete joints of the spillway. b) Remove the excess vegetation from the stilling basin area. c) Re-establish the rock stilling basin by installing new rock or reshaping the existing rock to provide adequate erosion protection where the spillway chute discharges into the creek channel. Also restore armouring in the channel immediately downstream of the dam where the pedestrian bridge abutment is undermined. d) Clean or replace the primary staff gauge, which is difficult to read. The adjacent broken gauge should be removed. e) An information sign should be posted at the dam to follow best practices described by the CDA and meet the intent of the BC Dam Safety Regulation	High / Low to Moderate (2023) (2023) (2024) (2023) (2023)
2	An updated dam break analysis and inundation study should be completed that considers both sunny day and flood induced failure scenarios. See Section 8.2 for more details.	High / Moderate (2024)
3	Evaluations should be carried out to assess the condition of the HDPE water supply pipe and whether any leaks are present, particularly the section extending from the upstream face of the dam to the vicinity of MH1 beyond the downstream toe.	Moderate/Moderate (2024)
4	The CRD should continue planning to install a downstream toe filter. However, given the observed groundwater conditions at the toe of the dam, alternate toe filter design concepts should be prepared. Further details are provided in Section 10.3.	High / Moderate (2023)
5	The following recommendations relate to instrumentation (Section 10.4): a) When collecting water level readings, surveillance staff should review the readings collected during the previous visit. If the reading is beyond the typical data range, repeated readings should be completed to improve confidence in the data. b) Surveillance staff should be mindful of the sediment level within MW16-02, which may still be accumulating. A water level within several centimeters of the sediment may not be an accurate indication of the phreatic surface within the dam. If a well is noted to be dry, this be noted in the record. c) Surveillance staff should sound the monitoring wells and well point installations to full depth at least annually to check for the	High / Low (Immediately) (Immediately) (2023)

THURBER

	accumulation of material within the wells. This information should be noted in the data spreadsheet. d) The seepage database should also include daily precipitation data from a nearby weather station. This practice is done for other CRD dams and including this information in the plot can provide added context when evaluating elevated seepage measurements. e) The CRD should retain an engineering consultant familiar with earth dams to review and interpret the piezometric data on an annual basis.	(2023) (starting 2023)
6	As discussed in Section 11.2, the CRD should confirm that local operations and surveillance personnel receive adequate dam inspection and emergency response training, and that refresher sessions be offered on a regular basis to support new and existing personnel. Training activities should be recorded.	High / Low (2023)
7	The following recommendations pertain to the OMS Manual (Section 11.3): a) Additional operational details should be included in the manual, including the pipework schematic plan, along with function of the five noted valves. A copy of this drawing is included in Appendix B. b) Details regarding instrumentation and data recording/management should be included in the surveillance section of the manual (rather than maintenance). The frequency of data collection at installed monitoring instruments should be specified. c) A comment should be included to sound the three standpipes (MW16-01, -02, and -03) to the bottom at least once a year to check for the development of sediment. If sediment builds up above the length of the well screen, the functionality of the instrument will be compromised, and it may be necessary to flush the well out to improve instrument performance. d) Additional detail should be provided in the surveillance section regarding what observations could trigger increased levels of surveillance, including how significant an increase in measured seepage rate would justify increased surveillance. Increasing water levels at the standpipe piezometer installations should also be listed as a trigger for increased levels of surveillance or the detection of cloudy seepage. The CRD should retain a consultant to assist in the development of alarm levels.	High / Low (2023) (2023) (2023) (2023)
9	The following recommendations pertain to the DEP (see Section 11.4 for more details): a) The description of the 5-step DEP process, including how to determine the appropriate emergency level, should be presented before discussion on the general roles and responsibilities during an emergency, since these actions depend on the emergency level. b) The drawings included in Appendix C should represent current conditions. c) Simplify/consolidate the presentation of information to make it easier to find. For example, delete Appendix I and include the information in Table 1 of the plan, where most of the information is	High / Low (2023) (2023) (2023)

THURBER

	already presented. Also consolidate Appendix D and Appendix G, as similar information is presented in both appendices. d) An assessment should be completed to evaluate the approximate drawdown rates associated with available rental equipment (i.e., pumps) and add this information to the emergency reservoir drawdown SOP included in Appendix J of the new DEP. This would assist with emergency planning.	(2023)
10	It is recommended that a training exercise be carried out to test the DEP once it is updated to allow local operations staff to become more familiar with their roles and responsibilities during an emergency (Section 11.4).	Moderate / Moderate (2024)

16. DAM SAFETY REVIEW ASSURANCE STATEMENT

Refer to Appendix H for the signed DSR assurance statement.

THURBER

REFERENCES

See Table 2 for a listing of background information that was reviewed in the preparation of this DSR report. The following is a listing of technical and regulatory references.

1. British Columbia Dam Safety Regulation, British Columbia Regulation 40/2016, February 29, 2016.
2. Dam Safety Guidelines, Canadian Dam Association, 2007 (Updated 2013)
3. Technical Bulletin – Geotechnical Considerations for Dam Safety, Canadian Dam Association, 2007.
4. Technical Bulletin – Hydrotechnical Considerations for Dam Safety, Canadian Dam Association, 2007.
5. Technical Bulletin – Inundation, Consequences and Classification for Dam Safety, Canadian Dam Association, 2007.
6. Dam Safety Review Guidelines, Dam Safety Section, Victoria, BC; November 2012, Version 3.
7. Legislated Dam Safety Reviews in BC, APEGBC Professional Practice Guidelines V3.0, October, 2016.
8. Adams, Allen, Halchuk and Kolaj (2019). Canada's 6^{th} Generation Seismic Hazard Model as Prepared for the 2020 National Building Code of Canada, 12^{th} Canadian Conference on Earthquake Engineering, June 2019, Quebec.

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

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

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

3. BASIS OF REPORT

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

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

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

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

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

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

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

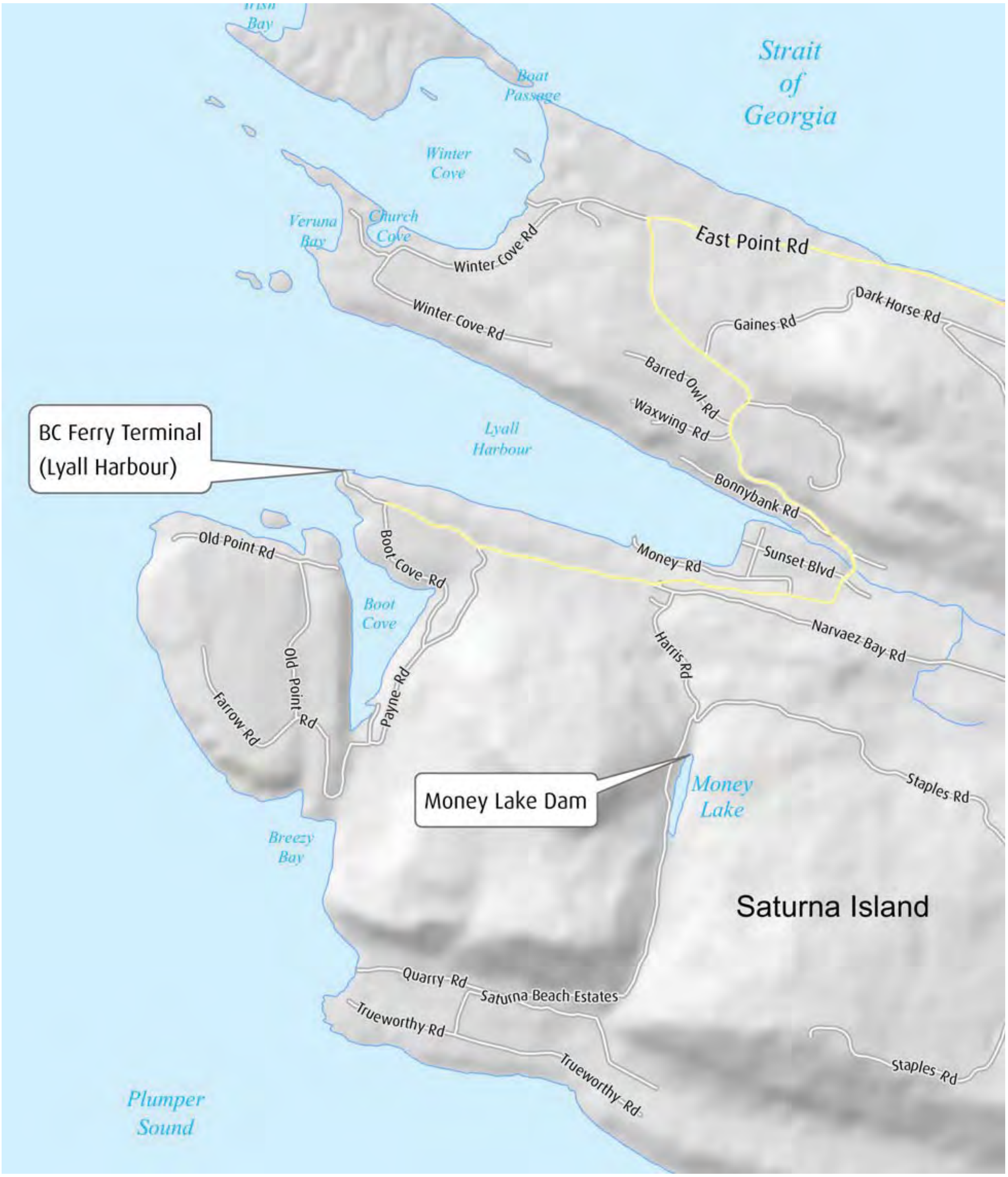
The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or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

THURBER

APPENDIX A

THURBER

MONEY LAKE DAM - 2022 DAM SAFETY REVIEW
SITE LOCATION PLAN



Reference: Image From CRD.

0 500 1000 1500m

FIGURE A-1

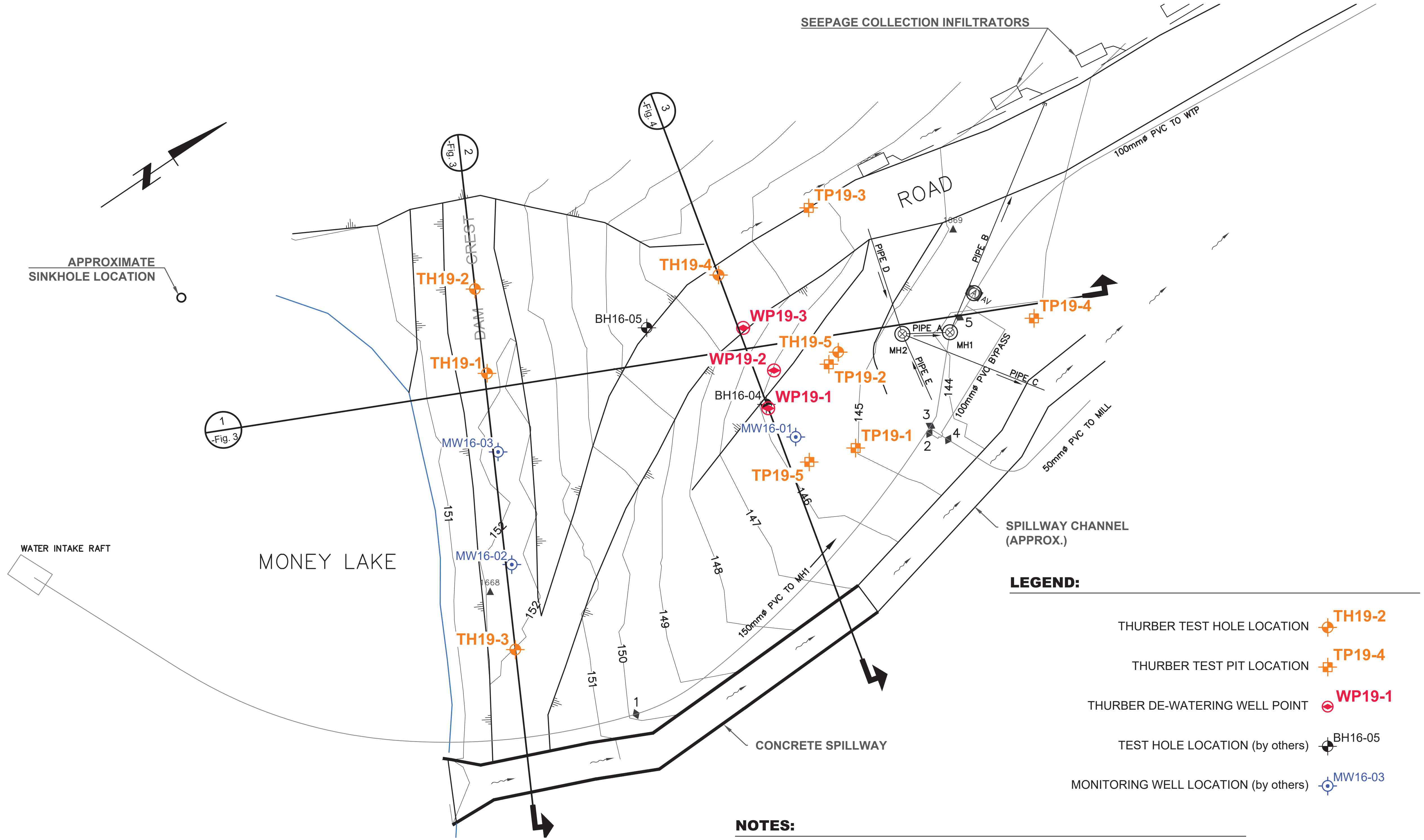
Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD001.dwg

Date: December 2, 2022

THURBER

MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SITE PLAN

SCALE 1:300



0 2 4 6 8 10 15 20m

SCALE 1:300

NOTES:

1. THURBER TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. BASE PLAN, INCLUDING LOCATIONS OF TEST HOLES AND MONITORING WELLS BY OTHERS, TAKEN FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.
3. 75 mm DIAM.PVC SEEPAGE RETURN PIPE NOT SHOWN.

FIGURE A-2

Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

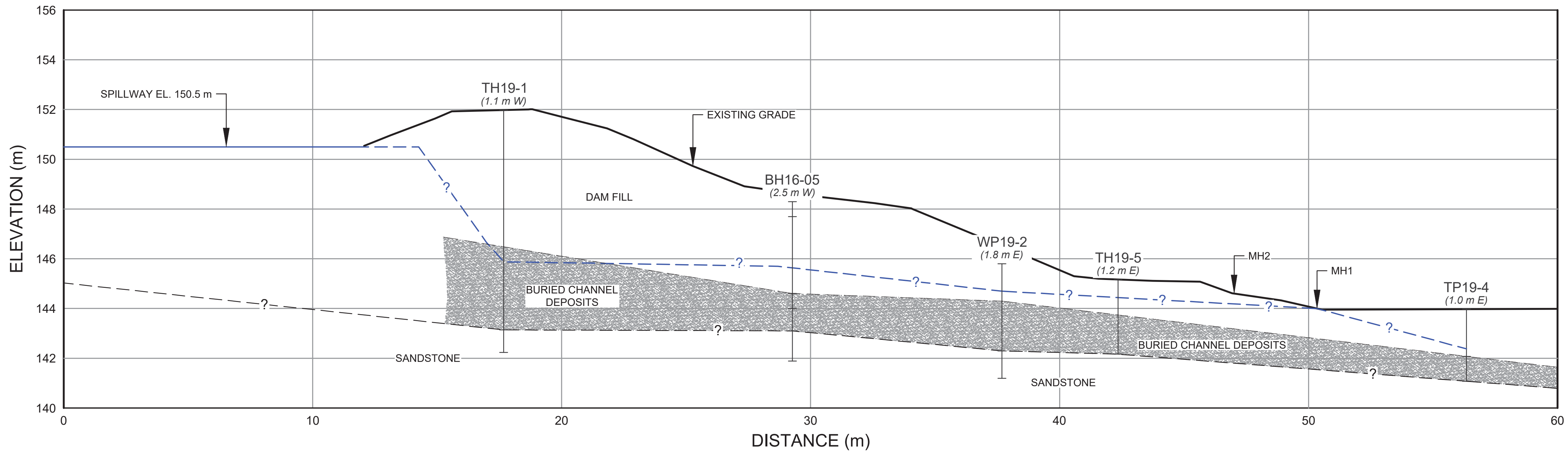
Date: December 13, 2022

THURBER

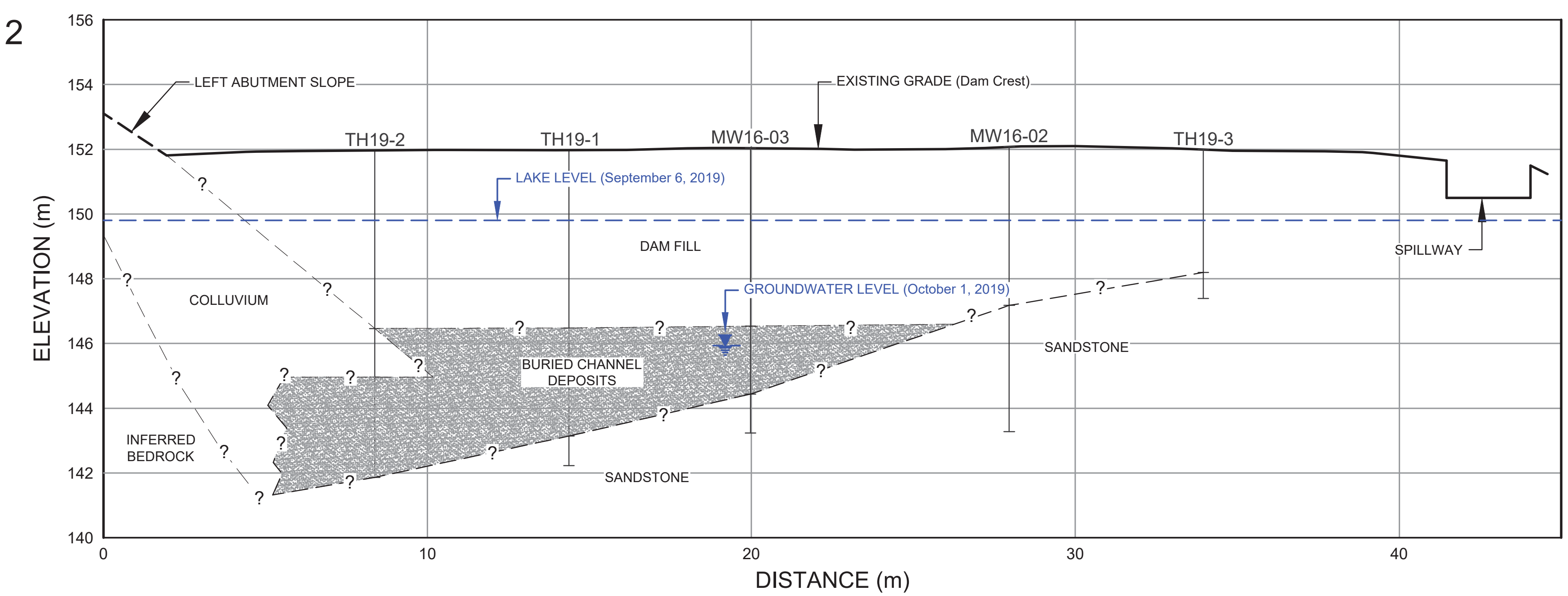
MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SECTIONS 1 & 2

SCALE 1:200

SECTION 1



SECTION 2



0 2 4 6 8 10 12m
SCALE 1:200

NOTES:

1. TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. SUB-SURFACE MATERIAL TYPES ARE BASED ON ENGINEERING INTERPRETATION OF THE AVAILABLE DATA. SEE LOGS FOR DETAILED INFORMATION.
3. GROUND SURFACE LINE DERIVED FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.

FIGURE A-3

Date: December 13, 2022

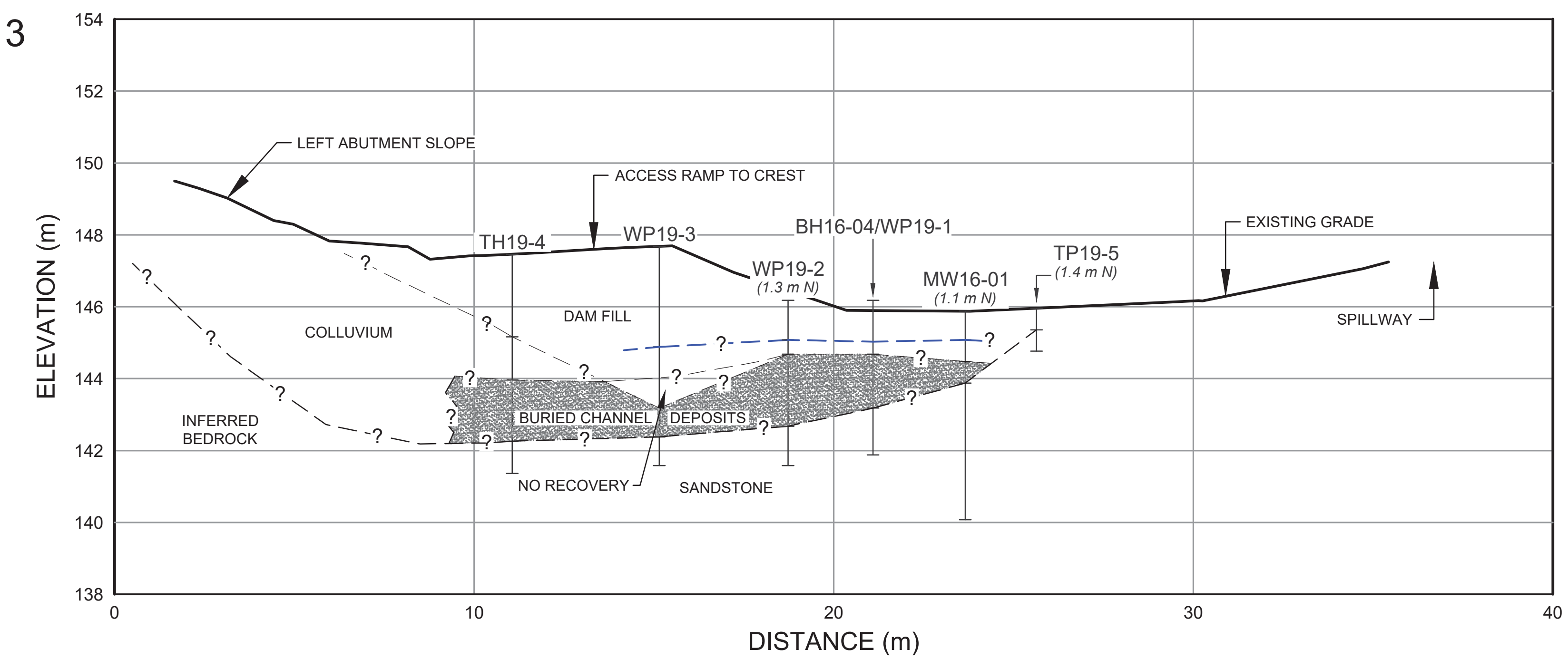
Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

THURBER

MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SECTIONS 3

SCALE 1:200

SECTION 3



NOTES:

1. TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. SUB-SURFACE MATERIAL TYPES ARE BASED ON ENGINEERING INTERPRETATION OF THE AVAILABLE DATA. SEE LOGS FOR DETAILED INFORMATION.
3. GROUND SURFACE LINE DERIVED FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.

0 2 4 6 8 10 12m
SCALE 1:200

FIGURE A-4

Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

Date: December 13, 2022

THURBER

MONEY LAKE DAM - 2022 DAM SAFETY REVIEW
MODIFIED INUNDATION MAP

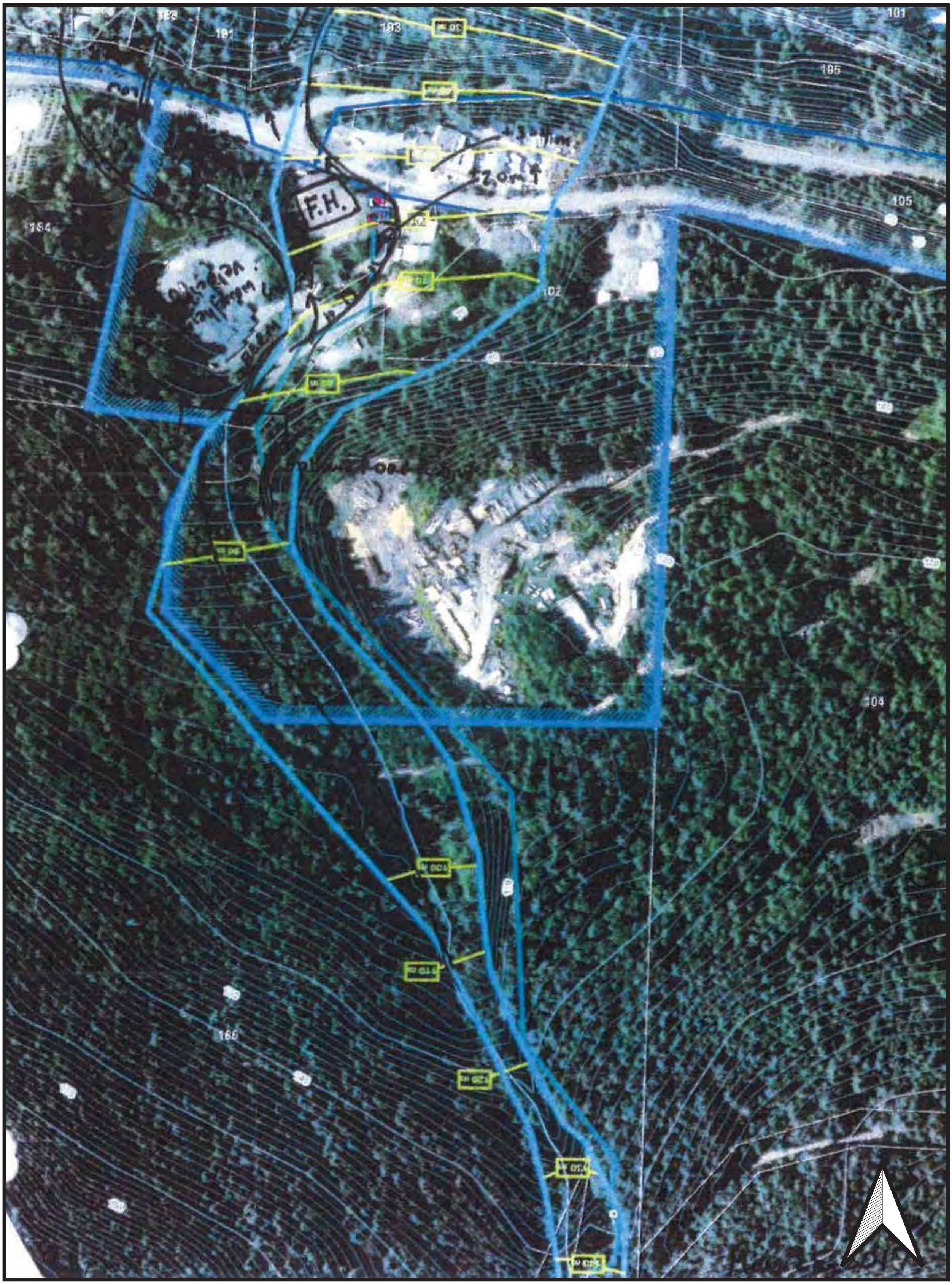


FIGURE A - 5

Client:Capital Regional District
File No.:21566
E-File:Figure_A_5_21566.pdf

January 12, 2023

THURBER

MONEY LAKE DAM - 2022 DAM SAFETY REVIEW
PIEZOMETRIC MONITORING DATA

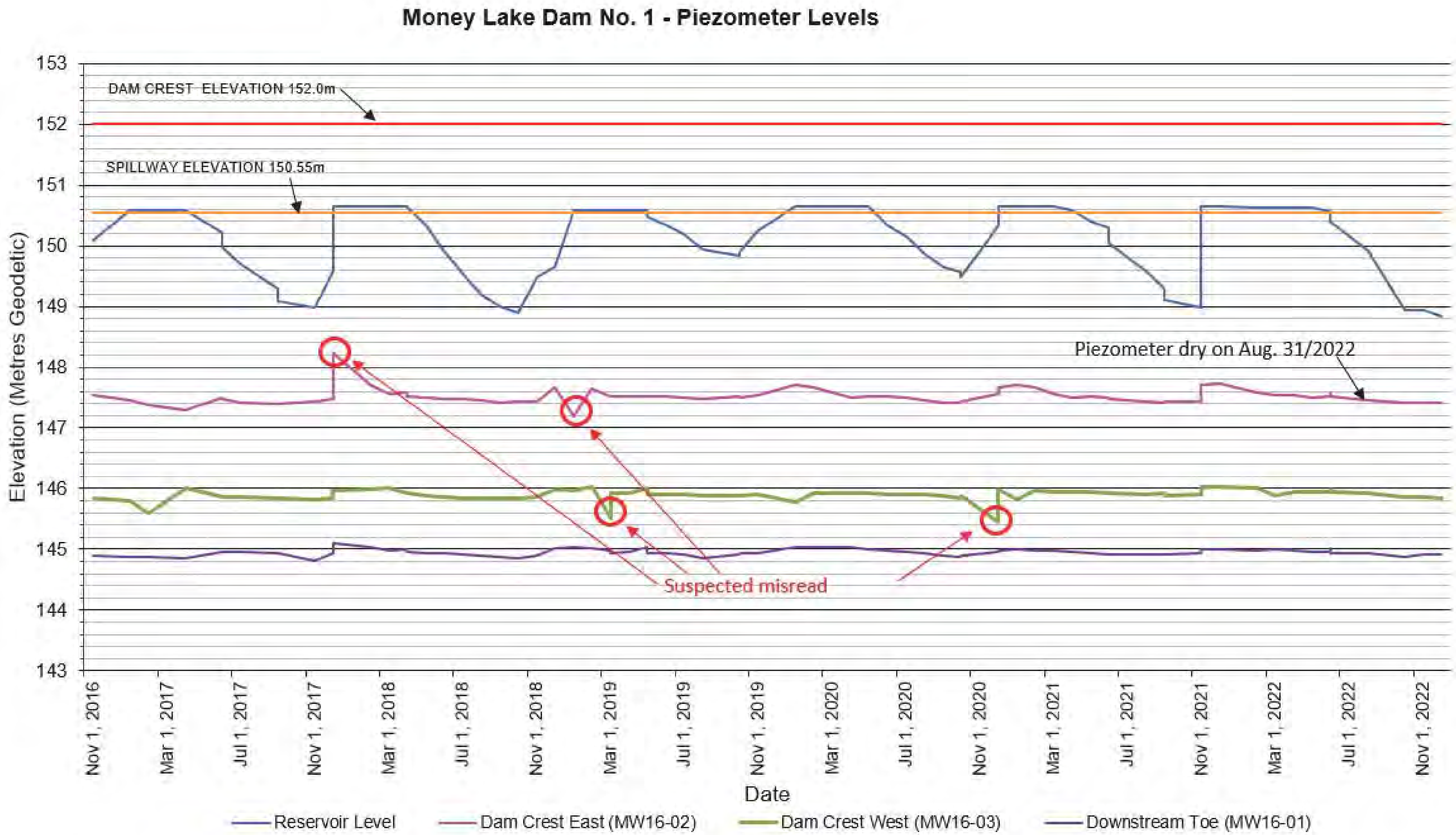


FIGURE A - 6

Client: Capital Regional District
File No.: 21566
E-File: Figure_A_6.pdf

January 12, 2023

THURBER

MONEY LAKE DAM - 2022 DAM SAFETY REVIEW
SEEPAGE MONITORING DATA

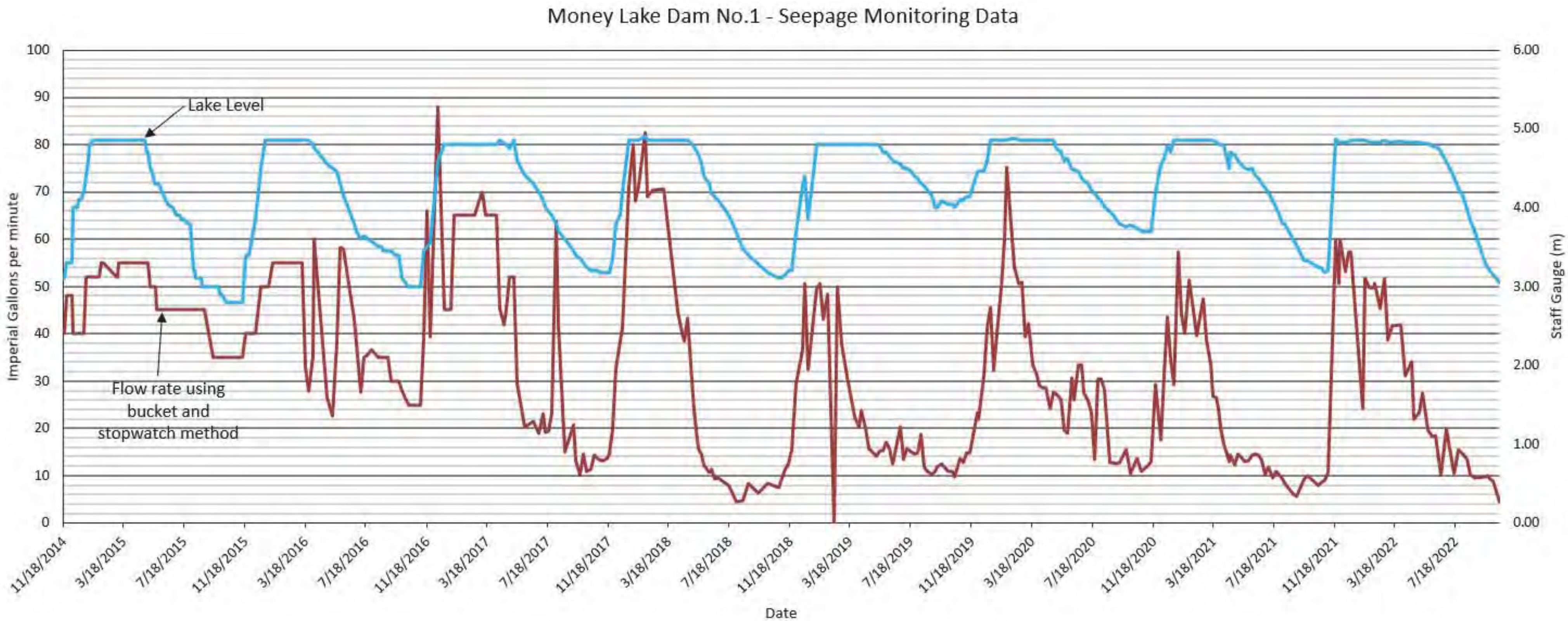


FIGURE A - 7

Client: Capital Regional District
File No.: 21566
E-File: Figure_A_7.pdf

January 12, 2023

THURBER

MONEY LAKE DAM - 2022 DAMS SAFETY REVIEW
HAZARDS AND FAILURE MODES MATRIX

Not Possible	Not Applicable	Satisfactory Outcome or Remote Chance of Occurring	Potential to Develop into a Concern	Critical Issue

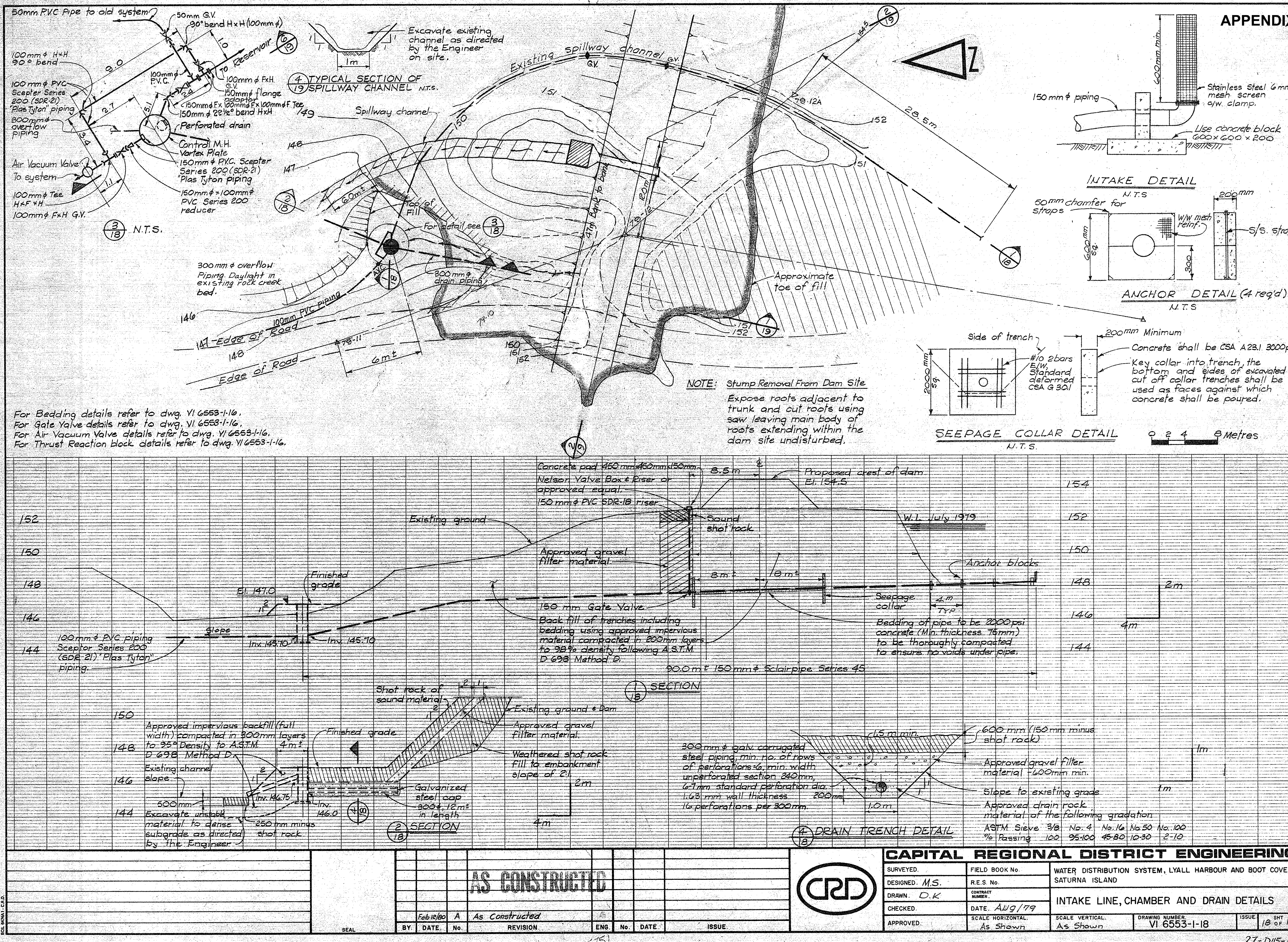
				E	F	G	H	I	J	K	L
GLOBAL FAILURE MODES		ELEMENT AND/OR ELEMENT FUNCTION	MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS	External Hazards				Internal Hazards (Design, Construction, Maintenance, Operation)			
				Meteorological	Seismic	Reservoir Environment	Human Attack	Water barrier	Hydraulic struct.	Mech/elec	Infrastructure & Plans
DAM COLLAPSE BY OVERTOPPING (erosion or overturning)	Water elevation too high	Inadequate installed discharge capacity	Meteorological inflow > buffer + outflow capacity	Satisfactory	Not Possible	Not Possible	Not Possible	Not Possible	Not Possible	Not Possible	Not Possible
		Inadequate available discharge capacity	Inadequate reservoir operation (rules not followed)	Not Applicable	N/A. Overflow Spillway	Satisfactory	Remote - overflow spillway	Not Applicable	Overflow Spillway	N/A - no such components	N/A. Overflow Spillway
			Random functional failure on demand	Satisfactory (remote change of waterstop failure)	N/A. Overflow Spillway	Satisfactory	N/A. Overflow Spillway	Satisfactory	Satisfactory (chance of valve failure damage is low)	N/A - no such components	N/A. Overflow Spillway
			Discharge capability not maintained or retained	Satisfactory (remote chance of log boom failure)	N/A. Overflow Spillway	Remote possibility of spillway being affected	Remote - overflow spillway	Remote (water supply pipe)	Not Applicable	N/A - no such components	Remote (spillway operation)
		Inadequate freeboard	Excessive elevation due to landslide or U/S dam	Satisfactory / Remote	Remote - Large-scale slide unlikely	Remote - Large-scale slide unlikely	Remote	Not Applicable	Not Possible	Not Possible	Satisfactory
			Wind-wave dissipation inadequate	Deficient freeboard during design flood	Satisfactory	Remote - small reservoir and shape	Not applicable	Remote	Not Possible	Not Possible	Not Applicable
	Management System Failure	Safeguards fail to provide timely detection and correction	Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy	Potential (road washout)	Potential (road closed)	Satisfactory	Satisfactory	Satisfactory	Satisfactory (overflow spillway)	N/A - no such components	Satisfactory (staff gauge)
DAM COLLAPSE BY LOSS OF STRENGTH (External or internal structural failure and weakening)			Operation, maintenance and surveillance fail to detect poor dam performance	Potential (road washout)	Potential (road closed)	Satisfactory	Satisfactory	Potential (detecting internal erosion)	Potential (unknown condition of water collection system)	N/A - no such components	Potential - inadequate instrumentation / review
	Crest elevation too low	Stability under applied loads	Mass movement (external stability:- displacement, tilting, seismic resistance)	Satisfactory / Remote	Reduced freeboard & deformations	Remote chance of rim instability affecting dam	Remote	Satisfactory	Satisfactory	N/A - no such components	Satisfactory
			Loss of support (foundation or abutment failure)	Satisfactory / Remote	Localized liquefaction in foundation	Remote chance of rim instability affecting dam	Remote	Potential loss of support from internal erosion in foundation	Satisfactory	N/A - no such components	Satisfactory
		Watertightness	Seepage around interfaces (abutments, foundation, water stops)	Satisfactory / Remote	Potential (damage to spilway)	Not applicable	Remote	Unfiltered seepage through foundation	Unfiltered seepage through buried channel deposits	N/A - no such components	Remote
			Through dam seepage control failure (filters, drains, pumps)	Potential	Increased seepage following EQ	Not applicable	Remote	Potential internal erosion into rockfill zones	Aging infrastructure not properly filtered	N/A - no such components	Remote
		Durability/cracking	Structural weakening (internal erosion, AAR, crushing, gradual strength loss)	Potential	Increased potential for internal erosion following EQ	Not applicable	Remote	Satisfactory / Remote	Suspected collapse / degradation of infrastructure	Not Possible	Remote
			Instantaneous change of state (static iquefaction, hydraulic fracture, seismic cracking)	Satisfactory	Potention / Critical (TBC)	Not applicable	Remote	Satisfactory / Remote	Satsifactory	N/A - no such components	Not Applicable

FIGURE A-8

THURBER

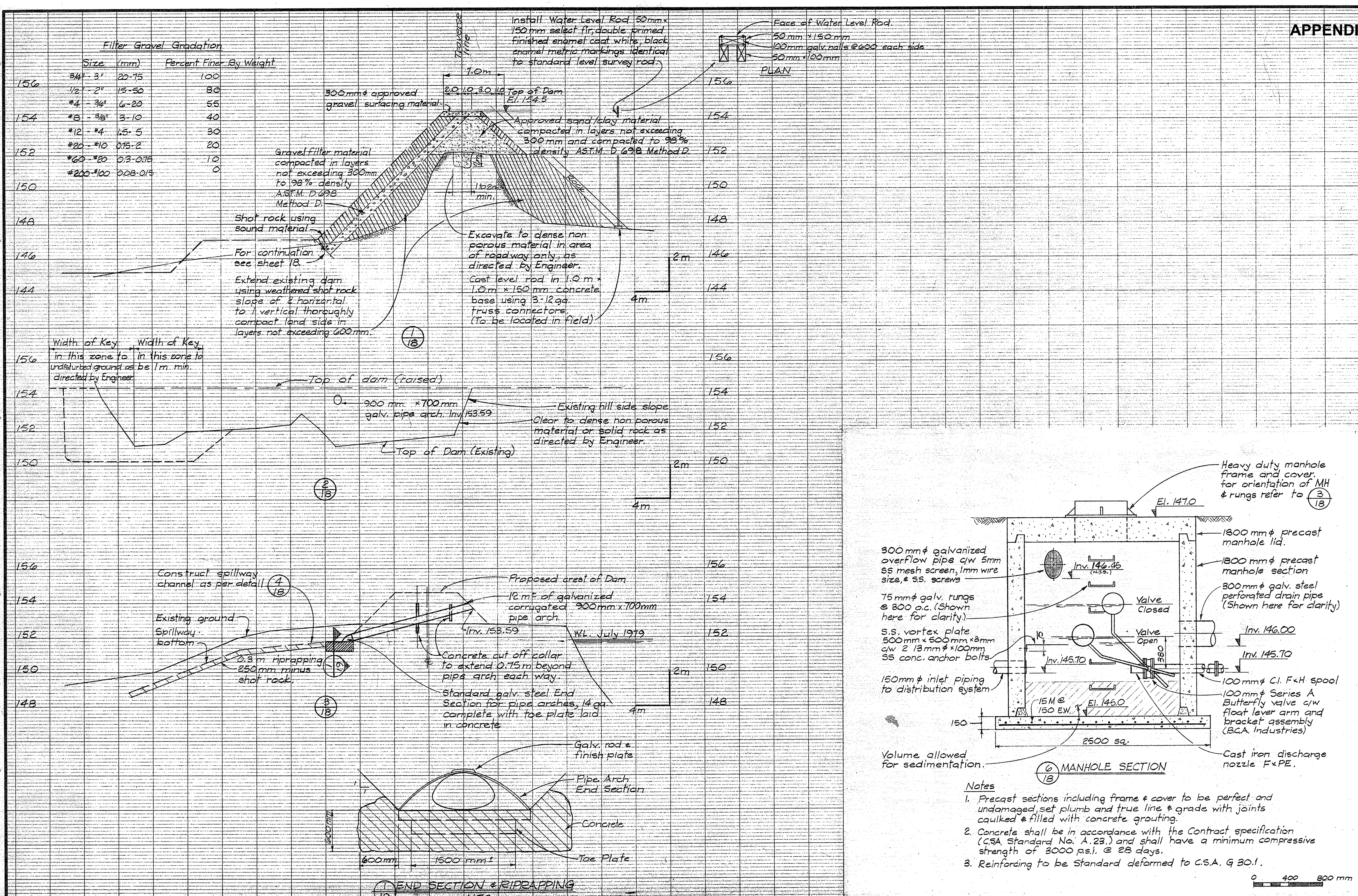
APPENDIX A

APPENDIX B


50mm P.V.C Pipe to old system
50mm G.V.
90° bend HxH (100mm ¢)
To Reservoir
100mm ¢ HxH 90° bend
100 mm ¢ PVC Scepter Series 200 (SDR-21) "Plas Tyton" piping
800mm ¢ overflow piping
Air Vacuum Valve To system
100mm ¢ Tee HxF x H
100mm ¢ FxH. G.V.
100mm ¢ P.V.C.
100mm ¢ FxH. G.V.
150mm ¢ flange adaptor
150mm ¢ Fx 100mm ¢ Fx 100mm ¢ F. Tee
150mm ¢ 22½° bend HxH
Perforated drain
Control M.H. Vortex Plate
150mm ¢ P.V.C. Scepter Series 200 (SDR-21) "Plas Tyton" piping
150mm ¢ x 100mm ¢ PVC Series 200 reducer
N.T.S.
Excavate existing channel as directed by the Engineer on site.
TYPICAL SECTION OF SPILLWAY CHANNEL N.T.S.
Existing spillway channel
Spillway channel
28.5m
Top of Fill
For detail see
300mm ¢ overflow Piping. Daylight in existing rock creek bed.
300 mm ¢ drain piping
100mm PVC piping
Edge of Road
Edge of Road
6m ±
4th Bank to bank
120m
Approximate toe of fill
NOTE: Stump Removal From Dam Site
Expose roots adjacent to trunk and cut roots using saw leaving main body of roots extending within the dam site undisturbed.
For Bedding details refer to dwg. VI 6553-1-16.
For Gate Valve details refer to dwg. VI 6553-1-16.
For Air Vacuum Valve details refer to dwg. VI 6553-1-16.
For Thrust Reaction block details refer to dwg. VI 6553-1-16.
150 mm ¢ piping
Stainless Steel 6mm mesh screen c/w. clamp.
Use concrete block 600 x 600 x 200
600mm min.
INTAKE DETAIL N.T.S
50mm chamfer for straps
W/W mesh reinf.
S/S. strap
ANCHOR DETAIL (4 req'd) N.T.S
Side of trench
#10 2bars E/W, Standard deformed CSA G 30.1
200mm Minimum
Concrete shall be CSA A23.1 3000psi
Key collar into trench, the bottom and sides of excavated cut off collar trenches shall be used as faces against which concrete shall be poured.
SEEPAGE COLLAR DETAIL N.T.S.
0 2 4 8 Metres
Concrete pad 450 mm x 450 mm x 150 mm
Nelson Valve Box & Riser or approved equal.
150 mm ¢ PVC SDR-18 riser
8.5m
Proposed crest of dam El. 154.5
Existing ground
Sound shot rock
W.L. July 1979
Approved gravel filter material
Anchor blocks
Finished grade
El. 147.0
8m ±
8m ±
Seepage collar
4m TYP
150 mm Gate Valve
Back fill of trenches including bedding using approved impervious material compacted in 200mm layers to 98% density following A.S.T.M. D 698 Method D.
Bedding of pipe to be 2000psi concrete (Min. thickness 75mm) to be thoroughly compacted to ensure no voids under pipe.
100mm ¢ PVC piping Sceptor Series 200 (SDE-21) "Plas Tyton" piping
Slope
Inv. 145.10
Inv. 145.10
90.0m ± 150mm ¢ Sclairpipe Series 45
SECTION
Shot rock of sound material
Existing ground & Dam
Approved gravel filter material
Weathered shot rock Fill to embankment slope of 2:1
Approved impervious backfill (full width) compacted in 300mm layers to 95% Density to A.S.T.M. D 698 Method D.
Finished grade
Existing channel slope
Inv. 146.75
Inv. 146.0
Galvanized steel cap 300 ¢, 12m ± in length
Excavate unstable material to dense subgrade as directed by the Engineer
250 mm minus shot rock
SECTION
300mm ¢ galv. corrugated steel piping, min. no. of rows of perforations 6, min. width unperforated section 240mm, 6.4mm standard perforation dia. 1.63 mm wall thickness 16 perforations per 300mm.
1.5 m min.
600 mm (150 mm minus shot rock)
Approved gravel filter material - 600mm min.
Slope to existing grade
Approved drain rock material of the following gradation.
ASTM Sieve 3/8 No. 4 No. 16 No. 50 No. 100
% Passing 100 95-100 45-80 10-30 2-10
DRAIN TRENCH DETAIL
AS CONSTRUCTED
Feb 18/80 A As Constructed
BY. DATE. No. REVISION ENG. No. DATE. ISSUE.
SEAL
CAPITAL REGIONAL DISTRICT ENGINEERING
SURVEYED. FIELD BOOK No.
DESIGNED. M.S. R.E.S. No.
DRAWN. D.K. CONTRACT NUMBER.
CHECKED. DATE. Aug/79
APPROVED. SCALE HORIZONTAL. As Shown
WATER DISTRIBUTION SYSTEM, LYALL HARBOUR AND BOOT COVE SATURNA ISLAND
INTAKE LINE, CHAMBER AND DRAIN DETAILS
SCALE VERTICAL. As Shown
DRAWING NUMBER. VI 6553-1-18
ISSUE. SHT 18 OF 19
27-D115-16

Filter Gravel Gradation

Size	(mm)	Percent Finer By Weight
3/4" - 3"	20-75	100
1/2" - 2"	15-50	80
#4 - 3/4"	6-20	55
#8 - 3/8"	3-10	40
#12 - #4	1.5-5	30
#20 - #10	0.15-2	20
#60 - #20	0.3-0.15	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 (C.S.A. Standard No. A.23.) and shall have a minimum compressive strength of 3000 p.s.i. @ 28 days.
3. Reinforcing to be Standard deformed to C.S.A. G 30.1.

CAPITAL REGIONAL DISTRICT ENGINEERING

WATER DISTRIBUTION SYSTEM, LYALL HARBOUR AND BOOT COVE SATURNA ISLAND

DAM, SPILLWAY AND MANHOLE CHAMBER DETAILS

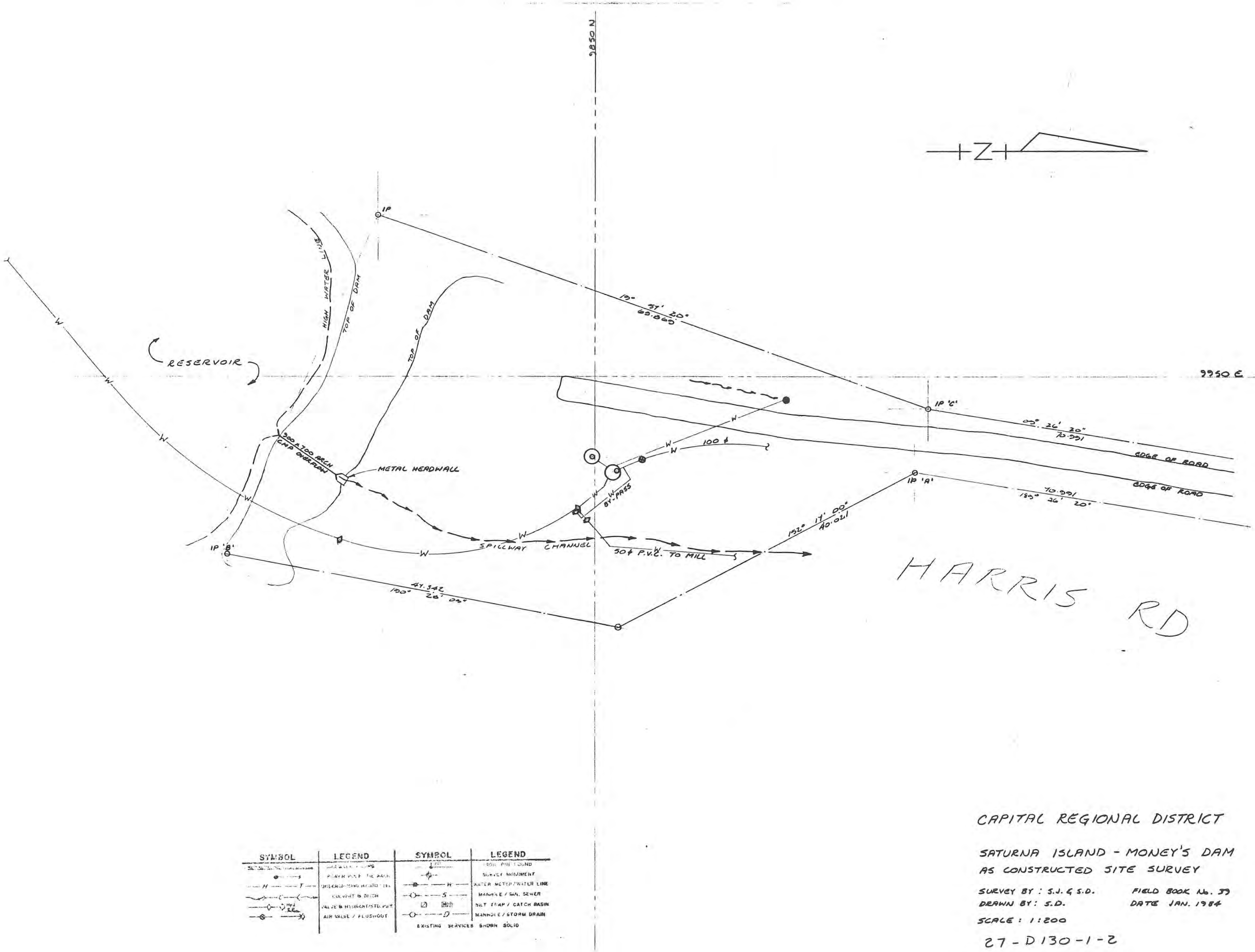
SURVEYED.	FIELD BOOK No.		
DESIGNED. M.S.	R.E.S. No.		
DRAWN. D.K	CONTRACT NUMBER.		
CHECKED.	DATE. Aug 1979		
APPROVED.	SCALE HORIZONTAL. As Shown	SCALE VERTICAL. As Shown	DRAWING NUMBER. VI 6553-1-19 · ISSUE. · SHT 19 OF 19

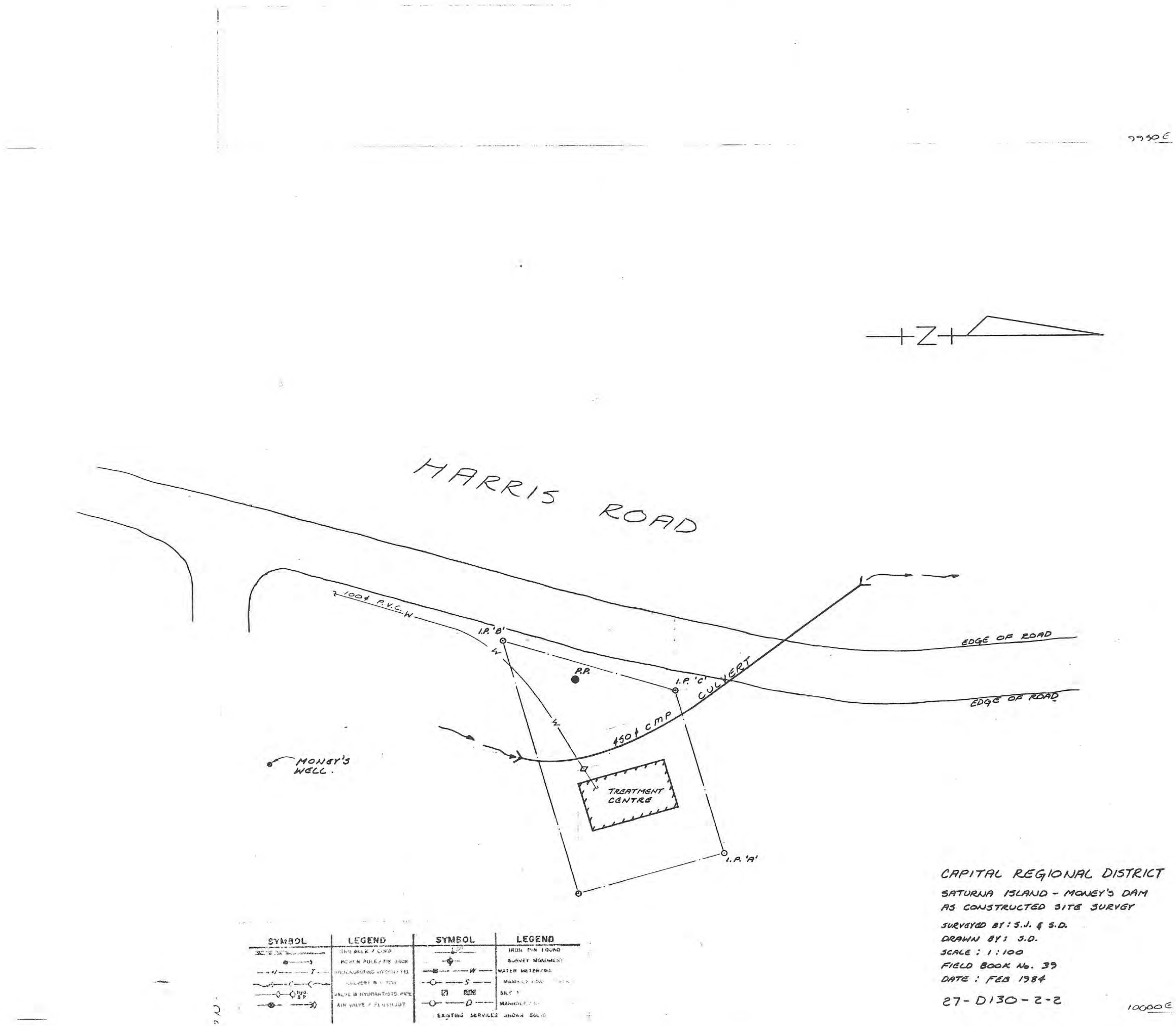
BY.	DATE.	No.	REVISION.	ENG.	No.	DATE.	ISSUE.
	Feb 12/80	A	As Constructed				

SEAL

15 M @ 150 E.W.

27-D115-19


9850 N
9950 E
IP
IP 'C'
IP 'A'
IP 'B'
RESERVOIR
HIGH WATER LINE
TOP OF DAM
TOP OF DAM
METAL HEADWALL
SPILLWAY CHANNEL
50φ P.V.C. TO MILL
100 φ
BY-PASS
EDGE OF ROAD
EDGE OF ROAD
HARRIS RD
CAPITAL REGIONAL DISTRICT
SATURNA ISLAND - MONEY'S DAM
AS CONSTRUCTED SITE SURVEY
SURVEY BY : S.J. & S.D.
FIELD BOOK No. 39
DRAWN BY : S.D.
DATE JAN. 1984
SCALE : 1:200
27 - D130 - 1 - 2
SYMBOL
LEGEND
SYMBOL
LEGEND
EXISTING SERVICES SHOWN SOLID


9950E
HARRIS ROAD
100ϕ P.V.C. W
I.P. 'B'
P.P.
I.P. 'C'
CULVERT
450ϕ CMP
EDGE OF ROAD
EDGE OF ROAD
MONEY'S WELL.
TREATMENT CENTRE
I.P. 'A'
CAPITAL REGIONAL DISTRICT
SATURNA ISLAND - MONEY'S DAM
AS CONSTRUCTED SITE SURVEY
SURVEYED BY: S.J. & S.D.
DRAWN BY: S.D.
SCALE : 1 : 100
FIELD BOOK No. 39
DATE : FEB 1984
27-D130-2-2
10000E
SYMBOL
LEGEND
SYMBOL
LEGEND
IRON PIN FOUND
SURVEY MONUMENT
WATER METER/WA
VALVE & HYDRANT/STD. PIPE
EXISTING SERVICES SHOWN SOLID

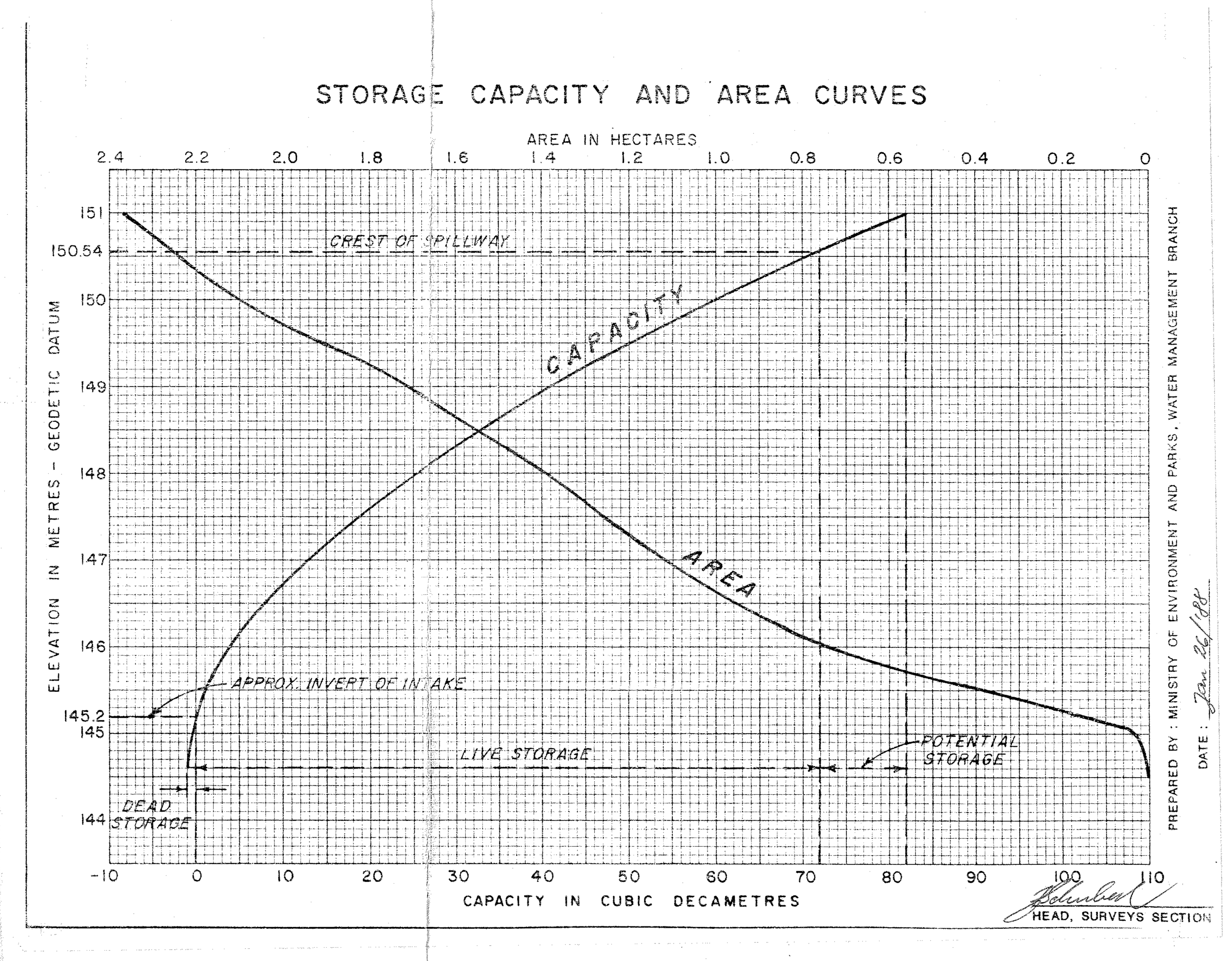
STORAGE CAPACITY TABLE

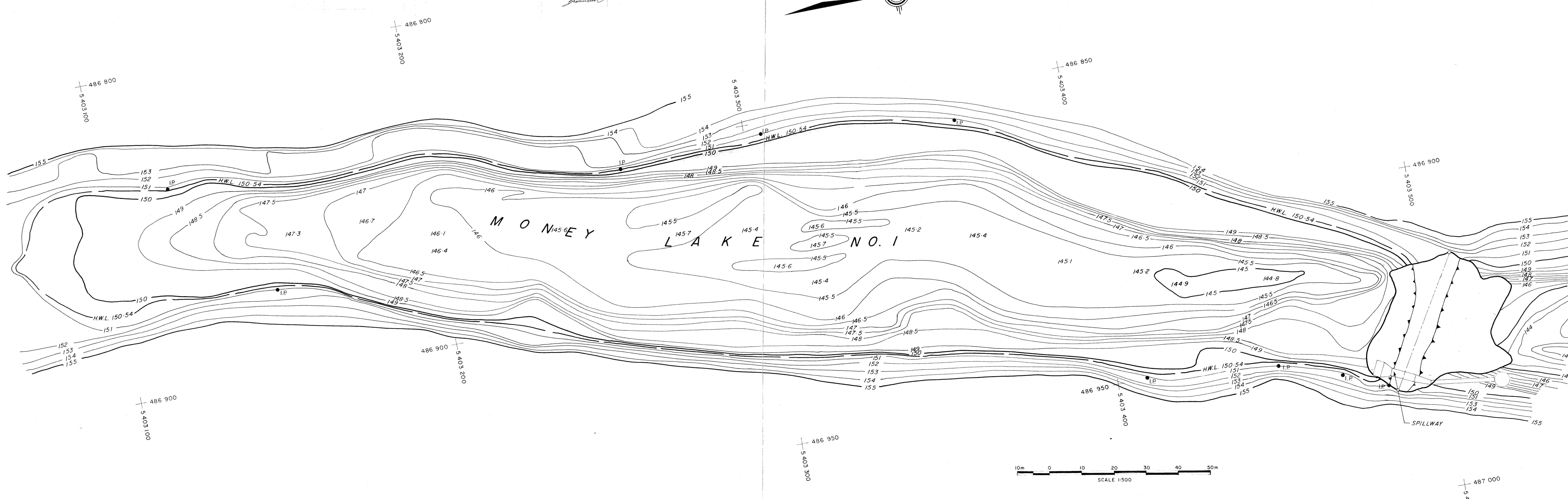
MAPPING DATA			STORAGE CAPACITY				REMARKS
CONTOUR ELEVATION Geodetic Datum	CONTOUR ELEVATION Local Datum	Area in Hectares	Depth of Storage in Metres	Area in Hectares	STORAGE IN DECAMETRES³ Net	STORAGE IN DECAMETRES³ Gross	
144.6	99.4		-0.6	0.00	0.0	0	Low Point in Lake
			-0.5	0.01	0.0	0	
			-0.4	0.02	0.0	0	
			-0.3	0.02	0.0	0	
145.0		0.03	-0.2	0.03	0.1	0	
			-0.1	0.10	0.1	0	
145.2	100.0	0.16	0.0	0.16	0.2	0	Approximate invert of pipe
			0.1	0.23	0.3	0	
			0.2	0.30	0.3	0	
145.5	100.3	0.37	0.3	0.37	0.4	1	
			0.4	0.44	0.5	1	
			0.5	0.51	0.5	2	
			0.6	0.59	0.6	2	
			0.7	0.66	0.7	3	
146.0	100.8	0.73	0.8	0.73	0.8	4	
			0.9	0.77	0.8	4	
			1.0	0.82	0.8	5	
			1.1	0.86	0.9	6	
			1.2	0.91	0.9	7	
146.5	101.3	0.95	1.3	0.95	1.0	8	
			1.4	0.98	1.0	9	
			1.5	1.02	1.0	10	
			1.6	1.05	1.1	11	
			1.7	1.09	1.1	12	
147.0	101.8	1.12	1.8	1.12	1.1	13	
			1.9	1.15	1.2	14	
			2.0	1.18	1.2	15	
			2.1	1.20	1.2	16	
			2.2	1.23	1.2	18	
147.5	102.3	1.26	2.3	1.26	1.3	19	
			2.4	1.29	1.3	20	
			2.5	1.31	1.3	21	
			2.6	1.34	1.4	23	
			2.7	1.36	1.4	24	

STORAGE CAPACITY TABLE

MAPPING DATA			STORAGE CAPACITY				REMARKS
CONTOUR ELEVATION Geodetic Datum	CONTOUR ELEVATION Local Datum	Area in Hectares	Depth of Storage in Metres	Area in Hectares	STORAGE IN DECAMETRES³ Net	STORAGE IN DECAMETRES³ Gross	
148.0	102.8	1.39	2.8	1.39	1.4	25	
			2.9	1.42	1.4	27	
			3.0	1.46	1.5	28	
			3.1	1.49	1.5	30	
			3.2	1.53	1.5	31	
148.5	103.3	1.56	3.3	1.56	1.6	33	
			3.4	1.59	1.6	34	
			3.5	1.62	1.6	36	
			3.6	1.64	1.7	38	
			3.7	1.67	1.7	39	
149.0	103.8	1.70	3.8	1.70	1.7	41	
			3.9	1.74	1.8	43	
			4.0	1.78	1.8	44	
			4.1	1.82	1.8	46	
			4.2	1.86	1.9	48	
			4.3	1.90	1.9	50	
			4.4	1.94	2.0	52	
			4.5	1.98	2.0	54	
			4.6	2.02	2.0	56	
			4.7	2.06	2.1	58	
150.0	104.8	2.10	4.8	2.10	2.1	60	
			4.9	2.13	2.1	62	
			5.0	2.16	2.2	64	
			5.1	2.18	2.2	66	
			5.2	2.21	2.2	69	
			5.3	2.24	0.9	71	
150.54	105.34	2.25	5.34	2.25	1.4	72	Crest of spillway
			5.4	2.27	2.3	73	
			5.5	2.29	2.3	75	
			5.6	2.32	2.3	78	
			5.7	2.34	2.4	80	
151.0	105.80	2.37	5.8	2.37		82	

January '88





FOR NOTES SEE DWG. No. 4977-52

LEGEND
TRIANGULATION STATION
REFERENCE MONUMENT (P.CON. or P.ROCK)
50 000 HORIZ. CONTROL POINT
60 000 VERT. CONTROL POINT
T.B.M. TEMPORARY BENCH MARK
TEMPORARY REFERENCE POINT
ROAD, TRAIL, CREEK,
CREEK INTERMITTENT, SWAMP
BASIN, SUB BASIN
AIR PHOTO CENTER

STORAGE LICENCES

LICENCE	PRIORITY DATE	AUTHORIZED ACRE-FEET	DEVELOPED ACRE-FEET

REFERENCES

DWG. No.	DESCRIPTION	DATE

REVISIONS

No.	DESCRIPTION	DATE

SURVEYED T. DIGNAN
DATE NOV. 1987
COMPILED K. SINCLAIR
CHECKED
DATE JANUARY 1988
DRAWN
APPROVED
HEAD, DRAFTING SECTION
DATE
ENGINEER

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

STORAGE INVENTORY PROGRAMME
SATURNA ISLAND — COASTAL ISLANDS SYSTEM

MONEY LAKE NO. 1 RESERVOIR

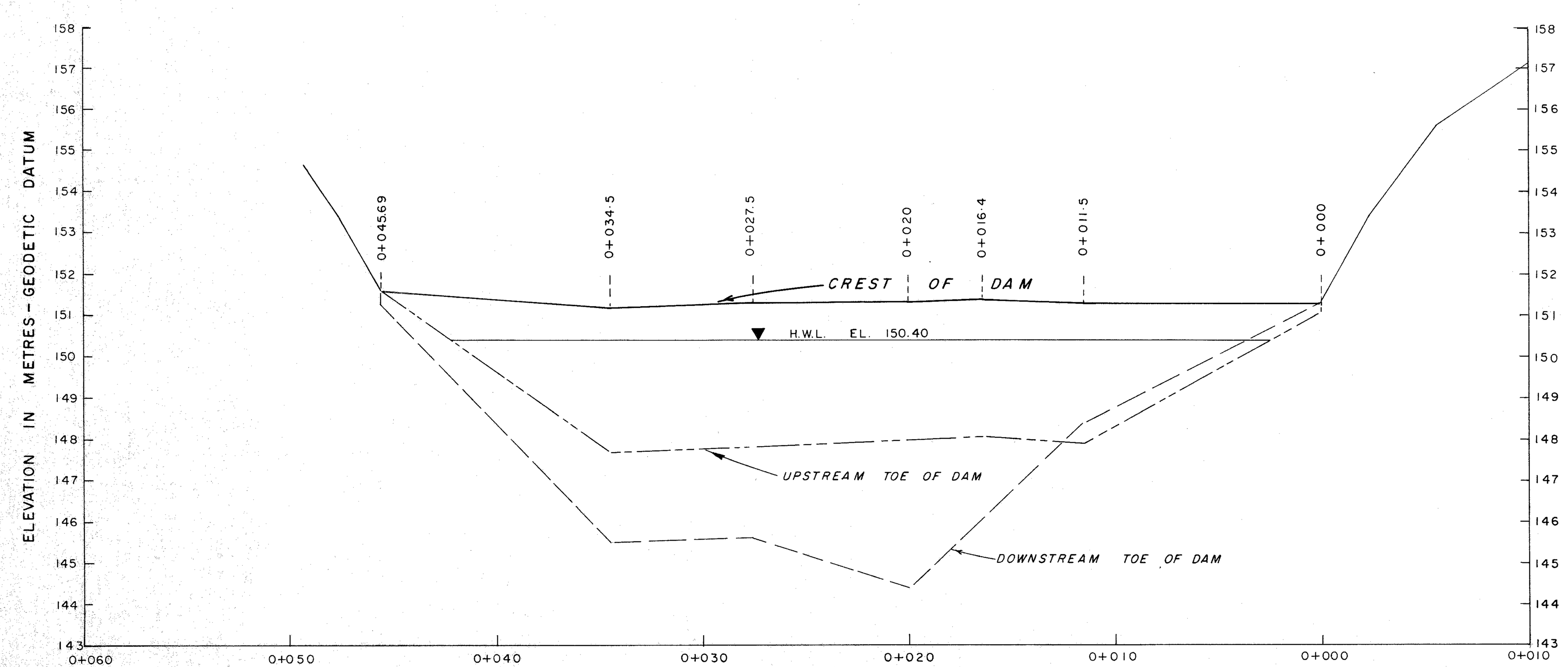
PLAN OF RESERVOIR

APPROVED B. R. Schubert
HEAD, SURVEYS SECTION
DATE JANUARY 1988

FILE Nos.
Branch
Inventory 0305080-29
SURVEY PROJECT No. 87-SIP-16
NTS Map No. 92B/14
Map Scale 1:50 000
SCALE 1:500
NEGATIVE NO. 272 524
DRAWING No. 4977-52-1
SHEET 1 of 1

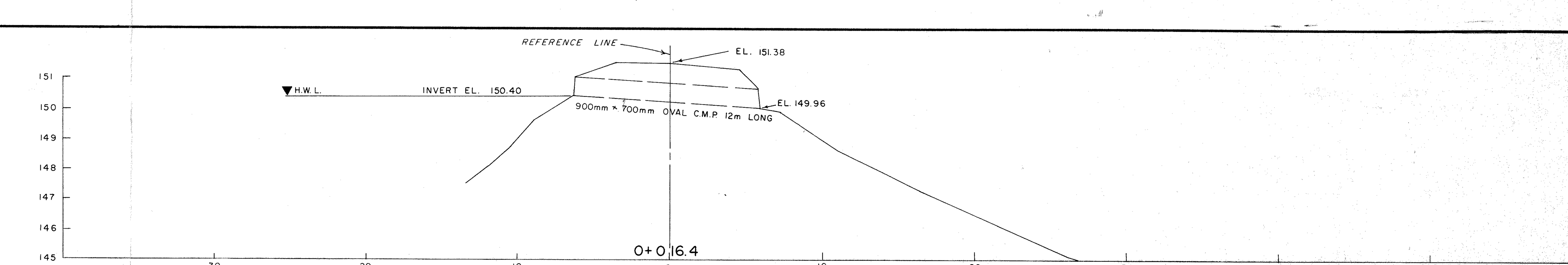
DDs

27-D105-2
BATHYMETRIC PRINT FILE



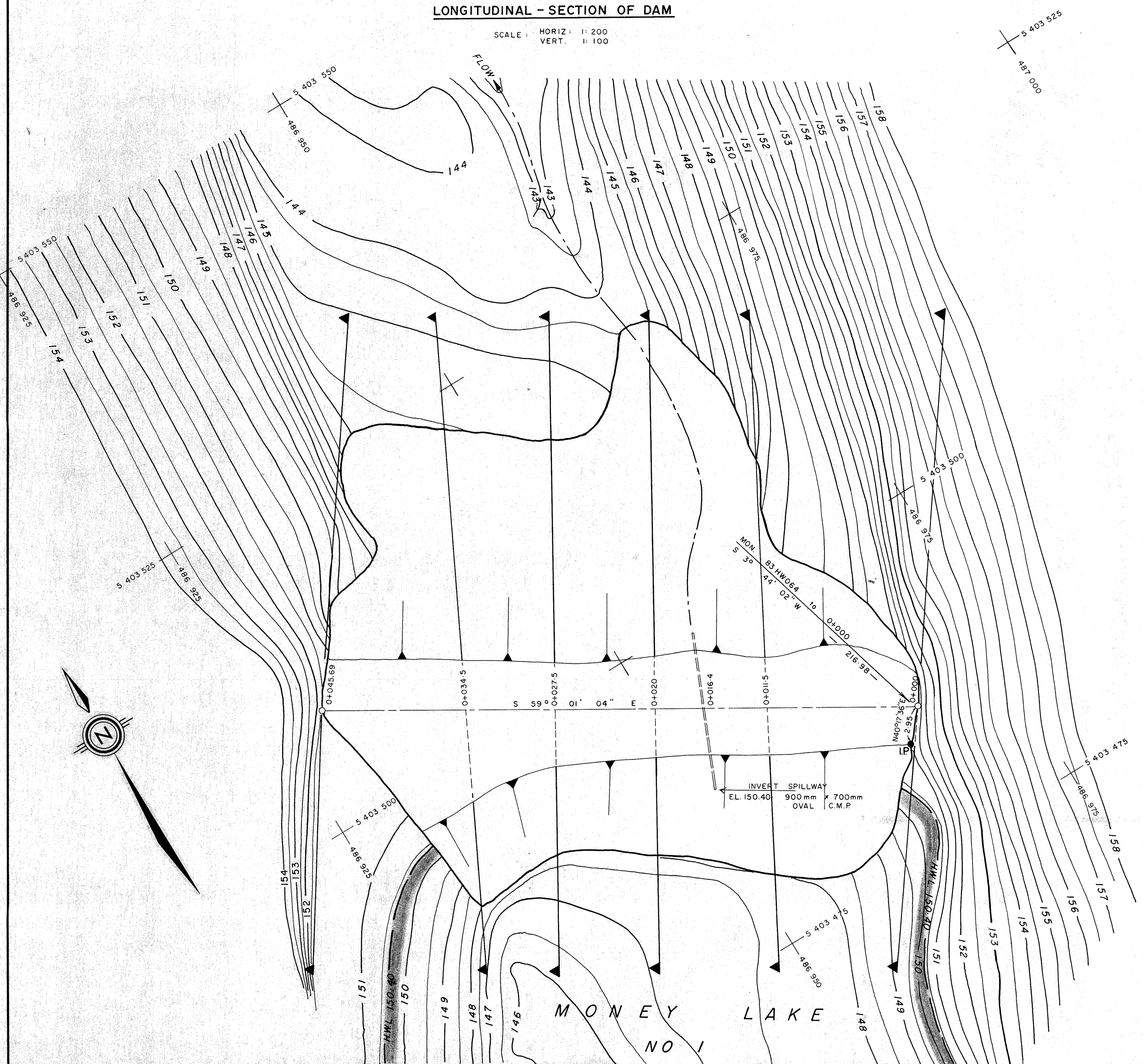
LONGITUDINAL - SECTION OF DAM

SCALE: HORIZ. 1:200, VERT. 1:100



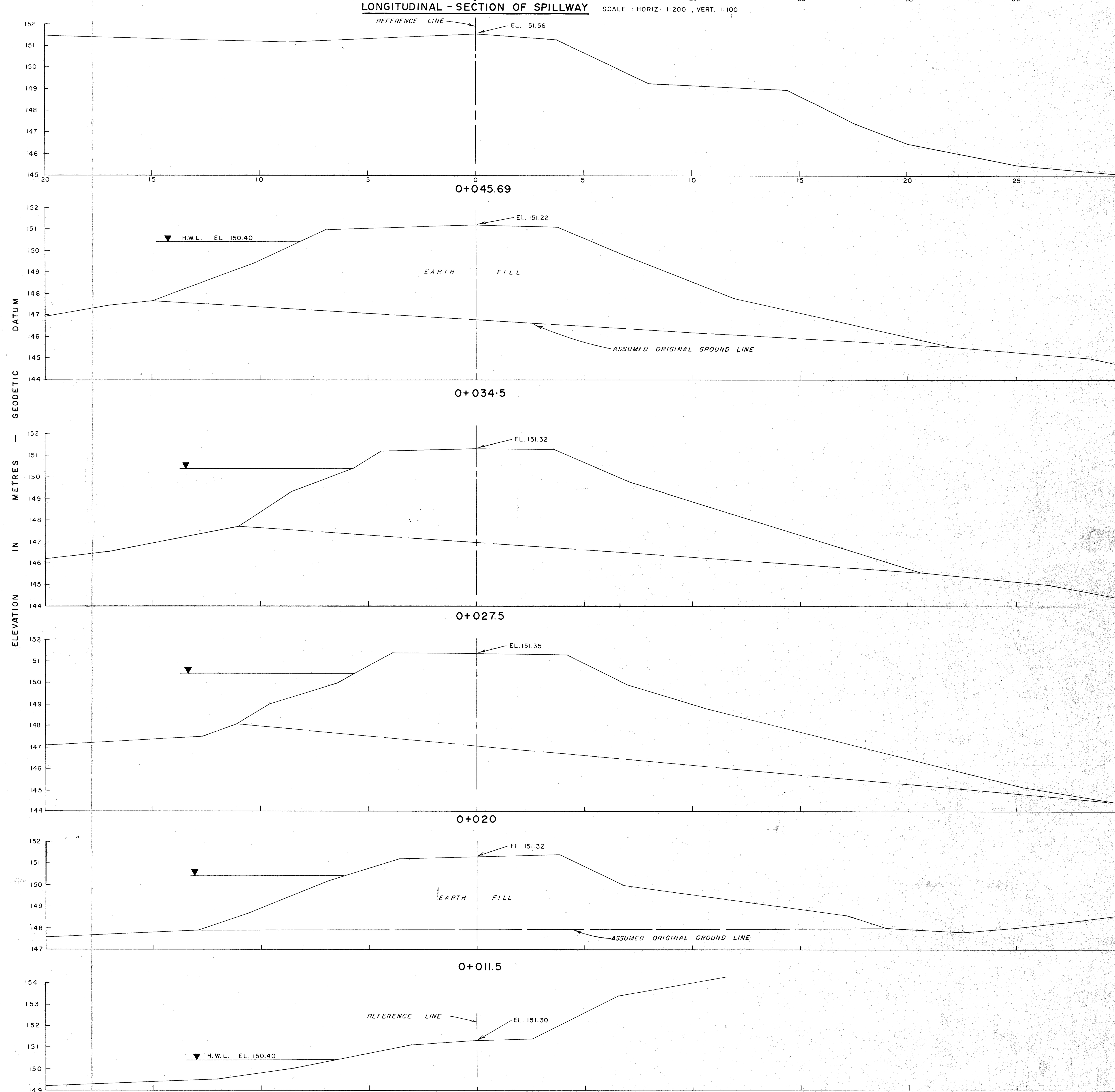
LONGITUDINAL - SECTION OF SPILLWAY

SCALE: HORIZ. 1:200, VERT. 1:100



GENERAL PLAN OF DAM

SCALE: 1:200



CROSS-SECTIONS OF DAM

SCALE: HORIZ. 1:100, VERT. 1:100

NOTES

1) This map has been prepared from field surveys carried out by the Surveys Subsection, Planning and Surveys Section, Water Management Branch, Ministry of Environment, Province of British Columbia.

2) SURVEY DATA:
a) Horizontal control was established by E.D.M. Traverse.
b) Subaqueous contours were drawn from depths established by Raytheon Depth Recorder Model DE-719B.
c) Position control for bathymetry was maintained by simultaneous fixes from theoldolites which were set over coordinated shore stations.
d) Topography and cross-sections of dam and contours above elevation 148.7 were obtained by stadia.
e) The survey was carried out in September 1983.

3) DATUM:
a) The horizontal control is based on Station Parke, marked by Brass Bolt No. 1467 and Canoe Pass Light House (L.T.) established by the Topographic Surveys Division of British Columbia.
b) Coordinates are Universal Transverse, Mercator, Zone 10, Central Meridian 123°.
c) Elevations are in metres and are referred to the Canadian Geodetic Datum.
d) Elevations originate at Station Parke and the vertical value of Mon. 83HW064 was established by E.D.M. traverse using second reading theodolites. Elevations in the project area are referred to Mon. 83HW064 and were established by conventional level network.

4) FIELD BOOKS:
Survey data are recorded in Field Book No.s 2407 F-1, 2407 L-1 and 2407 I-1.

5) REFERENCE MONUMENTS:

	Northing	Easting	Elevation
83HW064	5 403 701.863	486 981.801	136.735
I.P. (SE End of Dam)	5 403 483.097	486 965.765	151.097

83HW064 → I.P. (SE End of Dam) S04° 11'33"W 219.353 metres

Distance between Monument and I.P. as shown is GRID or PROJECTION Distance.

LEGEND

- TRIANGULATION STATION
- REFERENCE MONUMENT (P.CON. or P.ROCK)
- 50 000 HORIZ. CONTROL POINT
- 60 000 VERT. CONTROL POINT
- T.B.M. TEMPORARY BENCH MARK
- TEMPORARY REFERENCE POINT
- ROAD, TRAIL, CREEK,
- CREEK INTERMITTENT, SWAMP
- BASIN, SUB BASIN
- AIR PHOTO CENTER

STORAGE LICENCES

LICENCE	PRIORITY DATE	AUTHORIZED ACRE-FEET	DEVELOPED ACRE-FEET

REFERENCES

DWG. No.	DESCRIPTION	DATE
4977-52	PLAN OF RESERVOIR	FEBRUARY 1984
V16553-1,18+19	SATURNA ISLAND RESERVOIR EXPANSION (C.R.D. ENGINEERING)	AUG. 1979

REVISIONS

No.	DESCRIPTION	DATE

SURVEYED B. SCHUBERT DATE SEPT. 1983
COMPILED H. BRAZIER
CHECKED [signature] DATE FEBRUARY 1984
DRAWN [signature]
APPROVED
HEAD, DRAFTING SECTION
DATE
ENGINEER

Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

STORAGE INVENTORY PROGRAMME
SATURNA ISLAND - COASTAL ISLANDS SYSTEM

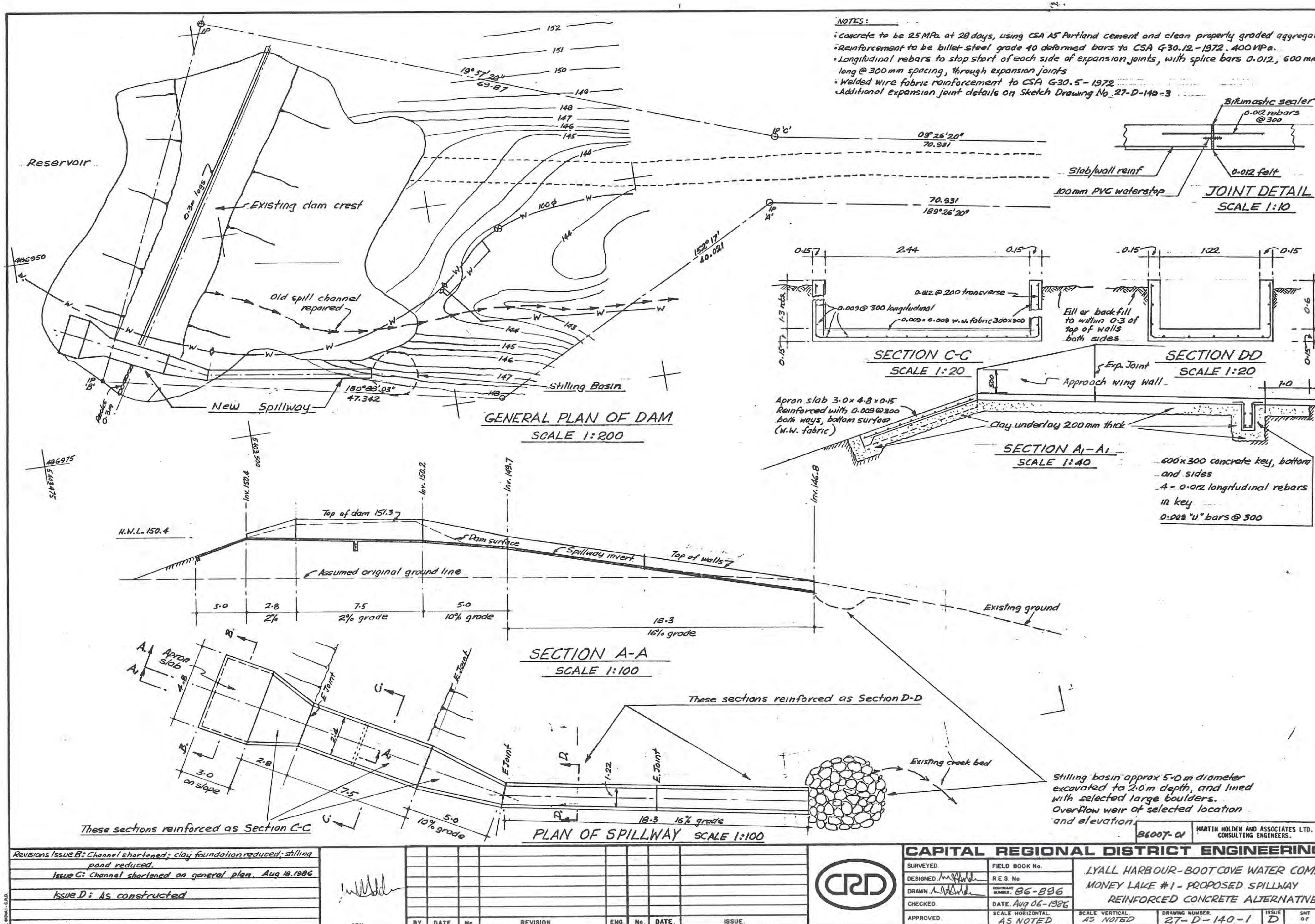
MONEY LAKE NO. 1 RESERVOIR
GENERAL PLAN OF DAM

APPROVED [signature] HEAD, SURVEYS SUBSECTION
DATE FEBRUARY 1984

FILE Nos.
Branch
Inventory 0305080-29
SURVEY PROJECT No. 83-SIP-8
NTS Map No. 92B/14
Map Scale 1:50 000
SCALE AS NOTED
NEGATIVE No. 250343
DRAWING No. 4977-52A
SHEET 1 of 1

DD

27-D101-2-2


NOTES:
• Concrete to be 25 MPa at 28 days, using CSA A5 Portland cement and clean properly graded aggregates
• Reinforcement to be billet steel grade 40 deformed bars to CSA G30.12-1972. 400 MPa.
• Longitudinal rebars to stop short of 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-140-3
Reservoir
Existing dam crest
0.3m logs
Old spill channel repaired
New Spillway
Stilling Basin
Rocks 0.5m
GENERAL PLAN OF DAM
SCALE 1:200
19° 57' 20"
69.87
09° 26' 20"
70.931
189° 26' 20"
152° 17'
40.021
180° 88' 03"
47.342
100 ø
Bitumastic sealer
0.012 rebars @ 300
Slab/wall reinf
100mm PVC waterstop
0.012 felt
JOINT DETAIL
SCALE 1:10
0.012 @ 200 transverse
0.009 @ 300 longitudinal
0.009 x 0.009 w.w. fabric 300x300
Fill or backfill to within 0.3 of top of walls both sides
SECTION C-C
SCALE 1:20
SECTION D-D
SCALE 1:20
Exp. Joint
Approach wing wall
Apron slab 3.0 x 4.8 x 0.15 Reinforced with 0.009 @ 300 both ways, bottom surface (W.W. fabric)
Clay underlay 200mm thick
SECTION A1-A1
SCALE 1:40
600 x 300 concrete key, bottom and sides
4 - 0.012 longitudinal rebars in key
0.009 "U" bars @ 300
H.W.L. 150.4
Top of dam 151.3
Dam surface
Spillway invert
Top of walls
Assumed original ground line
Existing ground
Inv. 150.4
Inv. 150.2
Inv. 149.7
Inv. 146.8
3.0
2.8
2%
7.5
2% grade
5.0
10% grade
18.3
16% grade
SECTION A-A
SCALE 1:100
Apron slab
4.8
E Joint
3.0 on slope
These sections reinforced as Section D-D
These sections reinforced as Section C-C
Existing creek bed
Stilling basin approx 5.0 m diameter excavated to 2.0 m depth, and lined with selected large boulders. Overflow weir at selected location and elevation.
PLAN OF SPILLWAY SCALE 1:100
86007-01
MARTIN HOLDEN AND ASSOCIATES LTD. CONSULTING ENGINEERS.
Revisions Issue B: Channel shortened; clay foundation reduced; stilling pond reduced.
Issue C: Channel shortened on general plan. Aug 18.1986
Issue D: As constructed
SEAL
BY. DATE No. REVISION ENG. No. DATE. ISSUE.
CAPITAL REGIONAL DISTRICT ENGINEERING
SURVEYED
DESIGNED
DRAWN
CHECKED
APPROVED
FIELD BOOK No.
R.E.S. No.
CONTRACT NUMBER 86-896
DATE Aug 06-1986
SCALE HORIZONTAL AS NOTED
SCALE VERTICAL AS NOTED
LYALL HARBOUR - BOOT COVE WATER COM.
MONEY LAKE #1 - PROPOSED SPILLWAY
REINFORCED CONCRETE ALTERNATIVE
DRAWING NUMBER 27-D-140-1
ISSUE D

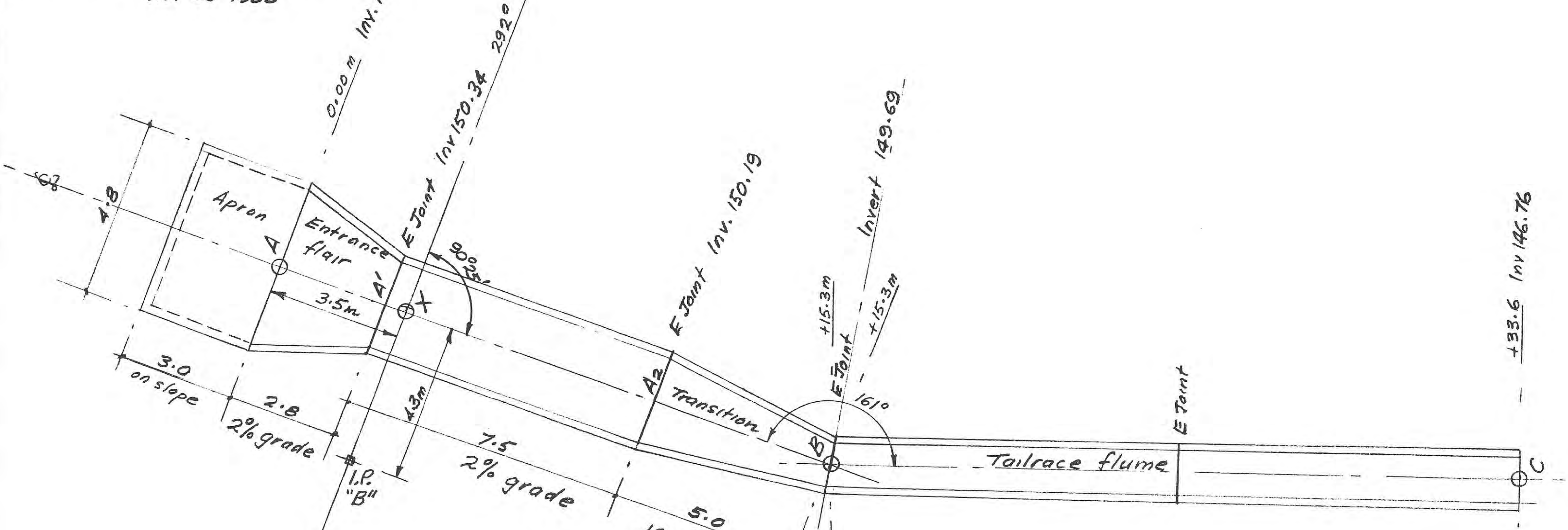
CAPITAL REGIONAL DISTRICT	
PROJECT 86-893 MONEY LAKE #1 SPILLWAY – SATURNA IS.	
GEOMETRY OF SPILLWAY – AS LAID OUT AT SITE ON AUGUST 29TH 1986.	
MARTIN HOLDEN AND ASSOCIATES LTD. CONSULTING ENGINEERS, VICTORIA, B.C.	DWG NO 27-D-140 – 05 ISSUE A August 29-1986 [signature] PEng
86007-05	CRD CONTRACT 86-893

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

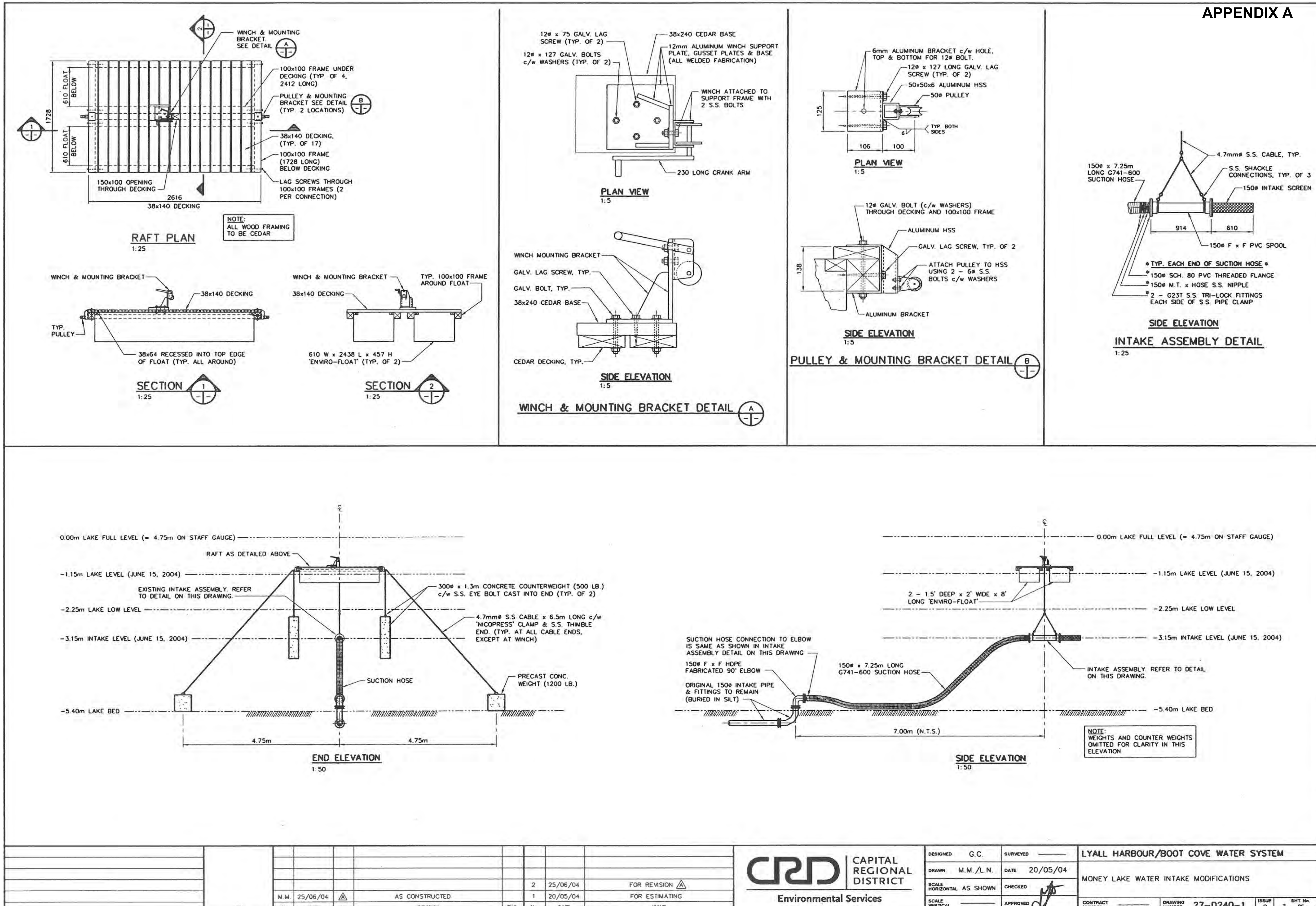
B = Centre line at +15.3m – Downstream end of transition section. ℄ changes direction 19° here
Grade stake at B is 1.0m above invert elev. at.

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

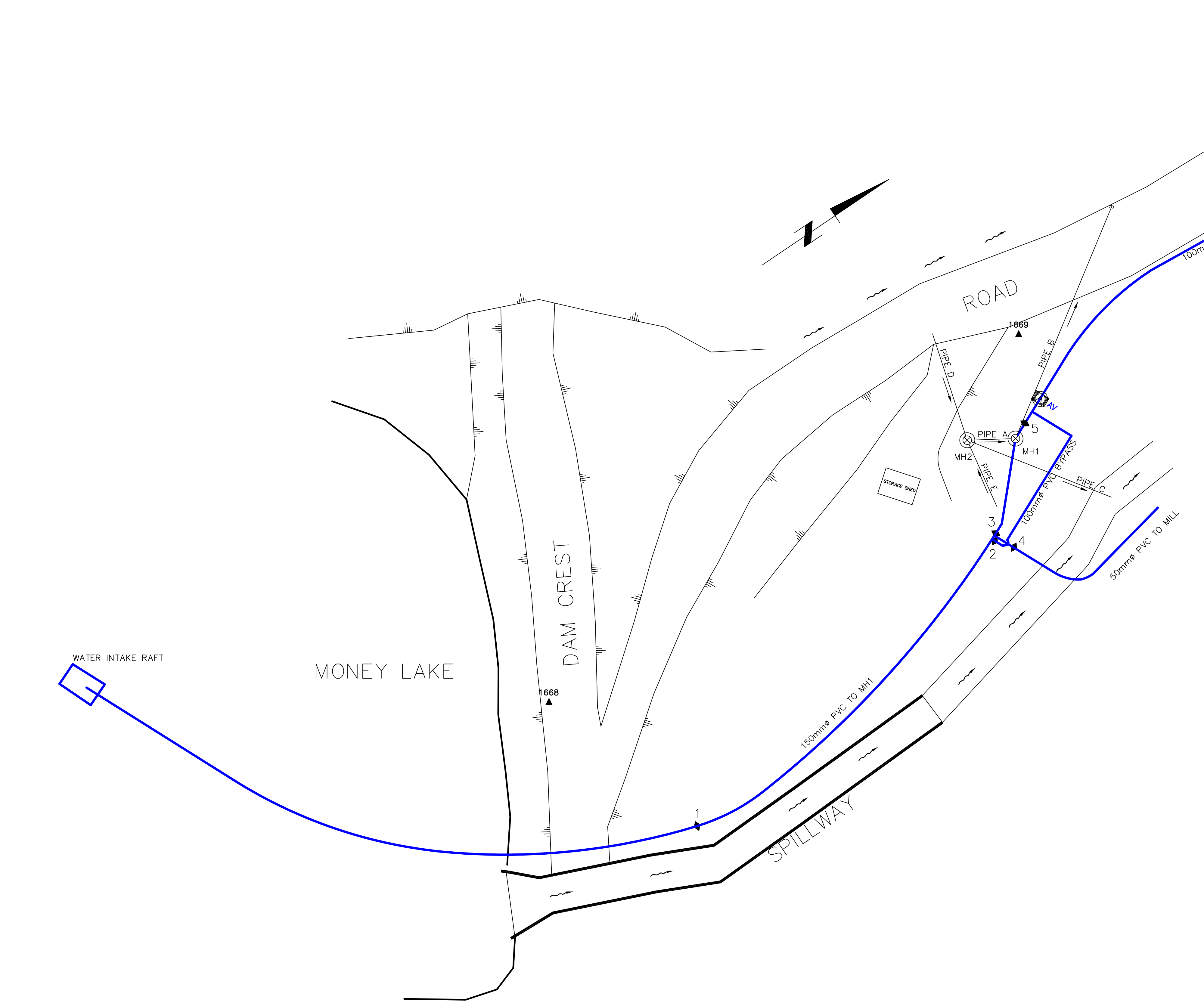


PLAN OF SPILLWAY
SCALE 1:100

27-D140-05



DRAWING REDUCED - NOT TO SCALE



INFORMATION BACKGROUND:

1. DIMENSIONS AND LINEWORK FOR THE DAM ARE BASED ON A SURVEY CONDUCTED MARCH 20, 2014. AT THAT TIME THE VALVES AND MANHOLES WERE PICKED UP. VALVE No.5 AND THE AIR VALVE WERE NOT LOCATED THEREFORE, THIER LOCATION IS BASED ON HISTORICAL DRAWINGS.
2. DURING PREVIOUS SITE INSPECTIONS MANHOLE No.1 (MH1) HAS BEEN OBSERVED TO HAVE CLEAR WATER FLOWING FROM THE LID.
3. PIPE A IS A 300mm ø CSP THAT CONNECTS MH1 AND MH2. MH1 & PIPE A WERE INSTALLED IN 1979 PRIOR TO THE INSTALLATION OF MH2.
4. PIPE B. THERE ARE NO RECORD DRAWINGS SHOWING DETAILS REGARDING PIPE B, HOWEVER THIS PIPE SHOWS UP ON HAND DRAWN RECORDS DATED JAN 84. ACCORDING TO RICHARD EDWARDS, P.ENG. PIPE B WAS INSTALLED TO ACT AS AN OVER–FLOW FROM MH1 TO THE DITCH WHERE THE INFILTRATORS NOW ARE LOCATED. ACCORDING TO JOSEPH MARR, P.ENG., AT THE TIME OF THE INSTALLATION OF THE INFILTRATORS THE CATCH BASIN THAT WAS AT THE DITCH WAS REMOVED, FILTER CLOTH COVERED THE OPEN PIPE AND DRAIN MATERIAL WAS PLACED AROUND THE END OF THE PIPE.
5. PIPE C IS A 300mm ø CSP DRAIN THAT RUNS FROM EITHER MH1 OR MH2. NO RECORDS FOR THIS PIPE. THE END IS VISIBLE IN THE SPILLWAY CHANNEL AND IS IN VERY POOR CONDITION. THERE WAS NO VISIBLE WATER AT THE CHANNEL END AT THE TIME OF INSPECTION. ACCORDING TO RICHARD EDWARDS THIS PIPE MAY HAVE BEEN CRUSHED.
6. PIPES D & E. NO RECORDS FOR THESE PIPES, HOWEVER THE PIPES ARE VISIBLE IN MH2 WITH THE WATER LEVEL IN THE MANHOLE NEAR THE TOP OF THE PIPES. THE PIPES ARE 300mm ø PERFORATED CSP. ACCORDING TO RICHARD EDWARDS THESE WERE INSTALLED AT THE TIME OF MH2 TO COLLECT SEEPAGE WATER AT THE TOE OF THE DAM THAT WOULD SUPPLIMENT THE LAKE WATER AS WATER SUPPLY.
7. THE CONCRETE MANHOLES ARE BELIEVED TO BE 1200mm ø WITH A DEPTH OF APPROX. 3 METERS.

LEGEND

PROPOSED	EXISTING						
		VALVE	STAND PIPE	ELECT. BOX	MANHOLE	IRON PIN	ASPHALT
		AIR VALVE	CATHODIC PROT.	GAS	FLUSH MH	LEAD PLUG	BANK
		HYDRANT	POLE	SEWER	SEWER MH	MONUMENT	BUSH LINE
		REDUCER	GUY WIRE	DRAIN	DRAIN MH	TRAVERSE HUB	TREE
		CAP	LAMP STAND	HYDRO	HYDRO MH	TEST PIT	BUSH
		METER BOX	SIGN	TEL	TEL MH	RIGHT OF WAY	STUMP
		WATER	CATCH BASIN	CABLE	CABLE MH	PROPERTY LINE	FENCE

VERIFY SCALES

BAR IS 20mm LONG ON ORIGINAL DRAWING.

0 20

IF NOT 20mm ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

REUSE OF DOCUMENTS

ALL UNDERGROUND UTILITY LOCATIONS SHOWN ARE APPROXIMATE AND SHOULD BE CONFIRMED BY MANUAL DIGGING. CAPITAL REGIONAL DISTRICT DOES NOT ACCEPT RESPONSIBILITY FOR ERRORS OR OMISSIONS IN THE INFORMATION SHOWN ON THIS DRAWING.

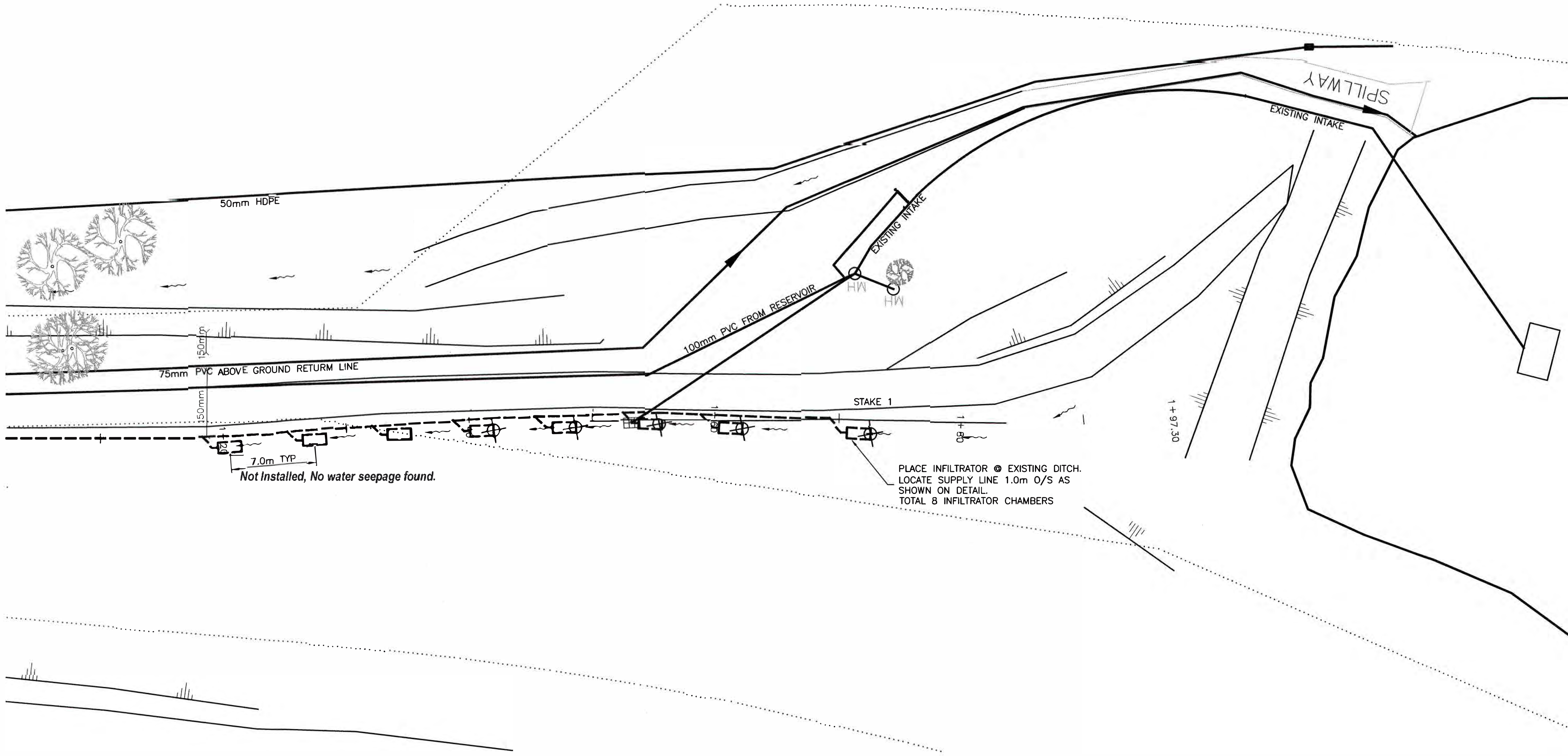
ENGINEER STAMP

no.	date	revision	chk	by

CRD
Making a difference...together

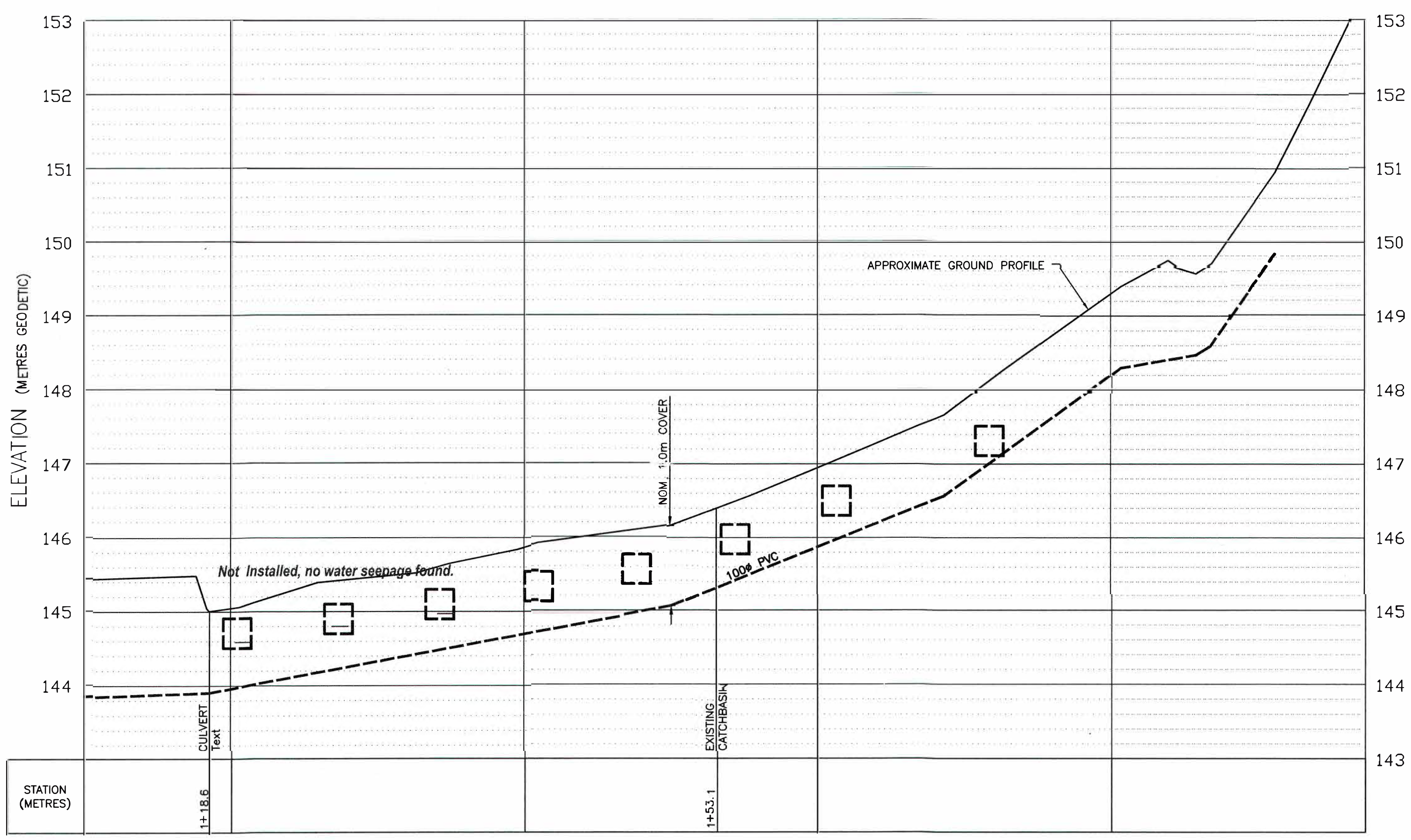
LYALL HARBOUR BOOT COVE
MONEY LAKE DAM
PIPEWORK SCHEMATIC

date: APR 14	scale: 1:150
designed:	drawn: F.H.
approved:	checked:
folder: \	acad file:
file no: .ZIP	cadastral no:
drawing no:	issue: A

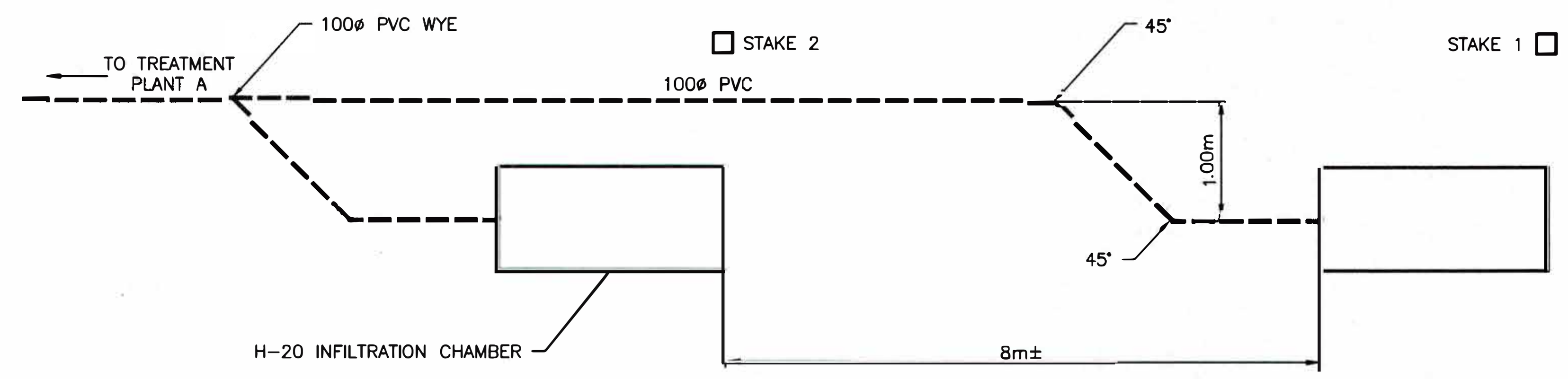


EXISTING 6 INFILTRATORS SITES WITH POLY COVERING AS PER DETAIL

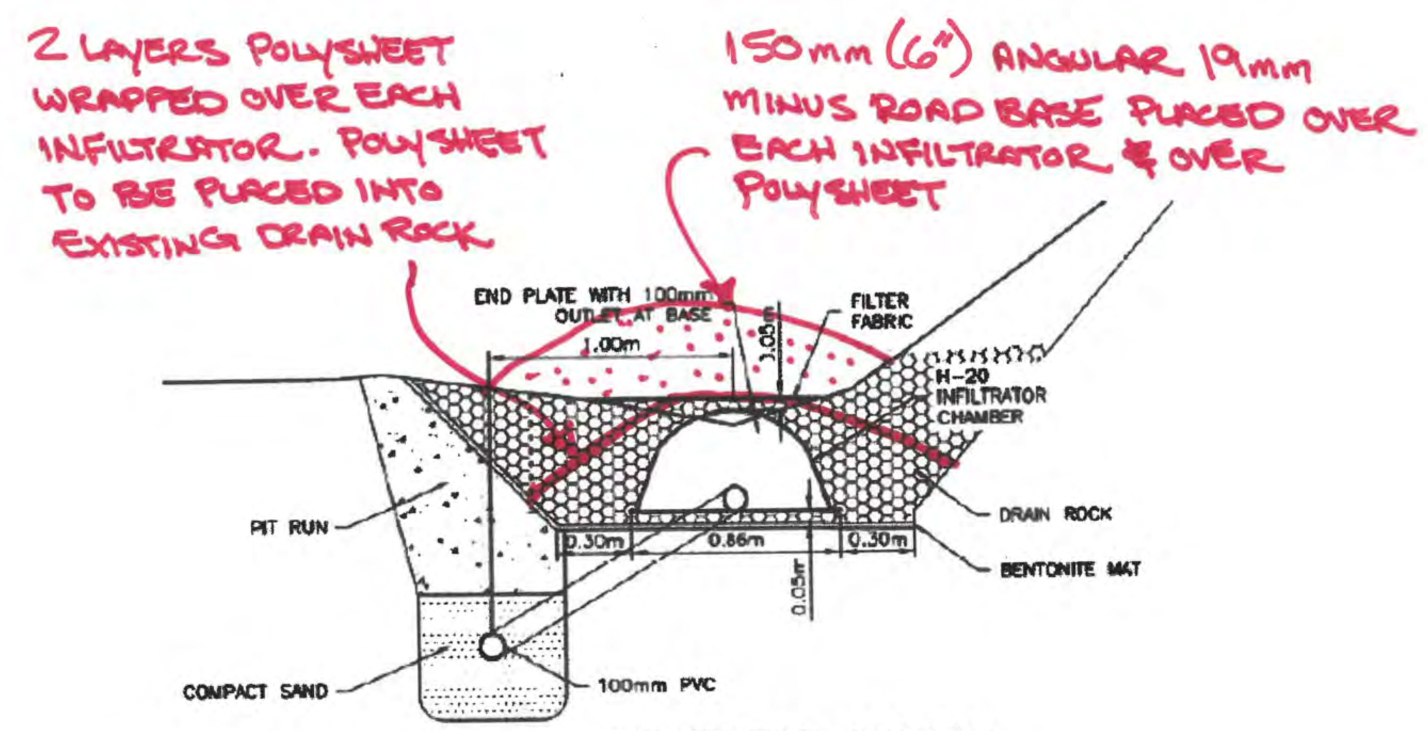
PLAN
SCALE 1:250



PROFILE
SCALE HORZ 1:250 VERT 1:50



INFILTRATOR PLAN
SCALE 1:50



INFILTRATOR SECTION

LEGEND

PROPOSED	EXISTING						
		VALVE	STAND PIPE	ELECT. BOX	MANHOLE	IRON PIN	ASPHALT
	AV	AIR VALVE	CATHODIC PROT.	GAS	FLUSH MH	LEAD PLUG	BANK
		HYDRANT	POLE	SEWER	SEWER MH	MONUMENT	BUSH LINE
		REDUCER	GUY WIRE	DRAIN	DRAIN MH	TRAVERSE HUB	TREE
		CAP	LAMP STAND	HYDRO	HYDRO MH	TEST PIT	BUSH
		METER BOX	SIGN	TEL	TEL MH	RIGHT OF WAY	STUMP
	W	WATER	CATCH BASIN	CABLE	CABLE MH	PROPERTY LINE	FENCE

VERIFY SCALES

BAR IS 20mm LONG ON ORIGINAL DRAWING.

0 20

IF NOT 20mm ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

REUSE OF DOCUMENTS

THIS DRAWING IS OF A CONFIDENTIAL NATURE AND SHALL NOT BE REPRODUCED IN ANY MANNER, NOR USED FOR ANY PURPOSE WHATSOEVER EXCEPT BY WRITTEN PERMISSION OF THE CAPITAL REGIONAL DISTRICT.

ALL UNDERGROUND UTILITY LOCATIONS SHOWN ARE APPROXIMATE AND SHOULD BE CONFIRMED BY MANUAL DIGGING. CAPITAL REGIONAL DISTRICT DOES NOT ACCEPT RESPONSIBILITY FOR ERRORS OR OMISSIONS IN THE INFORMATION SHOWN ON THIS DRAWING.

ENGINEER STAMP

no.	date		chk	by
1				

CRD
Making a difference...together

RECORD DRAWING
MONEY LAKE DAM - POLY COVERING OF INFILRATORS

date: DEC 08 2020	scale: AS SHOWN
designed:	drawn: BR
approved:	checked:
folder:	acad file:
file no:	map no:
drawing no: 5922	issue: A

THURBER

APPENDIX A

APPENDIX B

APPENDIX C

THURBER

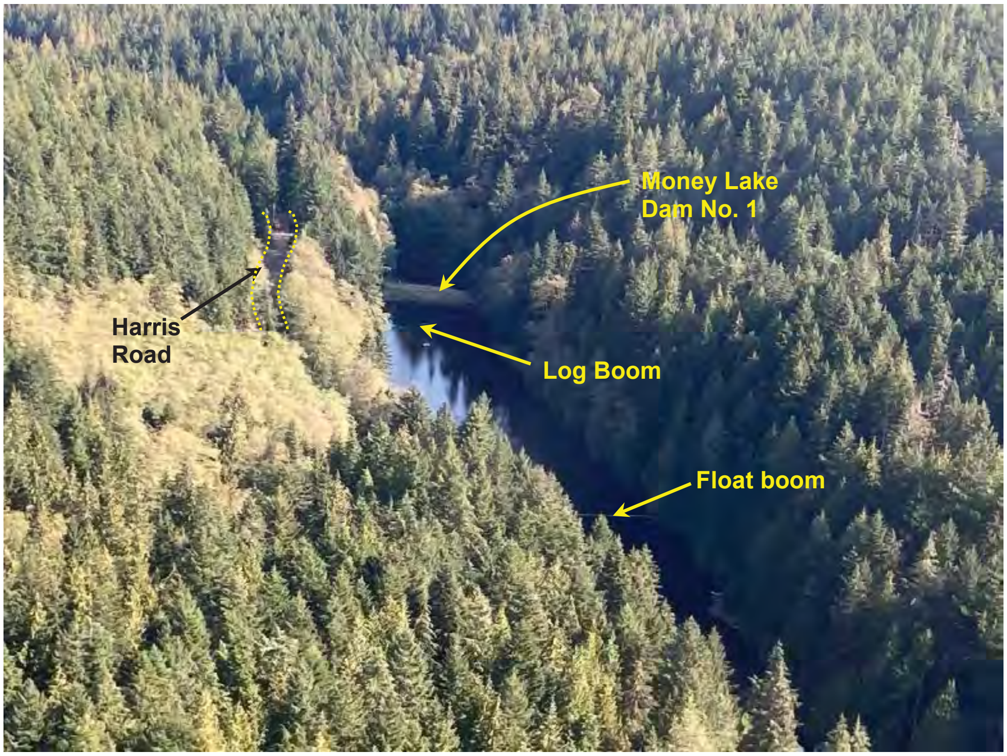


Photo 1: Money Lake Dam and reservoir looking northeast. (2022-08-31, JDM)

Photo 2: Looking some at reservoir from dam crest. (2022-08-31, JDM)

THURBER

Photo 3: Staff gauges – difficult to read. (2022-08-31, JDM)

Photo 4: Looking southwest from dam crest at log boom. Intake raft in distance. (2022-08-31, JDM)

THURBER

Photo 5: Sinkhole/depression upstream of left abutment. (2022-08-31, JDM).

Photo 6: Looking northeast at upstream slope of dam from left abutment area. (2022-08-31, JDM).

THURBER

Photo 7: Looking north at entrance to spillway. Note seepage return pipe. (2022-08-31, JDM)

Photo 8: Spillway entrance. Note aluminum weir plate. (2022-08-31, JDM).

THURBER

Photo 9: Spillway chute at right abutment (2022-08-31, JDM).

Photo 10: Downstream of spillway chute. (2022-08-31, JDM).

THURBER

Photo 11: Upstream slope of dam from right abutment. (2022-08-31, JDM)

Photo 12: Dam crest from left abutment. (2022-08-31, EPS).

THURBER

Photo 13: Downstream slope. (2022-08-31, JDM)

Photo 14: Current signage at dam crest. (2022-08-31, JDM).

THURBER

Photo 15: Looking downstream from crest. (2022-08-31, JDM)

Photo 16: Pedestrian bridge downstream of spillway. Limited armour protection. (2022-08-31, JDM).

Photo 17: Interior of MH1 after partial lowering of water level using pump. (2022-08-31, JDM)

Photo 18: Interior of MH2 – approximately 250 mm of fine sediment. (2022-08-31, JDM).

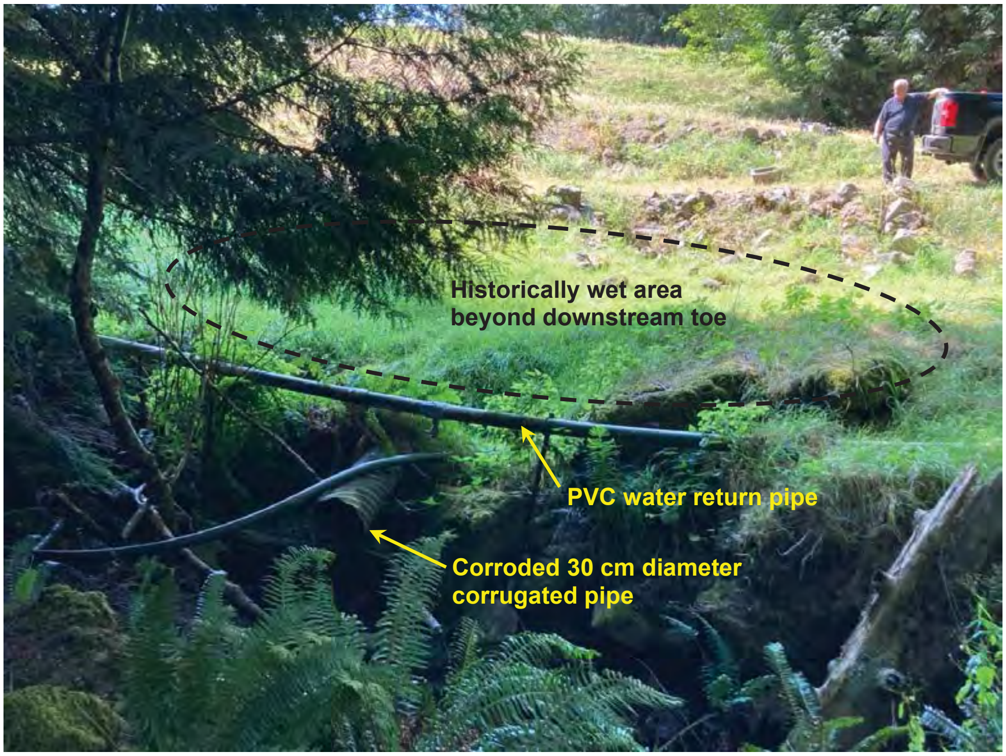


Photo 19: Area downstream of dam toe. (2022-08-31, JDM)

Photo 20: Unclear water pumped from MH1. (2022-08-31, JDM).

THURBER

Photo 21: Seepage collecting infrastructure downstream of left abutment. (2022-08-31, JDM)

Photo 22: Small downstream impoundment at Money Diversion Dam. (2022-08-31, JDM).

THURBER

Photo 23: Money Diversion Dam located ~450 m downstream of Money Dam No. 1. (2022-08-31, JDM)

Photo 24: Culvert location on East Point Road ~200 m west of Harris Road. (2022-08-31, JDM).

THURBER

APPENDIX A
APPENDIX B
APPENDIX C
APPENDIX D

THURBER

Actions:		
	N or Blank	None
	Ma	Maintenance
	Mo	Monitor
	R	Repair
	E	Evaluation

Money Lake Dam – Field Review Summary

Reservoir Name: Money Lake Structure: Money Lake Dam No. 1	Coordinates: Lat: 48.7862 Long: -123.1790	Date of Visit: Aug. 31, 2022 Inspectors: J. McIntyre, D. Meredith, I. Jesney, J. Kelly, J. Money
Structure Details: Crest Length: ~46 m Crest Width: 4.5 m Maximum Height: ~7 m Upstream Slope: 2H:1V Downstream Slope: 2H:1V	Crest Elevation: 152.0 m (approx.) Spillway Elevation: 150.55 m (SG 4.75 m) Freeboard: ~1.4 m Lake Level during visit: 149.45 m (SG 3.65 m) Downstream Consequence: **High**	Date Constructed: Unknown Upgrades: 1979, 1986 Construction Type: Zoned earthfill Foundation Type: Shallow bedrock near abutments. Channel deposits elsewhere.

Item No.	Observation	Comment	Action Required	Photo No.
1.	**Upstream Slope**			
1.1	Approximate Slope Angle	~2H to 1V to water line		11
1.2	Vegetation	Grass – needs trimming		11
1.3	Slope Protection	Riprap extending most of the way across upstream slope from spillway		6
1.4	Erosion	Very minor beaching at full supply elevation – no concern		
1.5	Evidence of Slides	Minor rockfall apparent on slope upstream of left abutment		5
1.6	Evidence of Cracking	No		
1.7	Bulges / Depressions	None observed on slope. Small sinkhole located above reservoir level upstream of dam's left abutment. Likely related to collapse in buried talus.	Mo – monitor sinkhole for changes	5
1.8	Burrows / Ruts	No		
1.9	Other Concerns	No		
2.	**Crest**			
2.1	Accessibility	From ramp crossing downstream slope. No issues		13, 15
2.2	Vegetation	Grass – needs trimming		12
2.3	Evidence of Overtopping	No		
2.4	Evidence of Settlement	No		

115

THURBER

2.5	Evidence of Cracking	No		
2.6	Burrows, Ruts	No		
2.7	Concrete Barrier Condition	n/a		
2.8	Other Concerns	No		
3.	**Downstream Slope**			
3.1	Approximate Slope Angle	~2H:1V, but variable given ramp		13
3.2	Vegetation	Grass		
3.3	Slope Protection	None		
3.4	Erosion	No		
3.5	Evidence of Slides	No		
3.6	Evidence of Cracking	No		
3.7	Bulges / Depressions	None apparent		
3.8	Burrows / Ruts	None observed		
3.9	Other Concerns	None		
4.	**Seepage**			
4.1	Seeps or Wet Areas	Green vegetation adjacent to spillway chute and along dam toe. Historic wet area near manholes but relatively dry at time of visit.		19
4.2	Quantity	Some of the standing water in MH1 pumped out using electric pump.		17
4.3	Sediment in Flow	Water pumped out of MH1 appeared cloudy. Sediment observed in base of MH2.	E – toe filter study underway	20, 21
4.4	Aquatic Vegetation	n/a		
4.5	How Monitored?	Not monitored at dam		
4.6	Notes / Causes	Seepage through / under dam.		
4.7	Embankment Drains	Seepage collection system at d/s toe, functionality uncertain. 30 cm overflow pipe corroded and split at outlet.	R –remove or decommission old system	19
5.	**Spillway & Channel**			
5.1	Type	Concrete overflow spillway near right abutment. Flow is conveyed in concrete chute beyond toe of dam.		
5.2	Concrete Condition	Good, foam water stops exposed in upper 2 joints.	R – repair water stops	

115

THURBER

5.3	Debris / Obstructions	None observed		
5.4	Vegetation	Cedars at spillway stilling basin impair inspection.	Ma – trim vegetation	
5.5	Log Boom	Log boom in-front of spillway and secondary float boom across lake upstream of dam. Appears OK – no debris observed in log boom.		1, 4
5.6	Spillway Gates	n/a		
5.7	Channel Obstructions	None		
5.8	Erosion/Undermining	Some channel erosion downstream of stilling basin threatens pedestrian bridge.	R – extend channel armour further d/s	16
5.9	Energy Dissipation	Possible loss or shifting of riprap within spilling basin.	R – replace or reconfigure riprap	
5.10	Other Concerns	None		
6.	**Low Level Outlet**	No LLO, but water supply pipe passes through dam.		
6.1	Valve type	Nelson gate valve (150 mm) buried about 4 m below grade		
6.2	Access to valve/gate	Valve accessed near spillway just d/s of dam crest.		
6.3	Controls	Manual crank.		
6.4	Conduit (size, material)	150 mm diameter Sclairpipe (HDPE)	E – evaluate pipe condition	
6.5	Leakage	None observed.		
6.6	Outlet Obstruction	No visible outlet.		
6.7	Tested as per OMS?	Not during visit but exercised annually by CRD		
6.8	Outlet Structure Condition	n/a		
6.9	Undermining	n/a		
6.10	Downstream Channel	n/a		
7.	**Reservoir / Watershed**			
7.1	Stability concerns	None apparent from vantage points. Talus slope along west shore of reservoir not expected to generate rock fall sizes to be of concern.		
7.2	Site Access	Good access to site. One route only. Controlled access for vehicles. Road washed out in November 2021.		

THURBER

7.3	Appropriate Signage	Sign posted on dam but does not include emergency contact information. This info posted at water treatment plant located on Harris Road.	Ma – update signage on dam	14
8.	**Instrumentation**			
8.1	Installed instruments	Two adjacent manual staff gauges. One is broken and the other is difficult to read. 3 standpipe piezometers – 2 on crest and 1 at toe. 3 larger diameter wells – near dam toe (not currently monitored). Established seepage measurement location d/s dam along access road.	Ma – clean or replace staff gauge	3

THURBER

APPENDIX A
APPENDIX B
APPENDIX C
APPENDIX D
APPENDIX E

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Technical Memorandum

DATE: March 8, 2023

TO: Mr. Jay McIntyre, M.A.Sc., P.Eng.
Thurber Engineering Ltd.

FROM: Dwayne Meredith, P.L.Eng.
Kerr Wood Leidal & Associates Ltd.

RE: **Money Lake Dam Safety Review**
Money Lake DSR Hydrotechnical Supplement
Our File 2767.033

1. Introduction

1.1 Scope of Work

Kerr Wood Leidal Associates Ltd. (KWL) sub-consulted to Thurber Engineering Ltd. (Thurber) to complete a dam safety review (DSR) on Money Lake Dam No.1 owned by the Capital Regional District (CRD). The scope of work was provided with our revised proposal dated July 20, 2022. The work generally focused on a site inspection and hydrotechnical elements of the DSR. Support and discussion was also provided to Thurber to complete the hazards and failure modes analysis and other tasks.

Notice to proceed and a sub-consultant agreement was executed on October 4, 2022.

1.2 Background References

Background information was provided for the Money Lake Dam and included the following listed in Table 1.

Table 1: Reference Material

Item	Title	Date
1.	EBA – Money Lake No.1 Dam Safety Review 2011	April 2012
2.	CRD Lyall Harbour Boot Cove, Money Lake Dam Pipework Schematic	April 2014
3.	Thurber – Figure 1: Location of Test Holes, Test Pits Well Points, and Monitoring Wells	December 16, 2019
4.	CRD - Record Drawing Money Lake Dam - Poly Covering of Infiltrators Drawing 5922A	December 8, 2020
5.	CRD - Money Lake Dam No. 1, Dam Emergency Plan and Operation, Maintenance and Surveillance Manual	January 6, 2022
6.	Thurber, IMG_1797.mov – Turbid Outflow	2022
7.	CRD Dam Inspection Checklist	October 3, 2022

2. Project Information

2.1 Site Description and Site Visit

The watershed is small, calculated at 1.02 km^2 including the 0.02 km^2 lake area. The reservoir is nestled between Mt. Fisher and Mt. Warburton which is federal Crown land as part of the Gulf Islands Nations Park Reserve. The reservoir is approximately 450 m long and 60 m wide with a median basin elevation of 230 m (EBA, 2012).

There are no dams upstream, but there is Money Diversion Dam almost 500 m downstream. The dam is sited on Section FRAC SEC 8, Portion SATURNA ISLAND with civic address 186 Harris Road owned by the CRD.

Money Lake Dam No.1 is a homogeneous earthfill dam 6.9 m high, 46 m long with a crest elevation of 151.3 m. It is well described within the 2011 EBA DSR Report completed in 2012. The dam risk level, as provided from the BC Water Resources Atlas, accessed November 28, 2022, is 2b-Caution with the deficiencies raised in the EBA DSR including:

- an inadequate spillway and replacement of the log boom;
- inoperability of the intake valve; and
- increasing the frequency of seepage monitoring and conducting a seismic stability analysis.

A site inspection was completed August 31, 2022, with members from the CRD, Thurber and KWL. Notes, field measurements and data were recorded to provide up to date knowledge of the dam and verify insitu conditions to available drawings. The CRD and Thurber are also completing a concurrent project to address seepage and seismic stability.

The spillway remains in good condition and similar to that previously described. However, the 2021 report indicates inability to inspect the floor surface due to excessive growth and debris. During this inspection, the concrete was visible and free from obstruction. The sealant covering the two upstream concrete joints was split on the right side exposing the water stops; the water stops were lifting out. Observed spalling was superficial and did not present a concern. Concrete soundings did not reveal any hollows or loss of support under the structure. There was a void, measured at 0.6 m depth, detected at the end of the concrete chute and transition to the rock stilling basin. The stilling basin has shifted, presumably from high flows, such that protection is adequate but could be improved.

The aluminum angle plate was in good condition as was the pedestrian bridge across the spillway from the crest. The 100 mm PVC pipe fixed to the inside left of the spillway was in good shape and firmly attached. This pipe conveys excess water from the community water system back to the reservoir; the pipe was flowing during the inspection.

A new log boom and anchors were installed in 2015. The boom and anchors are in satisfactory condition; functional but the logs sit deep into the water. The boom connections were not checked. A fine debris net was also installed around 2021 near the middle of reservoir, stretching across the reservoir. The purpose of the net was described as additional measures to prevent floating debris, such as algal mats from getting close to the floating intake for the community waterworks system. The net was not inspected during the site inspection. Previous reports of floating debris and logs within the reservoir were not observed during this inspection; the reservoir was free of debris.

The dam's upstream face angle was measured with a clinometer and remains unchanged. There was some beaching observed and angular rock near the current water level. The rock extends from the spillway for 20 m along the dam length. There was long grass on the slope from the full supply elevation to the current water line. A previous inspection report noted erosion of the upstream face which may be the beaching effect noted.

The downstream slope undulates with remnants of the old forestry road which was relocated following the dam construction. The remnant road now allows vehicle access to the crest. Other features such as the previous spillway alignment, rock piles, monitoring wells and the community waterworks infiltration gallery also add to the undulation on the slope.

The infiltration gallery installed near the dam downstream toe was intended to collect under dam seepage for the community water system. The infiltration gallery was the focus of much attention while on site due to the volume of water conveyed and the turbidity. The gallery sumps were pumped down during the inspection to view the inside of each chamber. The piezometers and monitoring wells were examined for water depths and total depths. Fine clay was noted in two piezometers. The infiltration gallery and piezometers were outside of KWL's scope and the details were left to Thurber.

The other instrumentation were the two manual staff gauges within the reservoir. From shore, both staff gauges were difficult to read due to the build up of organics on the face plate, and unclear metre markings. The smaller staff gauge was broken (the face plate was bent) but the large gauge read 3.63 m. This water level was well below the spillway sill, within the operating range of the reservoir, and typical considering the water consumed by the community. The weather had been dry and hot with little opportunity to recharge the reservoir for the previous two months.

There is no low level outlet, but there is the community water system pipe suspended from a floating dock within the reservoir. The intake was reconstructed in 2004 from a fixed screen intake with a foundation on the reservoir bottom, to a suspended floating intake screen. A valve chamber was observed near the dam crest and spillway, but the valve was not exercised. In conversation with the CRD staff on site, the majority of the community water comes from the infiltration gallery, and it was unknown when the floating intake was last used. The CRD 2021 inspection indicates “WIO reports that all valves are tested at least annually and are operational”. The buried depth of the water supply pipe was briefly discussed and assigned to Thurber for comment. Additional buried infiltration equipment covered with drain rock piles were seen adjacent to the access road well downstream of the dam. These were not inspected.

Approximately 15-20 m upstream from the left abutment, a sink hole with dimensions 0.8 x 0.7 x 0.4 m deep was observed. This sinkhole was previously identified in 2021 (CRD) and is slightly larger in size, but shallower in depth, indicating slumping in, but likely not progressed significantly in size. The location of the sinkhole was coincident with the colluvium debris slide. It was thought the sink hole developed from a pocket collapse within the slide material. As there is a level of awareness, the specific monitoring of this feature should continue. The slide was obvious on air photos. This matches discussion with Thurber regarding colluvium incorporated into the dam at the left abutment. While there are historical slides, observations suggest the slides are small in nature and not sufficient to cause safety considerations at the dam through reservoir rim instabilities. The design and construction implications of the colluvium at the left abutment were assigned to Thurber.

Access to the dam was provided through a locked gate. While the gate restricts vehicle access, walking public may easily access the dam. Adjacent to the gate, the stream channel crosses Staples Road through a 900 mm CSP. Beside this culvert, a 300 mm CSP culvert is used to pass the return water pipe from the water treatment building to the spillway inlet. Roughly 30 m below the crossing is the back up groundwater supply well and the Water Treatment Plant 1.

The creek crossing of Harris Road near the upper water treatment facility was under repair from the November 2021 atmospheric river event. This was a significant storm which the CRD (per comm, 2022) said the dam safely conveyed; however, the road was impassible through the canyon following the storm.

Recommendation R1: The items requiring repair as observed during the inspection include:

a. Repair and reseal the water stops within the concrete joints of the spillway;

b. Repair the rock stilling basin by installing new rock or reshaping the existing rock such that adequate erosion protection of the spillway chute transition to the creek channel; and

c. The manual staff gauge should be cleaned and, it is preferred to eliminate the second smaller staff gauge (currently broken) to reduce potential mis-reads.

2.2 Consequence Classification

Updating the flood inundation mapping was excluded from scope. The 2011 (EBA) mapping was updated during the 2017 annual inspection report with the correct creek alignment through the lower developed area. The updates were manual markups with the correct creek alignment and an estimation of flood extents.

The 2011 report used SMPDBK model which was commonly used for the period and is now considered simplistic in favor of contemporary hydraulic models incorporating LIDAR digital elevation models. From a review of downstream conditions during the inspection, the recently constructed Saturna Recreation and Cultural Centre, the firehall and lower water treatment facilities may be impacted by flood waters during a dam breach. The 2017 update excludes facilities from the impacted area. An updated Dam Failure Consequence Classification review would be required to resolve this discrepancy.

In addition, the reservoir is the primary water works system for a significant portion of the island's development with approximately 450 people reliant on this system (per comm, 2022). Below the reservoir near the Staples Road crossing, is the community's back up well and primary treatment facility which would be inundated in the event of dam failure. These features would be included in an updated assessment.

Recommendation R2: The dam failure consequence classification and inundation mapping should by updated to reflect the current creek alignment and development downstream.

3. Dam Safety Analysis

3.1 Hazards and Failure Modes

The Hazards and Failure modes analysis was completed through this project. This was a combined effort from KWL and Thurber where Thurber will be completing the reporting. However, to support this analysis and through the hydrotechnical review, the spillway was confirmed to be capable of conveying the Inflow Design Flood (IDF) using the 2018 survey information.

EBA completed calculations using the as-constructed drawings with the dam crest was measured to be 0.17 to 0.79 m higher. The higher measurements were discounted in the EBA report due to the lack of information (fill specification) in the apparent raise. Thurber has completed additional analysis to indicate the fill material was competent and KWL could rely on the geometry presented in the 2018 survey.

The freeboard assessment (Section 3.3) completed under this DSR demonstrate the dam has sufficient freeboard under normal conditions and minimum freeboard during an IDF event.

The vulnerability of the access road downstream of the dam was described as potential to develop into a concern. There were two potentials reviewed, in the event of significant flood conveyance past the dam leading to impassible conditions, and also should a seismic event cause a landslide within the canyon would also render the access road impassible thereby preventing operation, maintenance and surveillance (OMS) activities from occurring. Alternatives for access could include fly in for inspection and operation but that may not be possible during a significant meteorological event.

Other critical issues or concerns with potential to develop into concerns related to the current configuration of the infiltration gallery and supporting OMS activities, under dam seepage and construction incorporating the colluvium were discussed with Thurber who will detail these hazard-failure mode pairs.

3.2 Dam Safety Expectations

The dam is located on land owned by the CRD. The Regulation prescribes signage requirements for dams located within Crown land, or "*on land that is located partly or entirely surrounded by or adjacent to Crown land…."* While the Regulation is silent on land owned by local government, the latter definition applies and being publicly held land, with access to the dam by the public, good practice should include the incorporation of signage meeting the intent of the Regulation.

Reporting on the CRD dam safety management systems, OMS activities and the Dam Emergency Plan (DEP) were assigned to Thurber for reporting. From our review, the 2021 annual inspection report was completed by CRD staff and completed with exceptional detail. This, together with the ongoing maintenance of the dam, and methodically undertaking the deficiency investigations demonstrates the commitment the CRD has in fulfilling their obligations. Notable comments include:

a. It is recommended practice that the OMS manual and DEP are two separate stand alone documents. This is often preferred because the DEP supports decision making by the Dam Owner, Local Emergency Authority and emergency responding agencies. Most of the OMS activities are not required by the Local Emergency Authority or the emergency responders.

b. The specific SOPs addressing response procedures (e.g., emergency drawdown) are an excellent detail for the manual. It may help to include drawdown curves over time to help guide decision making.

c. The DEP may be improved by:

   i. Highlight the subset of information vital to emergency response agencies; this subset can then be managed through version control. The current DEP does not highlight this specific information.
   ii. Providing roles and responsibilities of individuals who are expected to participate in an emergency.
   iii. Adding guidance in Section 7.3 regarding events that are unusual, slowly developing, and not just those related to dam breach.
   iv. Adding pre-approved notification messages, particularly focused on public consumption.
   v. Adding text to manage/evacuate individuals (persons within the vicinity) and securing the dam site in the event of a breach or potential breach.

Recommendation R3: While the Regulation may be ambiguous in signage application to Money Lake Dam No.1, the dam remains accessible to the public and providing owner contact information could assist the CRD with surveillance. It is recommended to install signage to follow best practice described by the CDA and meet the intent of the Regulation, Section 11.

3.3 Hydrotechnical Review

Inflow Design Flood

Determination of 1:1000 Year Flood – Regional Analysis

The Inflow Design Flood (IDF) for Money Lake, based on a HIGH consequence classification, is 1/3 between the 0.001% Annual Exceedance Probability (1:1000 year peak instantaneous flood) and the Probable Maximum Flood (PMF), as per the Canadian Dam Association 2007 Dam Safety Guidelines. The Money Lake dam is in the Eastern Vancouver Island Hydrological Zone. The catchment area for the Money Lake Dam was determined to be 1.02 km^2, of which 0.02 km^2 is the lake itself, calculated using 1 m LIDAR data flown in 2019, obtained from the British Columbia Open LiDAR Data Portal.

A regional analysis using data from nearby Water Survey of Canada stations was completed to estimate the peak instantaneous flood to Money Lake Dam at various return periods up to the 1:1000 year event. The stations included in the pre-screening were the same stations that were used in the Regional Analysis completed in 2011 EBA DSR and all located within hydrologic zones 28 or 29 in British Columbia (Obedkoff, 2003). The stations were then screened based on the following criteria:

- watershed area approximately between 0.1 and 10 times the subject watershed;
- minimum 8 years of data;
- must not have any stream regulation; and
- data must be acceptable quality for analysis.
  - validation of Regional Homogeneity based on L-moments;
  - pass hypothesis tests on Flood Frequency Analysis using HYFRAN software; and
  - "Cr" ratio comparisons.

Three stations, refer to Table 2, remained after the pre-screening and a statistical analysis was completed. These stations were then used to perform a Mean Annual Flood (MAF) estimate for Money Lake Dam by developing three regressions equations to represent the relationships between the MAF-Elevation (mean catchment basin elevation), MAF-Area (drainage area) and MAF-Elevation-Area. All three equations had very good correlation so the MAF and Area equation was chosen as it provided more conservative peak flood estimates. The MAF for Money Lake Dam was estimated to be 0.52 m^3/s. The MAF was then used in conjunction with the "Cr" values from the chosen gauge stations to produce the instantaneous peak flows during the various return periods, as shown in Table 3.

Table 2: Stations Used in MAF Prediction

Station ID	Station Name	Area (km^2)	Mean Elevation (m)	MAF (m^3/s)	I:D Ratio	Period of Record
08HA016	Bings Creek near the Mouth	15.5	123	8.5	1.49	1961-2021
08HA060	Sandhill Creek at Pat Bay Highway	3.1	39	1.1	1.64	1993-2009
08HA072	Cottonwood Creek Headwaters	13.0	750	7.6	1.79	1997-2020

Table 3: Instantaneous Peak Flow Estimates for Money Lake Dam

Flood Event	Peak Instantaneous Flow (m^3/s)
	Money Lake Dam
MAF	0.52
2	0.8
5	1.1
10	1.3
20	1.5
50	1.7
100	1.9
200	2.1
500	2.4
1000	2.6

The revised 1000-year flood estimate is below the previous 2011 estimate of 3.7 m^3/s. The analysis was completed using representative stations with adequate lengths of records using gauged watersheds with similar attributes. This analysis is suitable for DSR purposes but should not be used for detailed design. Additional hydrological analyses are recommended for any detailed design requirements of the dam.

Determination of the Probable Maximum Precipitation (PMP)

The British Columbia Extreme Flood Project PMP guideline, published in July 2021, was used as a check against the PMP estimated in the 2011 DSR that used the Hershfield method. This tool produces PMP values at various grid points (transposition points) across BC and for different storm durations by transposing historical storms that have occurred in areas with similar climactic conditions and adjusting them based on differences in topography, proximity to moisture source, watershed area, etc. (DTN and MGS, 2020). In the MetPortal, storm temporal patterns are produced for a selected location, which can then be scaled to the PMP.

PMP values were given for watershed areas of 10 and 100 km^2 at the selected transposition point of 27513, which is located 22 km to the SW of Money Lake. For this study, a 24hr storm duration was selected and the time of year was set to all season (adjustment factor 1.0). Since the Money Lake Dam catchment area is below 10 km^2, a logarithmic scale was used for the watershed area size and a linear regression is used to scale the PMP to the Money Lake watershed size of 1.02 km^2.

The 24hr PMP for transposition point 27513, once adjusted for the smaller catchment area, is 276 mm. The previous DSR used the Hershfield method and estimated the PMP to be 322 mm. While both methods are deemed appropriate, the Hershfield method suits larger watersheds and applying this method to the small Money Lake watershed can result in an overestimation of the PMP. Therefore, while the results from the British Columbia Extreme Flood Project guideline methodologies is less conservative, it better approximates the PMP.

Determination of the Probable Maximum Flood (PMF) and Inflow Design Flood

The PMF is the theoretically largest possible flood that could occur based on the meteorologic and hydrologic conditions for a given location. The CDA guidelines provide the PMF as the maximum of the following events:

1. Summer/autumn PMF, which is generated by the summer/autumn PMP. The PMP event is typically modelled with a preceding lesser storm event, such as the selected 0.01% Annual Exceedance Probability (AEP, 100-year), 24-hour rainfall event;
2. Spring PMF, which is defined as the maximum of two cases:
   a. PMF computed with the Spring PMP and a 0.01% AEP (100-year) snow accumulation; or
   b. PMF computed with the Probable Maximum Snow Accumulation (PMSA) and a 0.01% AEP (100-year) rainstorm.

The results from the MetPortal of the British Columbia Extreme Flood Project PMP guideline demonstrate the maximum PMP for the Saturna Island area will occur in the winter months. Event 2a was selected as it provides the maximum runoff scenario. The cumulative distribution functions of two temporal patterns for storms provided by the MetPortal were scaled to the PMP estimates to produce storm hyetographs. This resulted in lower intensity storms than what is expected with synthetic hyetographs. Given the small size of the watershed, peak flows will be dictated by the intensity of the storm, therefore the lower intensity storms produced by the MetPortal are not representative for Money Lake. To estimate the storm hyetograph, a Soil Conservation Society (SCS) 1a distribution was selected as applicable for the region and results in an intensity more appropriate for the Money Lake watershed.

Snow accumulation was estimated using the following equation (Gray, 1975):

$$M = (0.074 + 0.007P)(Ta - 32) + 0.05$$

Where M = snowmelt (in/day)

P = precipitation (inch); and

Ta = Temperature (F)

Using an average daily temperature from November to March of 5.29 ^{o}C at Saturna Capmon station, snowmelt was calculated to be 38 mm/day. This was evenly distributed across the modelled hyetograph.

A HEC-HMS model was created in order estimate the PMF using the derived PMP and the calculated watershed size. For the model input, watershed runoff simulation is based on the SCS loss and lag time methods. The SCS loss is defined by its Curve Number (CN) which is dependent on soils, land use, and antecedent moisture conditions. The watershed consists of well- to rapidly draining soils (British Columbia Soil Survey, 1992) and the land use is forested. Therefore, the estimated CN for a normal antecedent moisture condition used for summer/autumn events (AMC II) is 55, and for a wet antecedent moisture condition (AMC III) used for spring events is 74.

The time of concentration (ToC) and lag time (LT) are measures of how quickly a catchment responds to runoff-producing rainfall and runoff arrives at the point of interest, in this case, the dam. The ToC and LT are functions of watershed properties such as slope, stream length, and land use. Empirical equations such as Kirpich, Bransby-Williams, Kerby and Watt & Chow were used to calculate the time of concentration (ToC) and lag time (LT). The average ToC and LT of 31 minutes and 19 minutes were used for the SCS method, respectively.

The model was not calibrated to streamflow, precipitation, or water level data as no continuous recorded data is available at the site. However, the model was validated by routing the 0.001% AEP pre-storm rainfall through the HEC-HMS model and comparing the resulting peak flow to the 1000-year return period flow determined by completing the regional analysis.

In addition to the watershed characteristics and the rainfall hyetographs, the Money Lake reservoir storage capacity obtained from the MOE 1984 drawings and the discharge curve for the existing spillway (described below) were incorporated into the model.

The PMP and snowmelt hyetographs were run through the HEC-HMS model to produce inflow hydrographs. The peak instantaneous inflow from a 24-hour PMP with snowmelt is 12.8 m³/s.

The IDF was calculated to be 6.0 m³/s using the following equation (CDA, 2007):

$$Q_{IDF} = Q_{1,000} + C(Q_{PMF} - Q_{1,000})$$

Where:

Q_{IDF} = Inflow design flood (m³/s)

$Q_{1,000}$ = 1,000-year flood (m³/s)

C = Coefficient (1/3 for HIGH Consequence Classification dams)

Outflow Determination

There is no operable low-level outlet (LLO) for the Money Lake Dam. Water is currently collected through an infiltration gallery downstream of the dam or the water supply pipe through the dam and into the reservoir. Neither of these means were used in the outflow calculations.

The Dam has a concrete rectangular spillway located on the main dam crest. The spillway is approximately 36.8 m long and the width varies from 4.8 m at the crest to 1.22 m at the downstream end. The slope also varies from 3% to 16%. The spillway discharges onto a rock stilling basin before entering the Money Lake Creek and flowing downstream.

A Stage-Discharge curve for the Money Lake spillway was estimated as weir flow using the following equation:

$$Q = 1.70 \, L \, H^{3/2}$$

Where*:*

Q = flow (m³/s)

B = base width of the weir (m)

H = hydraulic head (m)

The spillway control, transition and chute capacity were calculated to determine if the capacity of the spillway is controlled by the wider control, transition or the downstream thinner chute. The entrance flair is 4.3 m wide, 1.3 m deep and has a slope of 2%; the rectangular spillway is 2.4 m wide, 0.6 m deep, has a slope of 2% and the downstream chute (tailrace) is 1.2 m wide, 0.6 m deep and 16% slope. The chute capacity was calculated using manning's formula and was found to convey the IDF, but overtops the side walls at 7.5 m³/s. It was concluded that the spillway capacity is controlled by the weir crest and both the rectangular spillway and downstream chute do not constrict the flow.

TECHNICAL MEMORANDUM
Money Lake DSR Hydrotechnical Supplement
March 8, 2023

The resulting spillway stage-discharge curve is available in Figure 1. The IDF is safety routed through the spillway. A capacity check of the culverts downstream at Staples Road and Harris Road was not completed, however, they are undersized for the IDF. Considering this access is the primary means to enable staff to complete OMS activities or implement emergency measures, the access roads crossings should be improved.

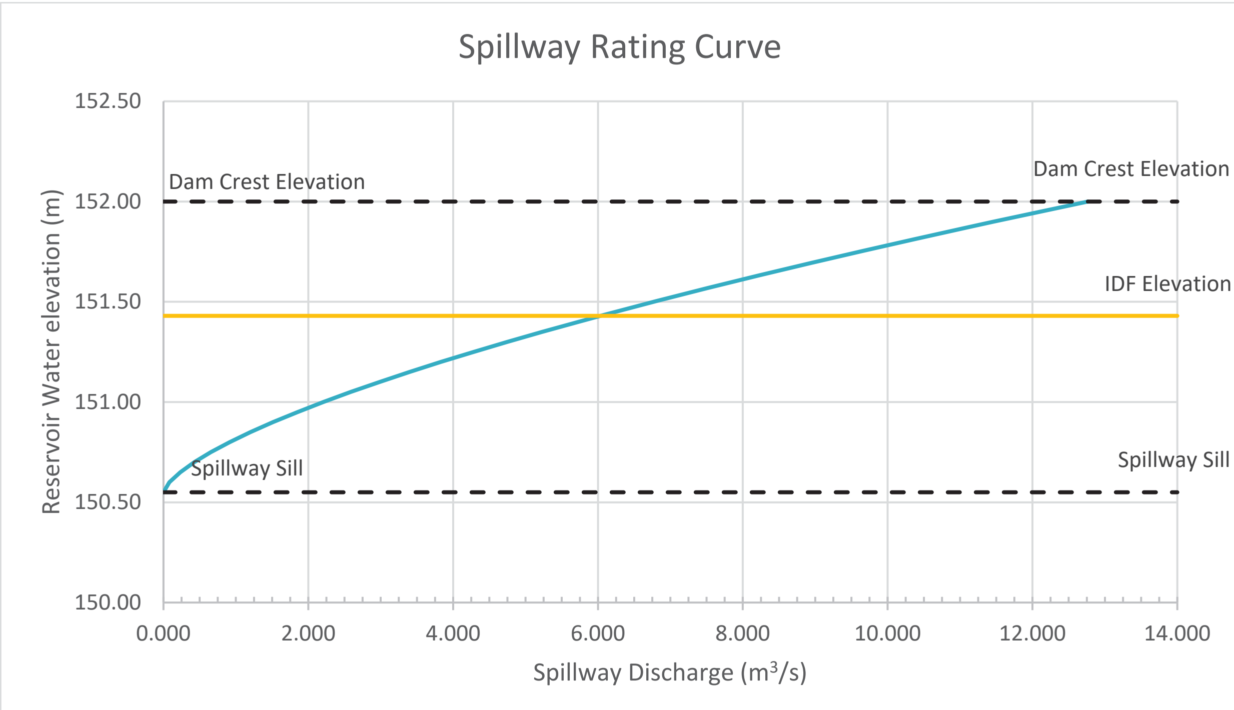


Figure 1: Spillway Stage-Discharge Curve for Money Lake Dam

Wind-Wave and Freeboard Analysis

The Dam, under the CDA guidelines, must have enough freeboard to provide an allowance for wave action, blockages and other variables that could result in overtopping of the dam crest. The CDA guidelines (2007) provide the following freeboard requirements:

1. Normal Freeboard – No overtopping by 95% of the waves caused by the 0.001% Annual Exceedance Probability (AEP) wind wave when the reservoir is at its maximum normal elevation [full supply level].
2. Minimum Freeboard – No overtopping by 95% of the waves caused by the 0.5% AEP wind wave when the reservoir is at its maximum extreme level during the passage of the IDF.

A wave analysis was completed using available hourly wind data, beginning in 1994, from the Saturna climate station. A frequency analysis was completed on the data to determine if any data gaps are present and to extract the yearly maximum wind events. The frequency analysis was completed for both the all-direction and SSW winds and the SSW was chosen as provides the maximum wind to generate waves compiling on the dam. The 0.5% AEP and 0.001% AEP wind speeds were calculated to be 17.2 m/s and 33.4 m/s, respectively. Figure 2 below shows the wind rose of the wind data from Saturna CS.

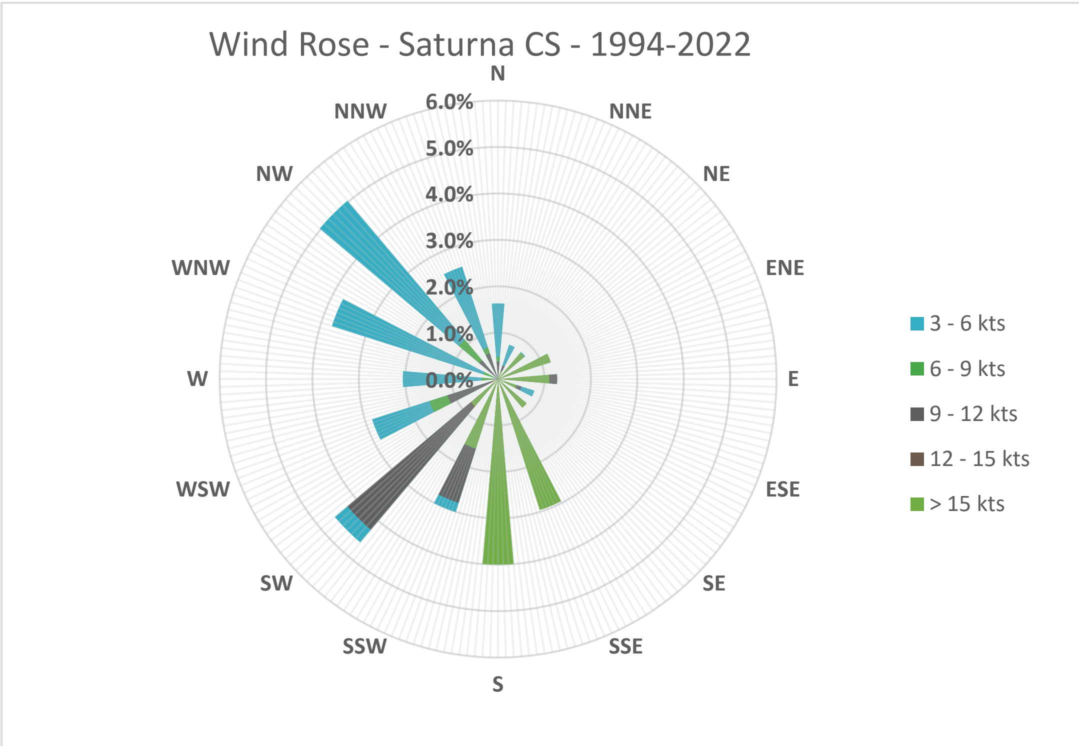


Figure 2: Saturn CS Wind Rose - 1994 to 2022

The SSW wind frequency data was used to find the hindcasted waves on the Dam Crest. The effective fetch was calculated to be 106 m by using the radial method for the different path lengths facing the dam as shown in Figure 3.

Figure 3: Radials used to calculate the effective fetch length

The maximum wave height and period were estimated using the Sverdrup-Munk-Bretschneider (SMB) hindcast (CERC, 1977), Wilson-Goda (Wilson-Goda, 2003), Kahma and Calkoen (Khama, 1992) and USACE Coastal Engineering methods (USACE, 2015). The EurOtop manual on wave overtopping method was used to calculate the design wave run up values for the 2-year and 1000-year wind events (EurOtop, 2018). A 2H:1V embankment slope and 5% percent wave event, as required by CDA guidelines, was used in the calculation. Table 4 provides a summary of the calculated wave heights, periods and design wave run ups.

Table 5 summarizes the freeboard assessment and current freeboard.

Table 4: Wave Analysis Results for 2-yr and 1000-yr Wind Events

Parameter	2 - Year	1000-Year
Wave Height (m)	0.18	0.39
Wave Period (m)	1.39	1.94
Design Wave Runup (m)	0.53	1.08

Table 5: Freeboard Requirements

Freeboard	Flood Surcharge (m)	Wave Runup (m)	Total Surcharge (m)	Elevation Surcharge (m)	Difference (m)	Meets Requirements
Normal	0	1.08	1.08	151.63	0.37	Pass
Minimum	0.95	0.53	1.41	151.96	0.04	Pass

The dam has 1.4 m of freeboard as calculated from the dam crest (2018 survey) to the spillway sill. During normal operations, the wave runup was calculated at 1.08 m surcharge and less than the insitu freeboard. The result passes the normal freeboard test. In addition, during an IDF storm, the reservoir elevation surcharge of 0.88 m added to the 2 year wave runup (0.53 m) is less than the insitu freeboard and thus the result passes the minimum freeboard test.

4. Discussion and Recommendations

The following recommendations have been prepared based on the site visit and overall dam safety review:

R1: The items requiring repair as observed during the inspection include:

a. repair and reseal the water stops within the concrete joints of the spillway;

b. repair the rock stilling basin by installing new rock or reshaping the existing rock such that adequate erosion protection of the spillway chute transition to the creek channel; and

c. the manual staff gauge should be cleaned and, preferred to eliminate the second smaller staff gauge (currently broken) to reduce potential mis-reads.

R2: The dam failure consequence classification and inundation mapping should by updated to reflect the current creek alignment and development downstream.

R3: While the Regulation may be ambiguous in signage application to Money Lake Dam No.1, the dam remains accessible to the public and providing owner contact information could assist the CRD with surveillance. It is recommended to install signage to follow best practice described by the CDA and meet the intent of the Regulation Section 11.

5. References

Canadian Dam Association (2013). Dam Safety Guidelines 2007

Coastal Engineering Research Center (US). (1977). Shore protection manual (3rd Edition). US Army Coastal Engineering Research Center.

DTN and MGS Engineering (2020). British Columbia Extreme Flood Project, Probable Maximum Precipitation Guidelines for British Columbia – Technical Report (Bulletin 2020-3-PMP). Report prepared by DTN, LLC and MGS Engineering Consultants, Inc. for the British Columbia Ministry of Forests, Lands, Natural Resources Operations, and Rural Development. December 16, 2020.

Eva, L.; Walker, A.; Chantler, A.; Grapel, C.; (2011). Money Lake No. 1 Dam Safety Review 2011. Report prepared by EBA Engineering Consultants Ltd., operating as EBA, a Tetra Tech Company for the Capitol Regional District. April 2012.

Goda, Y., (2003). Revisiting Wilson's Formulas for Simplified Wind-Wave Prediction. Journal of Waterway, Port, Coastal and Ocean Engineering 129. March 2003

Kahma, K. K., and C. J. Calkoen (1992), Reconciling discrepancies in the observed growth of wind-generated waves, J. Phys. Oceanogr., 22, 1389 – 1405.

US Army Corps of Engineers (2015). Coastal Engineering Manual – Part II. Department of the Army – U.S. Army Corps of Engineering, Washington, DC 20314-1000.

Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., (2018). Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. EurOtop, www.overtopping-manual.com.

W. Obedkoff. (2003). Streamflow in the Lower Mainland and Vancouver Island. Prepared by Aquatic Information Branch for the Province of British Columbia Ministry of Sustainable Resource Management. April 2003.

TECHNICAL MEMORANDUM
Money Lake DSR Hydrotechnical Supplement
March 8, 2023

6. Closure

This Dam Safety Review – hydrotechnical supplement, including the analysis and recommendations are only valid for the current operating regime and current overall environment of the Dam. It was a pleasure to work on this project. Should there be any questions regarding the contents of this report, please do not hesitate to contact the undersigned.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Caitlin Cain, P.Eng.
Water Resources Engineer

Reviewed by:

2023-03-10
D. W. MEREDITH
KWL Permit to Practice #1000698

Dwayne Meredith, P.L.Eng.
Dam Safety Engineer

CLC/DWM/tdl

Encl.: Enclosure A – Photographs – Money Lake Dam Inspection

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of Thurber Engineering Ltd. and Capital Regional District for the Money Lake DSR Hydrotechnical Supplement. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

Copyright Notice

Revision History

Revision #	Date	Status	Revision	Author
0	March 8, 2023	Final	Issued for Use	CLC/DWM
B	December 19, 2022	Draft	Incorporated Thurber Comments	DWM
A	December 6,2022	Draft	Draft Issued for Client Review	DWM

KERR WOOD LEIDAL
consulting engineers

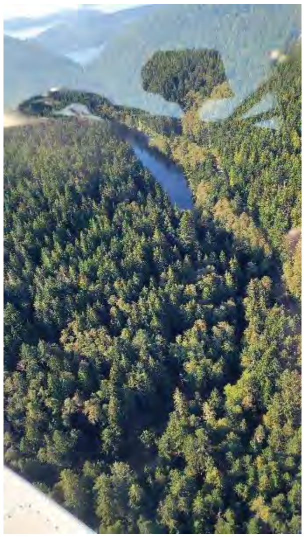
Enclosure A

Photographs – Money Lake Dam Safety Review

KERR WOOD LEIDAL
consulting engineers

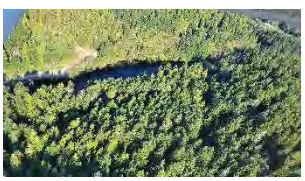
Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement

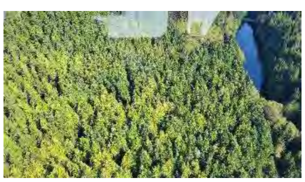


20220831_100419

20220831_100426



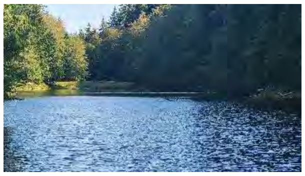
20220831_100434



20220831_100443

20220831_100444

20220831_103349



20220831_103355

20220831_103358

20220831_105021

20220831_105035

20220831_105129

20220831_105847

20220831_105852

20220831_105949

20220831_105955

20220831_110030

20220831_110125

20220831_110152

20220831_110159

20220831_110243

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement

20220831_110548

20220831_110559

20220831_110611

20220831_110629

20220831_110635

20220831_111215

20220831_111510

20220831_111528

20220831_111543

20220831_111555

20220831_111654

20220831_111706

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement


20220831_111844


20220831_112201


20220831_112827


20220831_113705


20220831_111851


20220831_112205


20220831_112828


20220831_113813

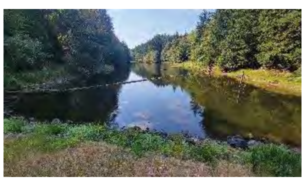
KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement

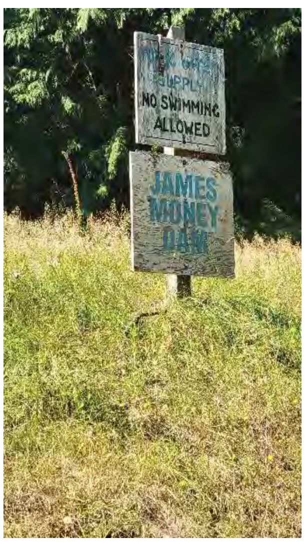
20220831_113848

20220831_113905



20220831_113932

20220831_113940



20220831_114416

20220831_114442

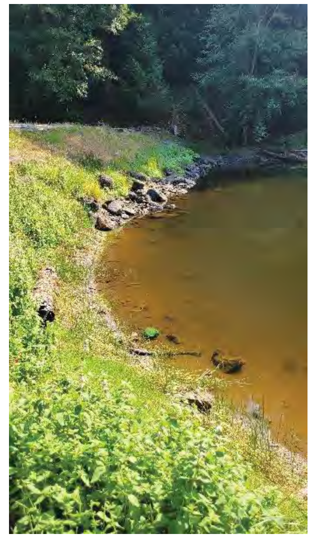
20220831_115628

20220831_115718

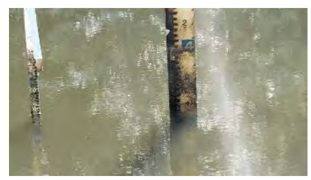
20220831_115720

20220831_115722

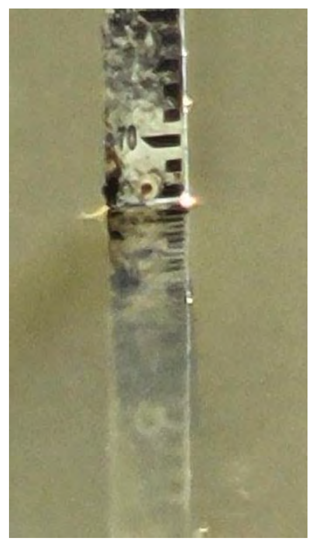
20220831_115811



20220831_115818



20220831_115834



20220831_115902

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement

20220831_115909

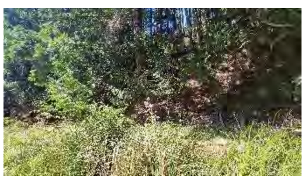
20220831_120223

20220831_120254

20220831_120424

20220831_120435

20220831_120450



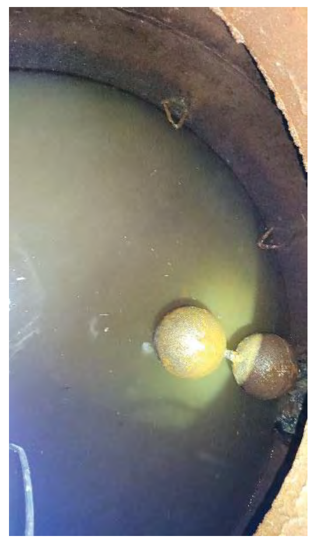
20220831_120546

20220831_120632

20220831_120717

20220831_120732

20220831_122415



20220831_122421

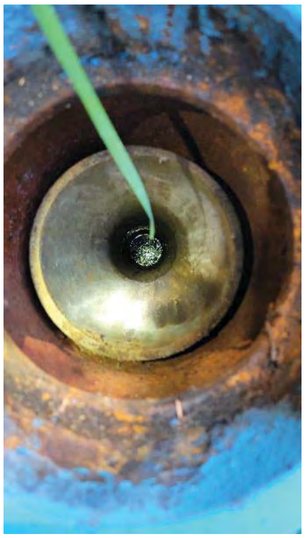
20220831_122434

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

Money Lake DSR – Hydrotechnical Supplement

20220831_122718



20220831_123253

20220831_123445

20220831_123453

20220831_123547

20220831_123550

20220831_124124

20220831_124149

20220831_124203

20220831_124205

20220831_124218

20220831_124226

20220831_124417

20220831_124449

KERR WOOD LEIDAL
consulting engineers

Okanagan
202 - 3334 30th Avenue
Vernon, BC V1T 2C8
T 250 503 0841
F 250 503 0847

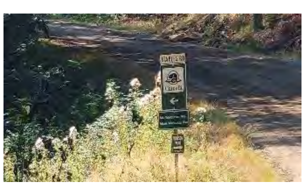
Money Lake DSR – Hydrotechnical Supplement


20220831_124611


20220831_124624

20220831_124700


20220831_124712

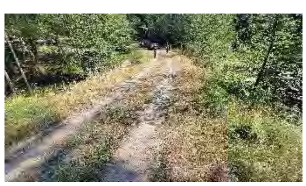

20220831_124716


20220831_124723

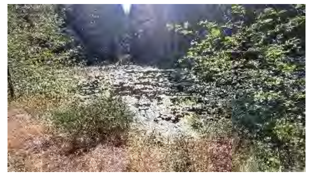

20220831_124728


20220831_124744


20220831_124908

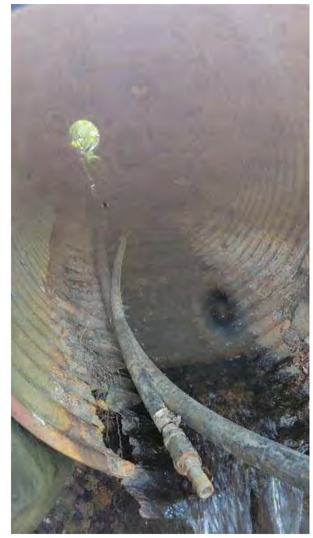

20220831_124951


20220831_124953


20220831_125005


20220831_125407


20220831_125410


20220831_125433


20220831_125435


20220831_125500

THURBER

THURBER

SEISMIC HAZARD CALCULATION

Building Code: NBC2020

Site Location: Lat. 48.786, Long. -123.179

Site Designation	Probability (AEP)	Sa(0.05) [g]	Sa(0.1) [g]	Sa(0.2) [g]	Sa(0.3) [g]	Sa(0.5) [g]	Sa(1.0) [g]	Sa(2.0) [g]	Sa(5.0) [g]	Sa(10.0) [g]	PGA [g]
Xb	1/2475	0.802	1.19	1.16	0.993	0.716	0.405	0.25	0.0643	0.0283	0.506

Selected coordinates are 48.786,-123.179

APPENDIX G

THURBER

Table G-1: Dam Safety Expectations for Money Lake Dam No. 1

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
1	**Dam Safety Analysis**							
1.1	Records relevant to dam safety are available including design documents, historical instrument readings, inspection and testing reports, operational records and investigation results.	X						
1.2	Hazards external and internal to the dam have been defined	X						
1.3	The potential failure modes for the dam and the initial conditions downstream from the dam have been identified	X						
1.4	Inundation study adequate to determine consequence classification. Flood and “sunny day” scenarios assessed.			X			NCi	Unclear if previous dam break analysis considered the “sunny day” failure scenario. Inundation mapping could be improved by completion of more sophisticated assessment incorporating a digital elevation model.
1.5	The Dam is classified appropriately in terms of the consequences of failure including life, environmental, cultural and third-party economic losses.	X						Classification appears appropriate based on current information. Updated inundation mapping would provide additional confidence and assist with emergency planning.
1.6	All components of the water barrier (including retaining walls, saddle dams, spillways, road embankments) are included in the dam safety management process.	X						
1.7	The EDGM selected reflects current seismic understanding	X						Seismic hazard available from NBCC online calculator, updated every ~5 years. The CRD should investigate the feasibility and potential benefits of using the seismic hazard model previously developed for the Sooke Lake and Goldstream River watersheds to obtain more site-specific seismic hazard information for Money Lake Dam.
1.8	The IDF is based on appropriate hydrological analyses	X						
1.9	The dam is safely capable of passing flows as required for all applicable loading conditions (normal, winter, earthquake, flood)	X						
1.10	The dam has adequate freeboard for all applicable operating conditions (normal, winter, earthquake, flood)	X						Confirmed through independent hydrotechnical assessment.
1.11	The dam safety analyses (stability & hydrological) use current information and standards of practice	X						
1.12	The approach and exit channels of discharge facilities are adequately protected against erosion and free of any obstructions and hazards that could adversely affect the discharge capacity of the facilities			X	X			Erosion is occurring at the channel downstream from the spilling basin. Additional riprap should be placed, or the existing riprap should be re-configured.
1.13	The dams, abutments and foundations are not subject to unacceptable deformation or overstressing			X		X		Previous analyses indicate significant embankment deformation could occur during a design level earthquake. More sophisticated deformation assessments have been recommended to evaluate earthquake performance and are currently underway.
1.14	Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion			X	X			As-built information indicates there are unfiltered zones within and below the dam. The presence of sediment within MH1 and MH2 suggests internal erosion may be occurring. This is difficult to establish definitively.
1.15	Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability			X				Hydraulic gradients are considered high enough to cause internal erosion / piping. This in itself is not considered a deficiency.
1.16	Slopes of the embankments have adequate protection against erosion, seepage, traffic, frost and burrowing animals	X						
1.17	Stability of reservoir slopes are evaluated under all conditions and any unacceptable risk to public safety, the dam or its appurtenant structures is identified.	X						
1.18	The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure has been assessed.			X			NCi	Given the lack of an LLO pipe, an emergency drawdown SOP has been prepared but its effectiveness as a potential safety measure has apparently not been evaluated.

THURBER

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
2	**Operation, Maintenance and Surveillance**							
2.1	Responsibilities and authorities are clearly delegated within the organization for all dam safety activities	X						
2.2	Requirements for the safe operation, maintenance and surveillance of the dam are documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure	X						
2.3	The OMS Manual is reviewed and updated periodically when major changes to the structure, flow control equipment, operating conditions or company organizational structure and responsibilities have occurred.	X						
2.4	Documented operating procedures for the dam and flow control equipment under normal, unusual and emergency conditions exist, are consistent with the OMS Manual and are followed	X						
	Operation							
2.5	Critical discharge facilities are able to operate under all expected conditions.	X						Overflow spillway only
a.	Flow control equipment are tested and are capable of operating as required.	X						
b.	Normal and standby power sources, as well as local and remote controls, are tested.		X					No power on site.
c.	Testing is on a defined schedule and test results are documented and reviewed.	X						
d.	Management of debris and ice is carried out to ensure operability of discharge facilities	X						
2.6	Operating procedures take into account:							
a.	Outflow from upstream dams		X					No upstream dams
b.	Reservoir levels and rates of drawdown	X						
c.	Reservoir control and discharge during an emergency	X						
d.	Reliable flood forecasting information	X						
e.	Operator safety	X						
	Maintenance							
2.7	The particular maintenance needs of critical components or subsystems, such as flow control systems, power supply, backup power, civil structures, drainage, public safety and security measures and communications and other infrastructure have been identified	X						Limited flow control infrastructure at this dam.
2.8	Maintenance procedures are documented and followed to ensure that the dam remains in a safe and operational condition	X						
2.9	Maintenance activities are prioritized and carried out with due consideration to the consequences of failure, public safety and security	X						
	Surveillance							
2.10	Documented surveillance procedures for the dam and reservoir are followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety	X						

THURBER

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
2.11	The surveillance program provides regular monitoring of dam performance, as follows:							
a.	Actual and expected performance are compared to identify deviations	X						
b.	Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions	X						
c.	Reservoir operations are confirmed to be in compliance with dam safety requirements	X						
d.	Confirmation that adequate maintenance is being carried out	X						Maintenance tasks are tracked in risk register.
2.12	The surveillance program has adequate quality assurance to maintain the integrity of data, inspection information, dam safety recommendations, training and response to unusual conditions	X						
2.13	The frequency of inspection and monitoring activities reflects the consequences of failure, dam condition and past performance, rapidity of development of potential failure modes, access constraints due to weather or the season, regulatory requirements and security needs.	X						
2.14	Special inspections are undertaken following unusual events (if no unusual events then acknowledge that requirement to do so is documented in OMS).	X						The OMS documents the requirement to undertake special inspections, if required.
2.15	Training is provided so that inspectors understand the importance of their role, the value of good documentation, and the means to carry out their responsibilities effectively.			X			NCi	Training documentation for Saturna Island operations / surveillance staff not found.
2.16	Qualifications and training records of all individuals with responsibilities for dam safety activities are available and maintained			X			NCi	Training documentation for Saturna Island operations / surveillance staff not found.
2.17	Procedures document how often instruments are read and by whom, where the instrument readings will be stored, how they will be processed, how they will be analyzed, what threshold values or limits are acceptable for triggering follow-up actions, what the follow-up actions should be and what instrument maintenance and calibration are necessary.			X			NCs	It doesn't appear that threshold values for instruments have been established that would trigger follow-up actions.
3	**Emergency Preparedness**							
3.1	An emergency management process is in place for the dam including emergency response procedures and emergency preparedness plans with a level of detail that is commensurate with the consequences of failure.	X						
3.2	The emergency response procedures outline the steps that the operations staff is to follow in the event of an emergency at the dam.	X						
3.3	Documentation clearly states, in order of priority, the key roles and responsibilities, as well as the required notifications and contact information.	X						
3.4	The emergency response procedures cover the full range of flood management planning, normal operating procedures and surveillance procedures	X						
3.5	The emergency management process ensures that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain.	X						
3.6	Roles and responsibilities of the dam owner and response agencies are defined.	X						

THURBER

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
3.7	Inundation maps and critical flood information are appropriate and are available to downstream response agencies.	X						The existing inundation map could be approved (see Section 8.2 of report)
3.8	Exercises are carried out regularly to test the emergency procedures.			X			NCp	No such exercises for local operators.
3.9	Staff are adequately trained in the emergency procedures.			X			NCp	Documentation could not be found
3.10	Emergency plans are updated regularly and updated pages are distributed to all plan holders in a controlled manner.	X						
4	**Dam Safety Review**							
4.1	A safety review of the dam ("Dam Safety Review") is carried out periodically based on the consequences of failure.	X						
5	**Dam Safety Management System**							
5.1	The dam safety management system for the dam is in place incorporating:							
a.	policies,	X						
b.	responsibilities,	X						
c.	plans and procedures including OMS, public safety and security,	X						
d.	documentation,	X						
e.	training and review,			X			NCp	Minimum training requirements or frequency is not specified.
f.	prioritization and correction of deficiencies and non-conformances,	X						
g.	supporting infrastructure	X						
5.2	Deficiencies are documented, reviewed and resolved in a timely manner. Decisions are justified and documented	X						
5.3	Applicable regulations are met	X						

Definitions of Deficiencies and Non-Conformances

1) Deficiencies:
   a) Actual – An unacceptable dam performance condition has been confirmed, based on the CDA Guidelines, BC Dam Safety Regulations or other specified safety standard. Identification of an actual deficiency generally leads to an appropriate corrective action or directly to a capital improvement project
      i) (**An**) Normal Load – Load which is expected to occur during the life of a dam.
      ii) (**Au**) Unlikely Load – Load which could occur under unusual load (large earthquake or flood)
   b) Potential – There is a reason to expect that an unacceptable condition might exist, but has not been confirmed. Identification of a potential deficiency generally leads to a Deficiency Investigation
      i) (**Pn**) Normal Load – Load which is expected to occur during the life of a dam.
      ii) (**Pu**) Unlikely Load – Load which could occur under unusual load (large earthquake or flood)
      iii) (**Pq**) Quick – Potential deficiency that cannot be confirmed but can be readily eliminated by a specific action.
      iv) (**Pd**) Difficult - Potential deficiency that is difficult or impossible to prove or disprove.
2) Non-Conformances: Established procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.
   a) Operational (**NCo**), Maintenance (**NCm**), Surveillance (**NCs**)
   b) Information (**NCi**) – information is insufficient to confirm adequacy of dam or physical infrastructure for dam safety.
   c) Other Procedures (**NCp**) – other procedures, to be specified

THURBER

APPENDIX G

APPENDIX H

DAM SAFETY REVIEW ASSURANCE STATEMENT – WATER RESERVOIR DAMS

Note: This statement is to be read and completed in conjunction with the current *EGBC Professional Practice Guidelines – Legislated Dam Safety Reviews in British Columbia*, ("EGBC Guidelines") and is to be provided for dam safety review reports for the purposes of the *Dam Safety Regulation*, BC Reg. 40/2016 as amended. Italicized words are defined in the APEGBC Guidelines.

To: The Owner(s) Date: _March 15, 2023___

Capital Regional District
Name

479 Island Highway, Victoria, BC V9B 1H7
Address

With reference to the *Dam Safety Regulation*, B.C. Reg. 40/2016 as amended.

For the dam:

UTM (Location): 48.7862, -123.1790

Located at (Description): Saturna Island, BC

Name of dam or description: Money Lake Dam No. 1

Provincial dam number: D730145-00

Dam function: Drinking water supply

Owned by: Capital Regional District

(the "Dam")

Current Dam classification is: **(Check one)**

☐ Low
☐ Significant
☑ High
☐ Very High
☐ Extreme

The undersigned hereby gives assurance that he/she is a Qualified Professional Engineer.

DAM SAFETY REVIEW ASSURANCE STATEMENT (CONTINUED)

I have signed, sealed and dated the attached dam safety review report on the Dam in accordance with the EGBC Guidelines. That report must be read in conjunction with this Statement. In preparing that report I have:

Check to the left of applicable items (see Guideline Section 3.2):

☑ 1. Collected and reviewed available and relevant background information, documentation and data

☑ 2. Understood the current classification for the Dam, including performance expectations

☑ 3. Undertaken an initial facility review

☑ 4. Reviewed and assessed the Dam safety management obligations and procedures

☑ 5. Reviewed the condition of the Dam, reservoir and relevant upstream and downstream portions of the river

☑ 6. Interviewed operations and maintenance personnel

☑ 7. Reviewed available maintenance records, the Operations, Maintenance and Surveillance (OMS) Manual

☐ 8. Confirmed proper functioning of flow control equipment

☑ 9. After the above, reassess the consequence classification, including the identification of required dam

☑ 10. Carried out a dam safety analysis based on the classification in 9. Above

☑ 11. Evaluated facility performance

☑ 12. Identified, characterized and determined the severity of deficiencies in the safe operation of the Dam and non-conformances in dam safety management system

☑ 13. Recommended and prioritized actions to be taken in relation to deficiencies and non-conformances

☑ 14. Prepared a dam safety review report for submittal to the regulatory authority by the Owner and reviewed the report with the Owner

☑ 15. The dam safety review report has been reviewed in meeting the intent of APEGBC Bylaw 14(b)(2)

Based on my dam safety review, the current dam classification is: **(Check one)**

☑ Appropriate

☐ Should be reviewed and amended

I undertook the following type of dam safety review: **(Check one)**

☑ Audit

☐ Comprehensive

☐ Detailed design-based multi-disciplinary

☐ Comprehensive, detailed design and performance

DAM SAFETY REVIEW ASSURANCE STATEMENT (CONTINUED)

I hereby give my assurance that, based on the attached dam safety review report, at this point in time:

(Check one)

☐ The Dam is reasonably safe in that the dam safety review did not reveal any unsafe or unacceptable conditions in relation to the design, construction, maintenance and operation of the Dam as set out in the attached dam safety review report

☐ The Dam is reasonably safe but the dam safety review did reveal non-conformances with the *Dam Safety Regulation* as set out in section(s) ____ of the attached dam safety review report.

☑ The Dam is reasonably safe but the dam safety review did reveal deficiencies and non-conformances as described in Table G-1 of the attached dam safety review report.

☐ The Dam is not safe in that the dam safety review did reveal deficiencies and/or non-conformances which require urgent action as set out in section(s) ____ of the attached dam safety review report.

Jay McIntyre, P.Eng.
Name

March 15, 2023
Date

Signature

2302 – 4464 Markham Street, Victoria, BC
Address

250-727-2201
Telephone

2023-03-15

(Affix Professional Seal here)

If the Qualified Professional Engineer is a member of a firm, complete the following:

I am a member of the firm Thurber Engineering Ltd. and I sign this letter on behalf of the firm.

Thurber Engineering Ltd.
Permit to Practice #1001319

Attachment 2

2024 Lyall Harbour Boot Cove Capital Budget

CAPITAL REGIONAL DISTRICT

5 YEAR CAPITAL PLAN

2024 - 2028

Service #: 2.640

Service Name: Lyall Harbour Boot Cove Water (Saturna)

PROJECT DESCRIPTION				PROJECT BUDGET & SCHEDULE									
Project Number	Capital Expenditure Type	Capital Project Title	Capital Project Description	Total Project Budget	Asset Class	Funding Source	Carryforward	2024	2025	2026	2027	2028	5 - Year Total auto-populates
19-01	Replacement	Air Valve Replacement - Ph 2	Replace aging air valves that are a safety concern.	$ 20,000	E	Debt	$ 20,000	$ 20,000	$ -	$ -	$ -	$ -	$ 20,000
19-02	Replacement	PRV Bypass Assembly Replacement	Construct bypasses on the East Point, Narvaez and Boot Cove PRV stations to maintain system operation while the PRV's undergo maintenance.	$ 8,000	E	Cap	$ 8,000	$ 8,000	$ -	$ -	$ -	$ -	$ 8,000
19-03	Replacement	Standpipe and Valve Replacement	Replace the standpipe valves at 119 and 155 East Point Road that are seized and inoperable	$ 8,000	E	Debt	$ 8,000	$ 8,000	$ -	$ -	$ -	$ -	$ 8,000
19-04	New	Alternative Approval Process	Conduct public consultation to inform strategies for a referendum (AAP) to borrow necessary future capital funds. If the grant is not successful.	$ 20,000	S	Res	$ 15,000	$ 15,000	$ -	$ -	$ -	$ -	$ 15,000
19-05	New	Autoflush Installation	Install 3 autoflushes within the water distribution system to maintain distribution wate quality.	$ 20,000	E	Debt	$ 20,000	$ 20,000	$ -	$ -	$ -	$ -	$ 20,000
20-02	New	Raw Water Turbidity Meter	Supply and install a new turbidity meter in the raw water line to aid in operation of the WTP.	$ 10,000	E	Debt	$ 10,000	$ 10,000	$ -	$ -	$ -	$ -	$ 10,000
21-01	Replacement	Source Water Viability Study	Study to determine vulnerability of the source water and its viability and assess recently acquired well.	$ 75,000	S	Debt	$ -	$ 30,000	$ 45,000	$ -	$ -	$ -	$ 75,000
22-01	New	Install Larger Supply Line to Tank	Construct a larger supply line to the tank to improve system reliability and operation.	$ 175,000	S	Debt	$ -	$ -	$ 175,000	$ -	$ -	$ -	$ 175,000
22-02	Renewal	Dam Improvement and Regulatory Requirements	Seismic reinforcement of Money Lake Dam based upon the 2016 Dam Safety Review. Includes seepage pit construction and Dam Safety Review.	$ 750,000	S	Cap	$ 260,000	$ 260,000	$ -	$ -	$ -	$ -	$ 260,000
22-02	Renewal		Currently unapproved portion of required grant funding aligned with GCF and including new well assessments.		S	Debt	$ -	$ -	$ 360,000	$ -	$ -	$ -	$ 360,000
24-01	Replacement	Culvert Replacement for the Water Service	Saturna Island - Harris Road - Culvert Replacement for the Water Service	$ 30,000	S	Grant	$ -	$ 30,000	$ -	$ -	$ -	$ -	$ 30,000
													$ -
													$ -
													$ -
													$ -
													$ -
			GRAND TOTAL	**$ 1,116,000**			**$ 341,000**	**$ 401,000**	**$ 580,000**	**$ -**	**$ -**	**$ -**	**$ 981,000**

Service: **2.640** **Lyall Harbour Boot Cove Water (Saturna)**

Project Number	19-01
Capital Project Title	Air Valve Replacement - Ph 2
Capital Project Description	Replace aging air valves that are a safety concern.
Project Rationale	The air valves are 35 years old and are corroded, giving rise to safety concerns.

Project Number	19-02
Capital Project Title	PRV Bypass Assembly Replacement
Capital Project Description	Construct bypasses on the East Point, Narvaez and Boot Cove PRV stations to maintain system operation while the PRV's undergo maintenance.
Project Rationale	The inlet and outlet piping at the East Point, Narvaez and Boot Cove PRV stations are 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.

Project Number	19-03
Capital Project Title	Standpipe and Valve Replacement
Capital Project Description	Replace the standpipe valves at 119 and 155 East Point Road that are seized and inoperable
Project Rationale	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 the valves and corroded 50mm supply line to the standpipe be replaced. The scope of work and material pricing was re-evaluated in 2016. It was determined that the budget needed to be increased from $5,000 to $8,000 to accommodate the required works.

Project Number	19-04
Capital Project Title	Alternative Approval Process
Capital Project Description	Conduct public consultation to inform strategies for a referendum (AAP) to borrow necessary future capital funds. If the grant is not successful.
Project Rationale	Future required projects to maintain public safety and level of service require funding in excess of current projected reserve balance. Future funding will be for improvements the Water Treatment Plant to increase reliability and optimize for improved operations, conducting a regulatory requirement for a dam safety review and construct a larger supply line to the storage tank.Funding is required to undertake public consultation to inform borrow strategies and conduct a referendum.

Service:	2.640	Lyall Harbour Boot Cove Water (Saturna)

Project Number	19-05	**Capital Project Title**	Autoflush Installation	**Capital Project Description**	Install 3 autoflushes within the water distribution system to maintain distribution water quality.
Project Rationale	Three watermains require frequent flushing to maintain disinfectant residuals and water quality. Flushing requires operator time which can be utilized conducting other maintenance tasks. Funds are required to construct 3 autoflushes.				

Project Number	20-02	**Capital Project Title**	Raw Water Turbidity Meter	**Capital Project Description**	Supply and install a new turbidity meter in the raw water line to aid in operation of the WTP.
Project Rationale	Install a new turbidity meter in the raw water line to aid in operation of the WTP.				

Project Number	21-01	**Capital Project Title**	Source Water Viability Study	**Capital Project Description**	Study to determine vulnerability of the source water and its viability and assess recently acquired well.
Project Rationale	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 de				

Project Number	22-01	**Capital Project Title**	Install Larger Supply Line to Tank	**Capital Project Description**	Construct a larger supply line to the tank to improve system reliability and operation.
Project Rationale	The supply line to the tank is undersized, installation of a larger supply line will improve operation. Funding is required to construct a larger supply line to the tank.				

Service:	**2.640**	**Lyall Harbour Boot Cove Water (Saturna)**	

Project Number	22-02	**Capital Project Title**	Dam Improvement and Regulatory Requirements	**Capital Project Description**	Seismic reinforcement of Money Lake Dam based upon the 2016 Dam Safety Review. Includes seepage pit construction and Dam Safety Review.
Project Rationale	Conduct Dam Safety Review (DSR) report to meet regulatory requirements. Build upon previous 2016 DSR to assess seismic performance and requirements for buttressing and drainage improvements. Once geot				

Project Number	24-01	**Capital Project Title**	Culvert Replacement for the Water Service	**Capital Project Description**	Saturna Island - Harris Road - Culvert Replacement for the Water Service
Project Rationale					

Attachment 3

Money Lake Dam No. 1 Seismic Performance Assessment

THURBER ENGINEERING LTD.

December 5, 2023 File: 21566

CRD Integrated Water Services
479 Island Highway
Victoria, BC V9B 1H7

Attention: Jared Kelly, P.Eng.

LYALL HARBOUR / BOOT COVE WATER SERVICE
MONEY LAKE DAM NO. 1 - 2023 SEISMIC PERFORMANCE ASSESSMENT

Dear Jared:

As requested, this letter presents the results of an updated seismic stability and deformation assessment completed for Money Lake Dam No.1 located on Saturna Island, BC.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. SCOPE OF WORK

Thurber's Scope of Work was described in our proposal to the Capital Regional District (CRD) dated July 27, 2022. Authorization to proceed with the work was received in the form of an amendment to Contract 2019-493, received July 29, 2022. This included completing updated limit equilibrium stability analyses and the design of a toe buttress to limit seismic deformations to a tolerable level.

Adjustments to the Scope of Work were made based on the results of the initial 2D limit equilibrium stability analyses in August 2022. These analyses determined that the size of the seismic buttress necessary to meet the standard factor of safety (FS) requirements would likely exceed the available space downstream of the dam. Based on observations made during a site visit on August 31, 2022, including the observed narrowing of the valley downstream of the dam, it was anticipated that more favourable results could be obtained by assessing seismic performance by completing a 3D analysis of the existing dam (without a buttress). Based on our experience completing similar assessments, it was anticipated the results would demonstrate that adequate seismic performance could be achieved without constructing a buttress.

2. FACILITY DESCRIPTION

Money Lake Dam No. 1 is owned and operated by the CRD and the impoundment provides drinking water to approximately 150 properties with the Lyall Harbour / Boot Cove water service area. Key attributes of the facility are summarized below in Table 1.

THURBER

TABLE 1 – KEY ATTRIBUTES OF MONEY LAKE DAM No. 1

Reservoir Full Supply Level	150.55 m
Dam Crest Elevation	~152.0 m
Normal Freeboard (Full Pool Level)	~1.4 m
Dam Crest Length	~46 m
Dam Crest Width	4.5 m
Embankment Height	~7 m
Original Construction Date	Unknown (prior to May 1978)
Dam Upgrades	Dam raised (1979/1980); Spillway replaced (1986); Intake modified (2004); Piezometers installed (2016)
Dam Construction Type	Zoned earth fill (following 1979 raising)
Upstream Embankment Slope	~2H:1V
Downstream Embankment Slope	~2H:1V (above ramp)

The facility has been assigned a failure consequence classification (FCC) of High per the BC Dam Safety Regulation (B.C. Reg 40/2016). As such, its design earthquake has an annual exceedance probability (AEP) of 1/2,475, which is equivalent to a 2% chance of occurrence in 50 years.

3. BACKGROUND INFORMATION

3.1 Dam History

The dam's current configuration was achieved by a dam raising undertaken in 1979 by the CRD. Based on the available record drawings, the embankment was raised by up to 3.5 m in some areas. The following is a summary of pertinent details related to the dam raising and subsequent modifications:

- For the 1979 raising, the central portion of the embankment was raised using sandy fill materials that were similar to the material used to construct the earlier dam. The dam raising was constructed with 2H to 1V upstream and downstream slopes.
- Seepage collection infrastructure was installed downstream of the dam as part of the dam upgrade, including perforated piping and a manhole (MH1). Additional modifications were made, including the installation of a second manhole closer to the downstream toe (MH2) and additional perforated pipes oriented parallel to the dam crest.
- Subsequently a ramp was constructed across the downstream face of the dam to improve access to the dam crest. A new concrete overflow spillway was also constructed near the dam's right abutment.

THURBER

3.2 Previous Engineering Studies

3.2.1 2016 Tetra Tech EBA Engineering Assessment

Following up on one of the recommendations from the 2011 DSR, the CRD retained Tetra Tech EBA Inc. (Tetra Tech) in 2016 to complete a geotechnical investigation and slope stability analysis for the dam. The following is a summary of the relevant findings from the assessment:

- An FS > 1.5 was calculated for both the upstream and downstream slopes of the dam under static conditions, indicating the stability of the embankment meets the minimum CDA requirement for static conditions.
- An FS of less than 1.0 was calculated for both the upstream and downstream pseudo-seismic analyses considering the full PGA of 0.48 g for the 1/2,475 seismic event. This finding means the dam does not meet the minimum CDA recommendations (CDA recommend FS ≥ 1.0) and that permanent deformations would be expected to occur under a design level earthquake. Using a simplistic deformation analysis method, permanent embankment displacements up to 0.65 m were estimated, which are generally assumed to occur along a critical slip surface.
- FS values of 0.8 and 0.6 were calculated for the post-earthquake slope stability analysis case for the upstream and downstream slopes (recommended minimum is FS ≥ 1.2), indicating the embankment does not meet the minimum CDA requirements. An FS < 1.0 for the post-earthquake condition also indicates the potential for a flow slide to occur, which may cause a sudden release of the reservoir.
- Given the predicted results, repair of the dam would be required following the design seismic event.

Tetra Tech recommended that dam upgrades be carried out to improve seismic performance. To meet dam safety expectations, Tetra Tech recommended either removing or replacing the dam or adding a downstream buttress along with other improvements related to mitigating the risk of internal erosion. Tetra Tech characterized the second option (i.e., the addition of a seismic buttress at the downstream toe) to be a risk mitigation measure as this approach would not address the failure of the upstream slope into the reservoir during a design level earthquake. The intent of the buttress would be to limit the deformation of the downstream slope such that a breach of the dam would not occur during or immediately after the earthquake. Depending on the level of damage, the dam may leak significantly following the earthquake and may require repairs.

3.2.2 2018 Thurber Conceptual Design

Thurber was retained in 2018 to conduct a conceptual design for the seismic buttress proposed in 2016 by Tetra Tech. The assessment utilized limit equilibrium analysis software to evaluate slope stability and used the interpreted dam cross-section developed by Tetra Tech in 2016, along with the same seismic design ground motions, which were obtained from Natural Resource Canada's (NRC) 2015 NBCC seismic hazard calculator.

THURBER

To achieve the minimum factors of safety recommended by the CDA, Thurber's analysis indicated the buttress would have an approximately height of 3.5 m, an approximate top width of 10 m (measured perpendicular to the dam centreline) and a downstream slope of 3H to 1V. Additionally, to achieve the desired results, the buttress design required that the ground below the buttress would undergo improvement to improve its strength. It was envisioned that this would involve sub-excavating potentially liquefiable soils from below the buttress and replacing them with compacted granular fill.

Tetra Tech's 2016 geotechnical assessment had indicated that liquefaction would be triggered in the foundation soil under the dam during a design level earthquake. Tetra Tech had recommended that the 'liquefaction during earthquake' scenario be considered during the buttress design. Given the likelihood of localized pockets of liquefied soil under the dam, it was not expected that the FS will remain above 1.0 during a larger earthquake, and in these circumstances an assessment of permanent deformation is required to assess the level of damage to the dam. The presence of liquefiable zones under the dam complicated the assessment, as simplified analysis methods are generally not reliable for estimating permanent ground deformations for sites with significant amounts of liquefied soil. Using a semi-empirical statistical analysis method, permanent deformations larger than 1 m were predicted and indicate the dam could experience significant damage as a result of earthquake even if the proposed seismic buttress were constructed.

Thurber suggested that more favourable results could possibly be achieved by utilizing more sophisticated analysis software (i.e., that incorporates complex soil models that can accommodate larger strains). Thurber's 2018 report also recommended that geotechnical investigations be completed to confirm the depth to sandstone bedrock to inform the seismic stabilization design as well as the design of a proposed toe filter.

3.2.3 2019 Thurber Geotechnical Investigations

Thurber completed phased geotechnical investigations in 2019 to better characterize the subsurface conditions and bedrock profile under and downstream of the dam. This work included both excavated test pits and drilled test holes. The investigation confirmed that the bedrock dips gradually in the downstream direction, but more steeply towards the left abutment. Buried stream channel deposits were generally found to the fill a depression in the bedrock surface under the dam and to be intermixed with colluvium deposits below the toe of the left abutment slope. The buried channel deposits are generally located below the groundwater table and vary in penetration resistance from very loose to compact. The colluvium was also very loose in some zones.

THURBER

4. SEISMIC HAZARD

The seismic hazard at Money Lake Dam No. 1 is influenced by three sources of earthquake shaking:

Crustal events: earthquakes that are within the crust of the North American plate,

Inslab events: deeper earthquakes beneath the Strait of Georgia and Puget Sound that are within the subducted plate,

Subduction zone events: giant "megathrust" earthquakes that occur off the west coast of Vancouver Island.

Each of these earthquake sources contributes to the seismic hazard in different proportions depending on the location of the site and on the period of ground motion considered. Each of the three seismic sources can produce damaging earthquakes (Rogers et al., 2015).

In the absence of a site-specific data, seismic hazard across Canada can be estimated using NRC's sixth generation (2020) seismic hazard model and its online hazard calculator. The calculator uses seismic hazard maps prepared by the Geological Survey of Canada (GSC) which are derived from statistical analysis of past earthquakes and from the advancing knowledge of Canada's tectonic and geological structure. Ground motion probability values are provided in terms of an annual exceedance probability (AEP) which is the likelihood of a given ground motion being exceeded within a particular time duration.

The 6th generation seismic hazard maps were recently released in preparation for the 2020 National Building Code of Canada (NBCC). In terms of local hazard, the principal changes to the new seismicity model are: 1) changes to the recurrence of the Cascadia subduction earthquake from an inter-event period of 532 years to 432 years, 2) breaking up the Strait of Georgia source zone into 3 smaller zones with varying depths to reflect the dip of the inslab source, and 3) inclusion of the Leech River Valley and Devil's Mountain Faults near Victoria. Table 2 below presents the seismic hazard obtained from the NRC calculator assuming seismic site class B (weak rock)

TABLE 2 – 2020 NBCC SEISMIC HAZARD VALUES (SITE CLASS B)

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)
1/2475	0.802	1.19	1.16	0.993	0.716	0.405	0.250	0.064	0.028	0.506

Sa = spectral acceleration in units of g (9.81 m/s^2)

THURBER

5. 2022/2023 THURBER ANALYSES

5.1 2D Limit Equilibrium Analyses

After receiving authorization to proceed, Thurber completed updated 2D limit equilibrium analyses using the new subsurface information obtained from the 2019 geotechnical investigations. The analysis results were similar to those obtained in 2018 and indicated that an impractically large buttress would be required to reduce earthquake deformations to a tolerable level. For this reason, Thurber recommended completing more sophisticated seismic deformation analyses that would incorporate 3-dimensional effects related to the narrowing valley downstream of the dam and the relatively confined zone of liquefiable deposits located under the dam (i.e., within a bedrock-controlled channel).

5.2 3D Finite Element Analysis

5.2.1 Analysis Methodology

Seismic slope displacements are conventionally estimated by using a combination of 2D limit equilibrium slope stability analyses (such as the software program Slope/W) combined with Newmark analyses to estimate seismic deformations. A true Newmark analyses requires earthquake time-histories which are numerically integrated to calculate displacements. The Newmark method is typically employed in practice using empirical correlations to actual Newmark analyses.

As discussed above, Thurber completed a revised assessment of the seismic performance of the dam that includes the effects of the 3-dimensional configuration of the dams and foundation soils. The seismic performance was assessed by predicting the slope displacements in the downstream direction using a combination of the 3-dimensional finite element program Plaxis 3D and Newmark deformation analyses. The Newmark analysis used the computer code from the United States' Geological Survey's software program Newmark implemented in Microsoft Excel using Visual Basic.

To calculate the Newmark displacement, the slope yield acceleration (i.e., the pseudo-static horizontal acceleration) needs to be determined. In limit equilibrium this is accomplished by increasing the horizontal acceleration until the factor of safety reduces to 1.0. The procedure is similar in the finite element method, except that the finite element method uses a strength reduction factor instead of a factor of safety. The finite element method using a strength reduction factor has been shown to calculate the same factor of safety and slope failure mechanism as limit equilibrium methods (Griffiths and Lane, 1999). Accordingly, using Plaxis 3D in this way is equivalent to completing a limit equilibrium analysis with the added benefit of accounting for 3-dimensional effects in the overall analysis.

The seismic hazard for the project was based on the uniform seismic hazard data from Natural Resource Canada's (NRC's) sixth generation (2020) seismic hazard model. The uniform seismic hazard is the aggregated seismic hazard from the three contributing earthquake types (i.e., the component crustal, inslab and subduction earthquakes). However, the NRC only provides the

THURBER

seismic deaggregation up to the fifth-generation seismic hazard model (2015) and does not intend to provide it for the 2020 seismic hazard model. This deaggregation is required to develop earthquake time-histories with the frequency contents representative of the three earthquake types.

In order to develop the required 2020 seismic hazard earthquake time histories, we scaled time-histories that were matched to the 2015 seismic hazard for the crustal, inslab and subduction earthquakes to the 1 in 2,475-year return period 2020 uniform seismic hazard for seismic site class B (weak rock). This data is available on-line from NRC's 2015 and 2020 seismic hazard calculators and NRC Open File 8090.

The time histories were based on seed time histories for the component earthquakes that were scaled and matched to the relevant part of the 2015 NRC uniform hazard spectra (UHRS). The seed crustal time histories were obtained from NGA West2 PEER ground motion database and the seed inslab and interface time histories were obtained from the USGS and CGS's Center for Engineering Strong Motions Data. The seed time histories were scaled and matched to the site-specific target UHRS using the software program SeismoMatch published by Seismosoft, which uses the wavelet addition algorithm RSPMATCH developed by N. Abramson. Three time-histories were developed for each scenario earthquake.

5.2.2 Analysis Results

The Plaxis 3D modeling was based on the dam configuration and interpretation of geotechnical conditions shown on Figures A1, A2 and A3 in Appendix A. The model assumed that the sand and gravel is entirely liquefiable under the design level earthquake. The material properties used in the model are summarized in Table 3 below.

TABLE 3 – MATERIAL PROPERTIES USED IN ANALYSIS

Soil Type	Density (kN/m^3)	Strength (Degrees)
Dike core	19	35
Dike shell	20	40
Non-liquefiable subgrade	20	40
Liquefiable subgrade	18	5.7

As discussed by Griffiths and Lane (1999) the elastic soil properties have an insignificant effect on the factor of safety and slope failure mode. Accordingly, the elastic modulus and Poisson's ratio were taken and 100 MPa and 0.2 for all materials, respectively. The model configuration (looking downstream) is shown in Figure 1 below.

THURBER

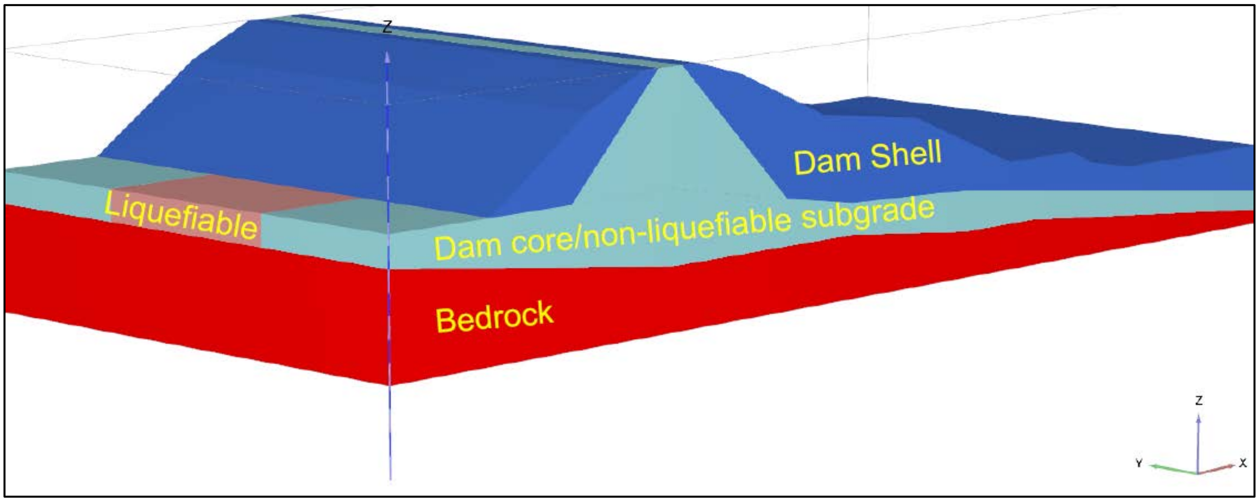


Figure 1: Plaxis 3D model configuration.

To assess the slope yield acceleration, a pseudo-static horizontal acceleration was applied in the downstream direction. The pseudo-static horizontal acceleration was incrementally increased until the model did not converge. The slope yield acceleration was taken as the highest pseudo-static horizontal acceleration where the model converged. Following convergence, a strength reduction factor analysis was completed to confirm the equivalent factor of safety. This analysis shows that at a pseudo-static horizontal acceleration of 0.185g, the downstream slope has a factor of safety of 1.05, which indicated the horizontal yield acceleration is about 0.185g. Output from the 3D finite element pseudo-static stability analysis is shown below. Small deformations are shown in blue and large deformations are show in red. The model shows that the slope failure mode is a narrow “slice” above the liquefied channel deposits and not failure of the entire dam, as would be predicted by a 2D analyses.

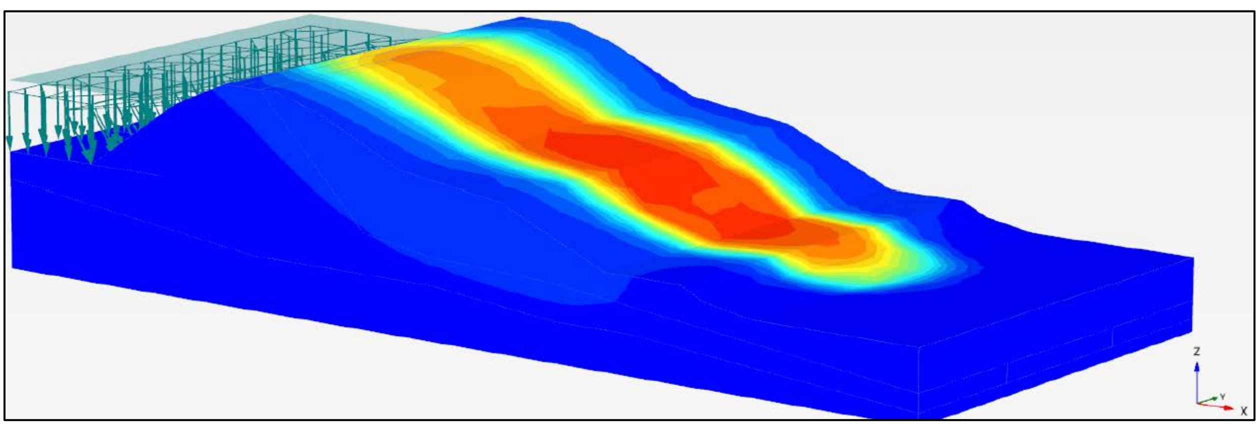


Figure 2: Plaxis 3D deformation analysis results.

THURBER

Newmark displacements were calculated using the six time histories developed for each of source zones (i.e., crustal, inslab and subduction). These time histories that were matched and scaled to the 2020 uniform seismic hazard as described above. The earthquakes were analysed in both directions (i.e., north-south and south-north) which resulted in a total of 36 Newmark analyses. The results of the Newmark analyses predict average seismic displacements of the downstream slope of about 30 mm for the crustal earthquake, 200 mm for the inslab earthquake and less than 5 mm for the subduction earthquake. Accordingly, the inslab earthquake controls the predicted displacement for the 1 in 2,475-year return period 2020 uniform seismic hazard.

6. DISCUSSION

The results of the finite element seismic deformation analysis indicate there are significant benefits related to 3-dimnensional effects at the Money Lake Dam site. It was determined that inslab seismic events will cause in the largest permanent deformations, and that displacements in the downstream direction up to ~200 mm are predicted for the design earthquake (1/2,475 AEP). Given the inherit uncertainties related to modeling the performance of earthen structures during earthquakes, it is common to assume that the actual deformations could range from 50% to 200% of the predicted amount, which would correspond to permanent deformations in the order of 100 mm to 400 mm. These results are significantly less than the deformation predicted using simpler analytical methods. Although these findings indicate that post-earthquake repairs may be required, a sudden collapse of the structure is not predicted. The anticipated damage would include surface cracking and subsidence near the centre of the dam, following the general pattern illustrated in Figure 2 above.

As identified in the OMS Manual for Money Lake Dam, the CRD should (promptly) complete an inspection of the dam following an earthquake to look for signs of sliding, cracking, bulging or increased seepage. An increased level of surveillance should also be initiated following a major earthquake as described in the manual. Depending on the observed performance, emergency response procedures may need to be implemented as outlined in the Dam Emergency Plan, including taking measures to lower the reservoir level and potentially evacuate properties located within the defined inundation zone until a suitable review of the dam's condition can be completed.

Emergency repairs could consist of placing well graded granular fill on the downstream slope of the dam to increase stability, as well as restoring a consistent crest elevation. If significant damage is apparent following an earthquake, the reservoir should be lowered to permit an inspection of the upstream slope.

THURBER

7. CLOSURE

We trust the above provides the information you require at this time. If you have any questions regarding this report, please contact us.

Yours truly,
Thurber Engineering Ltd.
Steven Coulter, M.Sc., P.Eng.
Review Engineer

Thurber Engineering Ltd.
Permit to Practice #1001319

Jay McIntyre, M.A.Sc., P.Eng.
Senior Geotechnical Engineer

Attachments:

- Statement of Limitations and Conditions
- Appendix A – Figures

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

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

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

3. BASIS OF REPORT

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

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

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

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

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

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

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

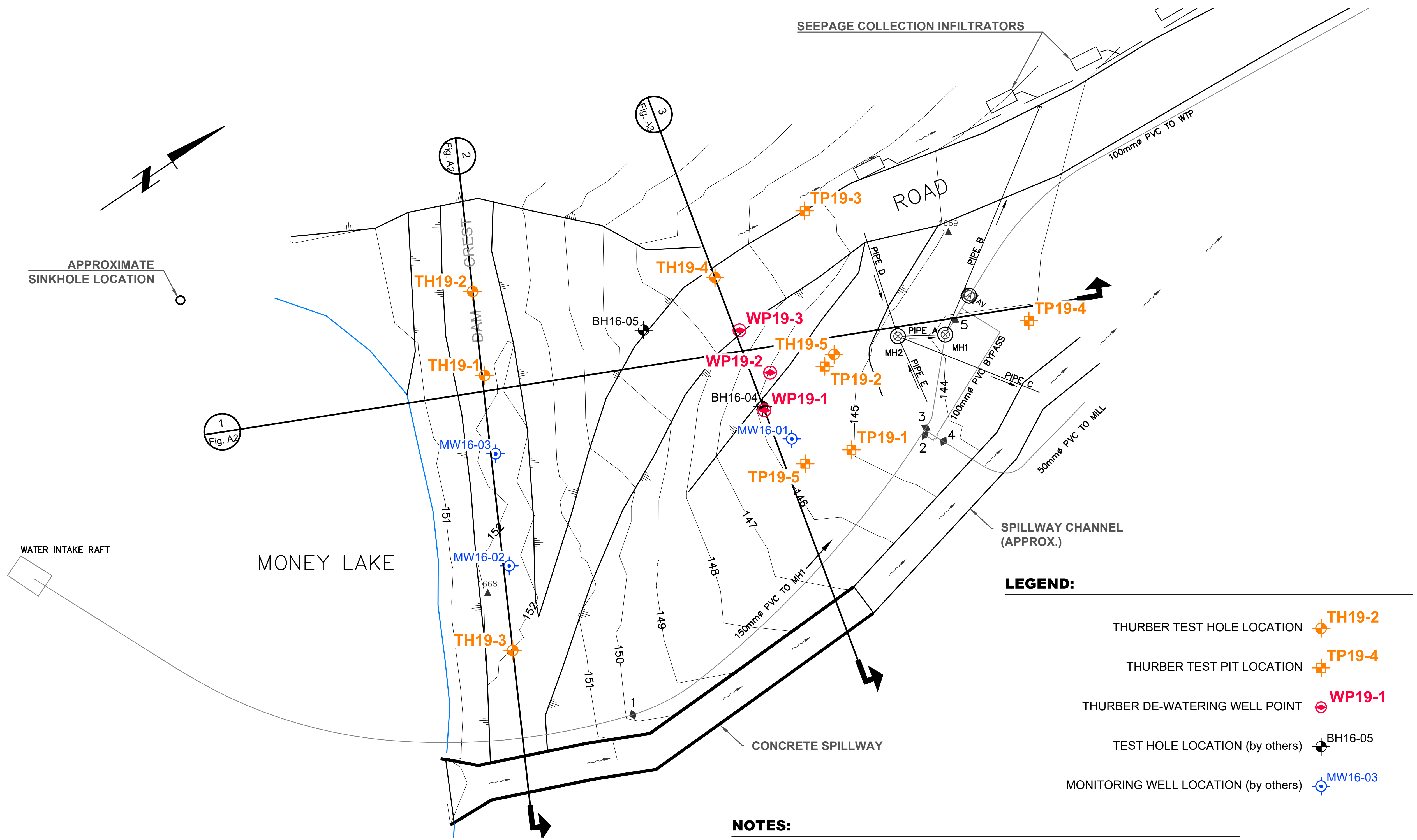
The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or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

THURBER

APPENDIX A

MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SITE PLAN

SCALE 1:300



0 2 4 6 8 10 15 20m
SCALE 1:300

NOTES:

1. THURBER TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. BASE PLAN, INCLUDING LOCATIONS OF TEST HOLES AND MONITORING WELLS BY OTHERS, TAKEN FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.
3. 75 mm DIAM.PVC SEEPAGE RETURN PIPE NOT SHOWN.

FIGURE A1

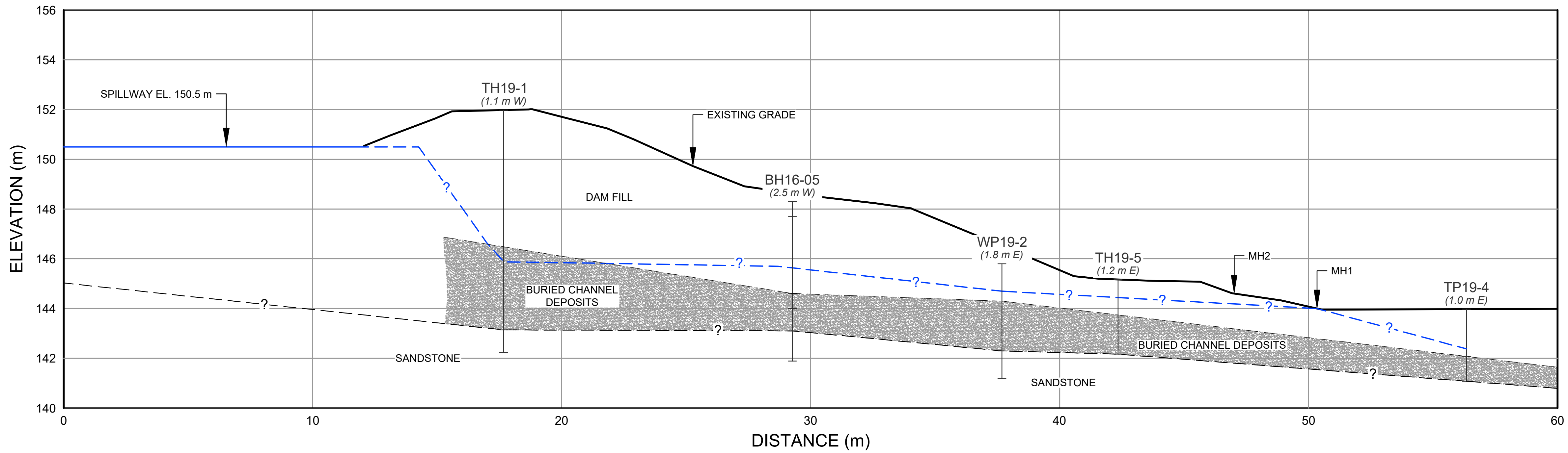
Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

Date: April 21, 2023

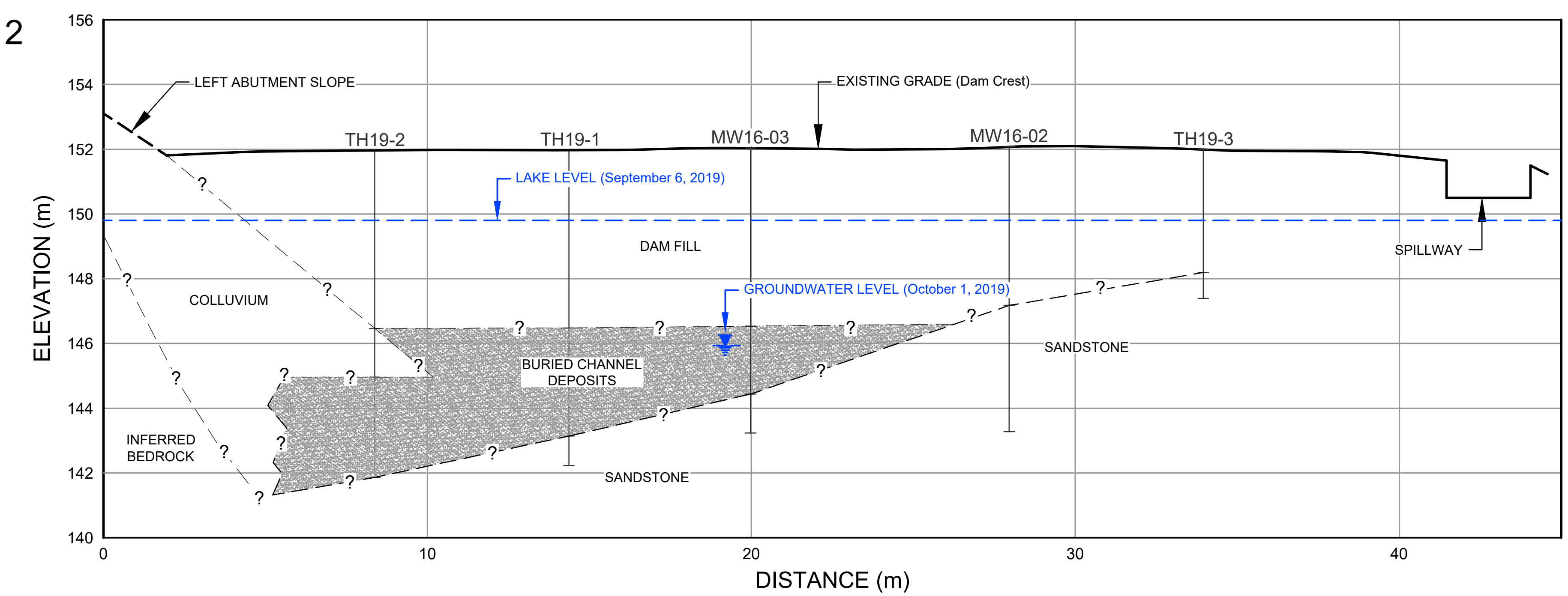
MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SECTIONS 1 & 2

SCALE 1:200

SECTION 1



SECTION 2



0 2 4 6 8 10 12m
SCALE 1:200

NOTES:

1. TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. SUB-SURFACE MATERIAL TYPES ARE BASED ON ENGINEERING INTERPRETATION OF THE AVAILABLE DATA. SEE LOGS FOR DETAILED INFORMATION.
3. GROUND SURFACE LINE DERIVED FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.

FIGURE A2

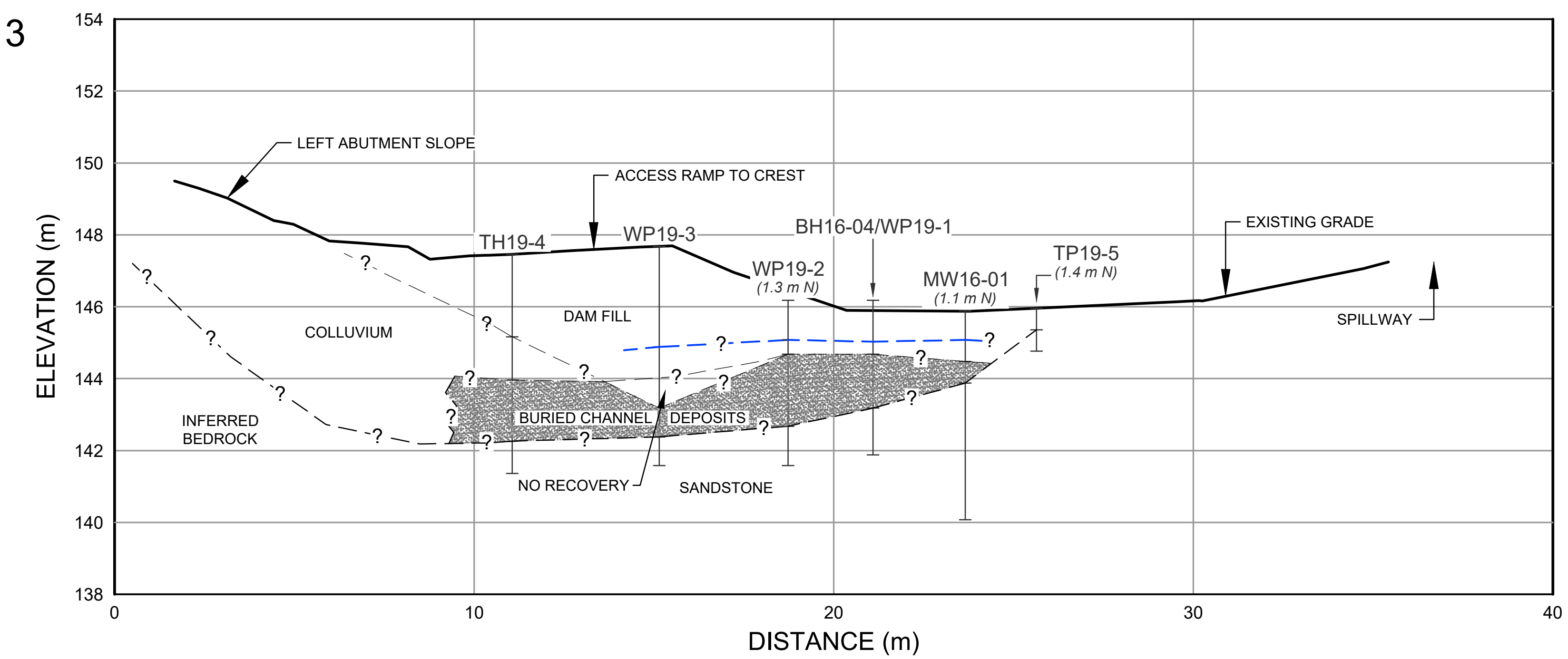
Date: April 21, 2023

Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

MONEY LAKE DAM № 1
2022 DAM SAFETY REVIEW - SECTIONS 3

SCALE 1:200

SECTION 3



NOTES:

1. TEST HOLE, TEST PIT AND DE-WATERING WELL POINT LOCATIONS ARE APPROXIMATE ONLY.
2. SUB-SURFACE MATERIAL TYPES ARE BASED ON ENGINEERING INTERPRETATION OF THE AVAILABLE DATA. SEE LOGS FOR DETAILED INFORMATION.
3. GROUND SURFACE LINE DERIVED FROM AUTOCAD FILE "MONEY DAM 2018.DWG" PROVIDED BY CRD.

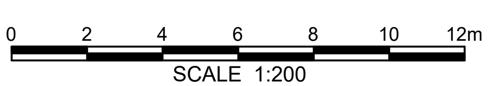


FIGURE A3

Client: Capital Regional District
File No.: 21566
E-File: 21566-CAD002.dwg

Date: April 21, 2023