Final Report for

February 25, 2021

Elinor Lake North Dam
2020 Dam Safety Review Report

For Regional District of Okanagan-Similkameen

HATCH

H362819-00000-228-230-0003

Report

Elinor Lake North Dam - 2020 Dam Safety Review Report

H362819-00000-228-230-0003

Feb. 26, 2021

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA S. J. MURPHY # 48322

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA D. V. BONIN # 42966
2021-02-26

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA P. ASHAYER # 43014
2021-02-26

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA A. PASHAN # 33146
2021-02-26

2021-02-25	**0**	**Approved for Use**	**S. Murphy/ P. Ashayer**	**D. Bonin**	**A. Pashan**
DATE	**REV.**	**STATUS**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**
				Discipline Lead	**Functional Manager**

Disclaimer

The Elinor Lake North Dam – 2020 Dam Safety Review report and all associated reference files have been prepared by Hatch Ltd. for the sole and exclusive use of the Regional District of Okanagan-Similkameen (RDOS) (the "Client") for the purpose of assisting the management of the Client in making decisions with respect to this structure. Any use which a third party makes of this report and all associated reference files, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Hatch accepts no responsibility or liability for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report contains opinions, conclusions and recommendations made by Hatch, using its professional judgment and reasonable care. Use of or reliance upon this report by the Client is subject to the following conditions:

a) The report and associated reference files being read in the context of and subject to the terms of contract RDOS-20-PW-04 between Hatch Ltd. and the Client dated May 8, 2020 (the "Agreement"), including any methodologies, procedures, techniques, assumptions and other relevant terms or conditions that were specified or agreed therein.

b) The report being read as a whole, with sections or parts hereof read or relied upon in context.

c) The conditions of Elinor Lake North Dam may change over time or may have already changed due to natural forces or human intervention, and Hatch takes no responsibility for the impact that such changes may have on the accuracy or validity or the observations, conclusions and recommendations set out in this report.

d) The report is based on information made available to Hatch by the Client or by certain third parties; and unless stated otherwise in the Agreement, Hatch has not verified the accuracy, completeness or validity of such information, makes no representation regarding its accuracy and hereby disclaims any liability in connection therewith.

Table of Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

A Dam Safety Review (DSR) of the Elinor Lake North Dam and associated works was carried out by Hatch. The review has been completed in compliance with the Engineers and Geoscientists B.C. (EGBC) Professional Practice Guidelines – Legislated Dam Safety Reviews V3.0 [EGBC, 2016], Canadian Dam Association – Dam Safety Guidelines published in 2007 (revised 2013) [CDA, 2013a], meeting the requirements of the B.C. Water Sustainability Act and the B.C. Dam Safety Regulation [Reg. 44/2016], and generally accepted engineering practice.

A dual classification system was adopted for this dam, as described in the report "Naramata Dam Breach Assessment and Inundation Mapping" (Hatch, 2021) carried out as part of this study. Under this type of system, spill capacity is solely determined based upon the potential incremental consequences of failure during a potential flood. A second classification, used for establishing the level of care for other aspects of dam safety, is determined through an evaluation of the worst case of potential incremental consequences of failure – whether caused by a Sunny Day event or failure during one of the IDF Flood events. This worst case will govern for dam classification for all aspects of dam safety except spill capacity. Elinor Lake South Dam is considered to be a Very High classification dam in terms of loss of life and potential damage in the event of an uncontrolled release of the impounded water for all aspects of dam safety except for spill capacity, where it is considered a High classification. Therefore, the associated Inflow Design Flood (IDF) for this classification is 1/3 between the 1,000 year flood and PMF with a peak flow of 2.4 m3/s which can be discharged at a reservoir level of 1277.17 m.

This report represents the condition of the dam and ancillary structures at the time of the site visit on July 9, 2020. The geotechnical analysis is representative of the site conditions during construction and previous field investigations as no drilling program was included as part of this study. This constitutes the second formal DSR completed for the Elinor Lake North Dam. The first was completed in 2010 by EBA.

The discussion, conclusions and recommendations of this DSR are based on a review of selected project information including drawings, reports, manuals, photographs, instrumentation records and other miscellaneous documents as well as detailed visual site observations/assessments of all accessible components of the site and discussions with operating and surveillance staff.

This review follows a full dam breach analysis, consequence classification and inundation mapping study conducted as part of this project. The dam breach study includes an updated assessment of the hydrology/hydraulic aspects of the project, including an assessment of the IDF, and a review of the hydraulic capacity of the project. This report can be found under separate cover in Naramata Dam Breach Assessment and Inundation Mapping (2021). Results from this analysis are used to inform the studies within this report. In addition, this dam safety review includes a review of freeboard considerations to ensure capability to safely pass the specified IDF.

This review includes a review and assessment of the geotechnical and concrete components of the works, including an evaluation of the performance of the dam and foundations up to the time of the site visit, the nature, condition and suitability of the instrumentation and monitoring systems, and the process of evaluating and reporting on data.

This report recommends that the next independent DSR be done in 2030 to comply with the B.C. Dam Safety Regulation [B.C. Reg 44/2016] under the Water Sustainability Act.

As stated in the DSR assurance statement this DSR found that the “Dam is reasonably safe but the dam safety review did reveal deficiencies and non-conformances as set out in Section 12 attached dam safety review report”. These items are summarized along with recommended actions in the following List of New and Existing Outstanding Deficiencies and Non-Conformances. The issues identified were classified based on non-conformance, actual deficiency or potential deficiency. The actual and potential deficiencies were given an overall priority rating of the risks, defined as high, medium and low, based upon the potential of the issue leading to a critical failure of the structure. The non-conformances were assigned a ranking of high, medium or low based on how they impact dam safety. The actual or potential deficiencies and non-conformances are summarized in Table E-1.

Table E-1: List of New and Existing Outstanding Deficiencies and Non-Conformances

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating
EN-1	Dam classification – dam is currently classified as High consequence. Recommended dam classification is Very High.	2020 DSR FLNRO, 2019		New	Classify the Elinor North Dam as a Very High consequence dam. This should be reviewed annually in accordance with the BC Dam Safety Regulation, noting changes downstream of the dam.	Low
EN-2	Poor documentation currently exists of the dam construction and performance history, site-specific geotechnical information, embankment materials, among other details. The Elinor North dam is assumed to use the same construction methodology and materials as the Elinor South Dam. This includes the presence of an impervious core, however this could not be confirmed. The 2010 DSR recommended a topographic survey of the dam (EBA, 2010).	2010 DSR, FLNRO, 2019 2020 DSR	NCi	Outstanding	If not already completed, a thorough review should be conducted for records related to design, construction and performance of the dam. In the absence of geotechnical data, detailed analyses of the dam's stability, and resilience against risks such as seepage and seismic events cannot be evaluated in detail.	Medium
EN-2b	There is no topographic survey to confirm elevations.	2010 DSR		Resolved		
EN-2c	Lack of as-built information. Geotechnical information not available.	2020 DSR	Nci	Outstanding	A geotechnical investigation should be conducted to provide necessary input for further engineering analyses. The investigation should consist of test pits and boreholes at the dam crest to attempt to locate and characterize the material zones of the dam, if present. Laboratory and in-situ testing should be conducted to determine the material properties.	High
EN-2d	Lack of instrumentation.		NCi,s	Outstanding	Piezometer(s) should be installed with the borehole drilling to enable continued monitoring of the pore water pressure conditions within the dam.	N/A
EN-3	There is currently no ability to measure quantity of seepage in areas where seepage has been observed historically.	2010 DSR 2020 DSR	NCi,s	Outstanding	If possible, install new weir at the downstream toe of the dam to allow for quantitative measurement of seepage flows. A seepage monitoring program should be developed and maintained.	Medium
EN-4	Evidence of seepage was observed at the downstream toe. However, heavy vegetation limited access to the area where seepage was observed.	2010 DSR FLNRO, 2019 2020 DSR	NCs	Outstanding	Extend limits of vegetation clearing downstream of the dam to allow for inspection of the toe and regular seepage observations.	Medium
EN-5	A detailed geotechnical assessment could not be completed due to the absence of construction documentation and site-specific geotechnical data. The dam is potentially susceptible to failure modes including slope instability, piping, and liquefaction.	2010 DSR 2020 DSR	NCi	Outstanding	Geotechnical assessments should be undertaken upon completion of the recommended geotechnical investigation. These should evaluate risks of common failure modes including seismic and normal slope stability, piping, and liquefaction. It is expected that the results of these assessments may lead to a recommendation for construction of a toe berm or similar improvements to limit seepage and increase the stability of the dam at the downstream toe. In addition, internal stability assessment of dam core and filter compatibility assessment should be conducted.	High
EN-6	The risk of piping failure was found to be in the unacceptable risk zone as outlined by the CDA Guidelines (EBA, 2010)	2010 DSR	NCi, An	Outstanding	The risk level remains similar to the previous assessment, however, due to an increase in dam classification the acceptable risk threshold decreases and this further emphasize on the unacceptable condition. The recommendations above to complete a geotechnical investigation and improve seepage monitoring and instrumentation can contribute to reducing the risk of piping failure.	Medium
EN-7	Topographic survey data from 2012 shows the dam crest elevation is lower than the assumed design elevation of El. 1278 m (EBA, 2013), assumed as there is no original design documentation is available for this dam. The topographic survey shows a minimum crest elevation of approximately 1277.31 m. Flood routing and freeboard analysis indicates that during the IDF, the reservoir surcharges to El. 1277.31 m when wind and wave effects are included, with no remaining additional freeboard to the lowest portion of the dam. This meets CDA requirements. However, overall risk should be taken into consideration, including unknown material and erodibility, and the presence of ATV traffic causing rutting. Any additional loss of freeboard in the dam would result in a deficiency.	2010 DSR FLNRO, 2019 2020 DSR	NCm	Outstanding	Place material to re-grade the crest to the design/typical elevation to provide additional freeboard.	High

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating
EN-8	Security/access issues leading to damage on dam crest and face from ATV traffic. Recent inspections also note damage by cattle and vehicles. Note that any additional loss of freeboard would result in a freeboard deficiency.	2010 DSR FLNRO, 2019 2019 Risk Survey 2020 DSR	NCp	Outstanding	Review security and access protocols and implement appropriate restrictions including those recommended in the 2019 Risk Control Study (Precise Services, 2019) to prevent damage or vandalism.	High
EN-9	No Operations, Maintenance and Surveillance (OMS) manual was prepared for the dam as of the previous Dam Safety Review.	2010 DSR		Resolved		
EN-10	Dam Safety Review schedule	2020 DSR		New	In accordance with the High consequence classification, the next Dam Safety Review should be conducted in 2030, and every 10 years thereafter.	N/A
EN-11	Dam Emergency Plan – the Emergency Preparedness Plan (EPP) should be updated to comply with the updated requirements for a Dam Emergency Plan (DEP) in the Dam Safety Regulation.	FLNRO, 2019 2020 DSR		Resolved		
EN-12	Lack of sufficient instrumentation and data assessment for performance monitoring	2020 DSR		New	The instrumentation monitoring shall include continuous records, plotting, and interpretation of seepage flow quantities against reservoir elevation. The piezometer information should be closely monitored once available.	Medium
EN-13	Currently no riprap or erosion protection layer on the dam crest or upstream slope.	2020 DSR	NCm	New	Provide appropriately sized armour protection along the upstream face of the dam from the crest to 1 m below the low water level.	Low
All-1	OMS could be improved by including supporting confirmation that highlighted maintenance activities are being completed.	2020 DSR	NCs	New	Regular verification of the completion of maintenance items recorded in the weekly site surveillance form would further support that maintenance items are being completed.	Low
All-2	OMS does not have a table with positions and associated names describing roles and responsibilities.	2020 DSR	NCo	New	Update table in OMS to include positions and associated names describing roles and responsibilities.	Medium
All-3	Routine Dam Inspection Report format does not contain all aspects of BC Dam Safety Office's Site Surveillance Form for weekly inspections.	2020 DSR	NCp	New	Routine Dam Inspection Report format should be improved to more closely follow the BC Dam Safety Site Surveillance Form for weekly inspections.	Low
All-4	No formal Dam Safety Policy is in place for their dam safety program.	2020 DSR	NCp	New	The RDOS appears to be meeting the intent of a dam safety management system and should continue to improve and develop their system and adopt a formal policy statement on Dam Safety for their program to satisfy the CDA Dam Safety Guidelines. This will demonstrate a commitment to the regulation and provide a reason to perform necessary works.	Medium
All-5	OMS could be improved by including more information to assist Dam Safety inspectors in detecting and responding to an emergency situation.	2020 DSR	NCp	New	In the OMS, inflow forecasting should include alarm limits on what scenario of Snow Survey combined with reservoir levels would create a need for action. Actions to be taken should be described. Any recommended drawdown in anticipation of large spring runoff events should also be documented.	Medium
All-6	Emergency notification systems to alert the public should be expanded to include a text message template to facilitate public notification in the event of an emergency.	2020 DSR	NCp	New	It is recommended that the RDOS emergency call alert system, CivicReady be setup to allow for public signup in order to receive external text message notifications during an emergency.	Medium
All-7	No available documentation provided to show if regular dam safety training is provided to the inspector(s).	2010 DSR, 2020 DSR	NCs	Outstanding	RDOS staff responsible for the DEP should regularly attend BC Dam Safety Dam Management seminars on dam safety and inspections (understood to be provided annually in most areas of BC, including Penticton). Records of attendance at these inspection workshops should be documented along with information on any additional training completed. This could include review of material provided on BC Dam Safety website.	Medium
All-8	No available documentation to show that exercises are carried out regularly to test the emergency procedures.	2020 DSR	NCp	New	Provide documented training to staff in emergency procedures and carry out and document regular exercises to test the emergency procedures. Follow additional recommendations in proposed new Dam Emergency Plan (DEP) procedure.	Medium

Refer to Table 12-1 *for legend and definitions of the type of deficiencies and non-conformances.*

1. Introduction

1.1 DSR Report Purpose and Scope

This report has been prepared by Hatch Ltd. (Hatch) for the Regional District of Okanagan-Similkameen (RDOS) to document the Dam Safety Review (DSR) that was conducted for the Elinor Lake North Dam. The review has been completed in compliance with the Engineers and Geoscientists B.C. (EGBC) Professional Practice Guidelines – Legislated Dam Safety Reviews V3.0 [EGBC, 2016], Canadian Dam Association – Dam Safety Guidelines published in 2007 (revised 2013) [CDA, 2013a], and meeting the requirements of the B.C. Water Sustainability Act and the B.C. Dam Safety Regulation [Reg. 44/2016]. The scope of services provided are outlined in RDOS contract RDOS-20-PW-04 between Hatch Ltd. and the Client dated May 8, 2020 and in accordance with Hatch Proposal No. 031390 dated March 23, 2020.

1.2 Previous Dam Safety Reviews

The most recent Dam Safety Review for the Elinor North Dam was completed in 2010 by EBA Engineering under the previous version of the B.C. Dam safety regulation. According to the B.C. Dam Safety Regulation (B.C. Reg 44/2016) under the Water Sustainability Act, a new Dam Safety Review is required in 2020.

1.3 Objective

The objective of this Dam Safety Review is to determine if the dam facilities meet the recommendations in the Engineers and Geoscientists B.C. (EGBC) Professional Practice Guidelines – Legislated Dam Safety Reviews V3.0 [EGBC, 2016], Canadian Dam Association – Dam Safety Guidelines [CDA, 2013a], and the requirements of the B.C. Water Sustainability Act and the B.C. Dam Safety Regulation [Reg. 44/2016], and to present the findings as either confirmation of the dam's safety, or identification of deficiencies, non-conformances and issues for further investigation. The scope of the complete Naramata Dams study includes a dam breach and inundation study including dam failure consequence classification, Inflow Design Flood (IDF) selection and inundation zone mapping. Results from this work are used to inform this DSR.

The major conclusions and recommendations of this DSR for the Elinor North (Saddle) Dam components have been summarized at the end of this report. The recommendations have been ranked using the prioritization system outlined in Section 12.

2. Description of Development

2.1 General

There are four Naramata area dams located from elevations 900 m to over 1250 m above the main populated regions along Okanagan Lake in British Columbia. These dams include:

- Big Meadow Lake Dam
- Elinor Lake North (Saddle) Dam
- Elinor Lake South Dam
- Naramata Lake Dam.

The locations of these dams are shown in Figure 2-1.

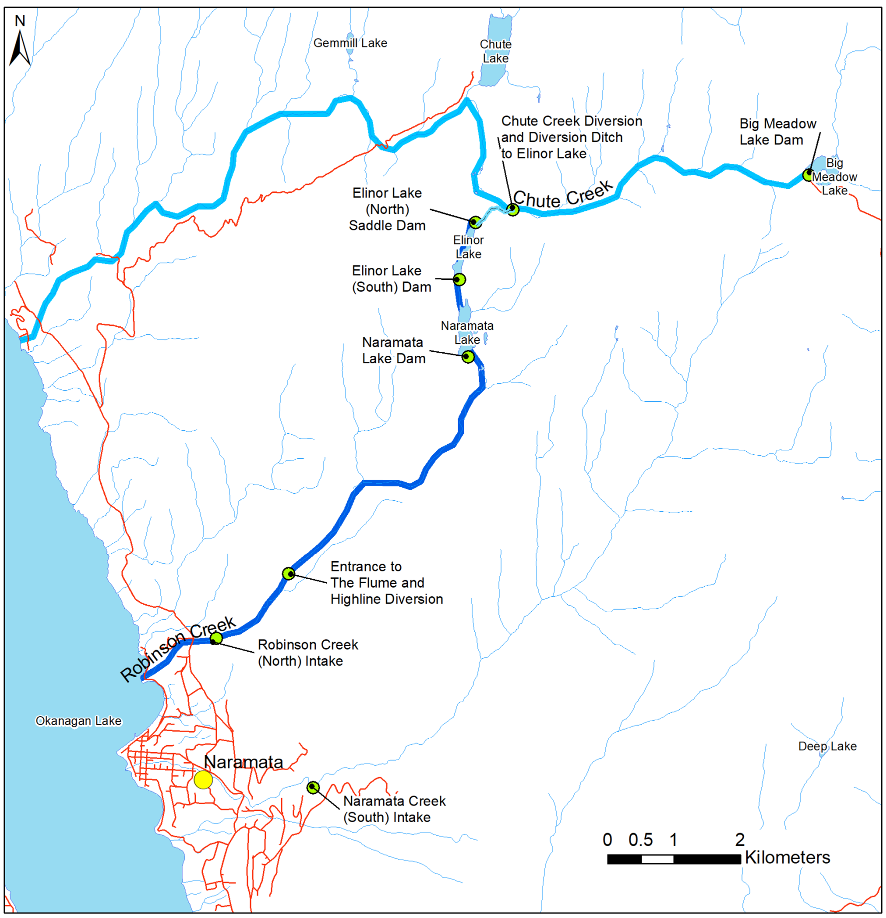


Figure 2-1: Naramata Dams Location Map

The Elinor Lake North Dam and Elinor Lake South Dam are a part of this four-dam system which forms three interconnected reservoirs that provided a historical upland source of potable water to the Township of Naramata. The dams were constructed during the first half of the twentieth century by the Naramata Irrigation District (NID), which has been subsequently incorporated into the Regional District of Okanagan-Similkameen (RDOS). These dams are no longer required for the potable water due to the construction of Naramata UV Water treatment Facility in 2006, and the RDOS continues utilizing these facilities for maintaining essential creek flows, emergency backup supply of water and supplying irrigation water to agricultural lands.

2.2 Site Description

The Elinor Lake North and South Dams are situated in a north to south trending valley situated approximately 9.2 km and 8.4 km respectively to the northeast of Naramata Township.

The Elinor Lake North Dam in approximately 77.7 m long and a maximum of approximately 6 m high with a crest elevation ranging from 1277.31 m to 1277.93 m. Flows from the Elinor Lake Reservoir discharge via a low level conduit through Elinor Lake South Dam into Robinson Creek which in turn discharges into the Naramata Lake Dam Reservoir.

Vehicle access to the dams is provided via Elinor Lake Forestry Service Road, which extends off Chute Lake Road to the north which in turn extends off North Naramata Road to the west. Figure 2-2 illustrates the current configuration and nomenclature used for the remainder of this report to identify the various parts of the structures.

Figure 2-2: Elinor North Dam Major Component Layout

The key physical dimensions of Elinor Lake North dam are in Table 2-1.

Table 2-1: Key Dimensions of Elinor North (Saddle) Dam

Structure	Details
Type of Dam	Earthfill
Maximum Height	5.7 m
Crest Length	77.7 m
Crest Width	6.5 m
Crest Elevation	1277.31 m minimum to 1277.93 maximum MSL
Upstream Slope	2.5H:1V
Downstream Slope	3.75H:1V (Typical as used in this DSR)
Retained Water (at Elinor South Dam spillway crest)	271,000 m^3
Low Level Outlet	See Elinor South Dam
Spillway	See Elinor South Dam
Dam Failure Consequence Classification	Very High
Full Supply Level (FSL)	1276.55 m
IDF Level	1277.08 m
IDF	2.4 m^3/s

There is no instrumentation at the Elinor North Dam.

Currently, seepage from the dam accumulates in a small shallow pond, immediately downstream of the dam. No instrumentation exists to measure seepage quantity.

2.3 History of Dam and Reservoir

Limited information is available with respect to the design and construction of the Elinor Lake North Dam. Based on the review of the existing drawings of the South Dam, it was originally constructed in 1946 and comprises a granular earthfill embankment with central clay core. The North Dam is assumed to have a similar design to the South dam, since no drawings were available for the North Dam. A review of the oldest available aerial photography from 1938 indicates that two interconnected lakes existed at the location of the reservoir prior to construction of the dams.

No drawings exist showing the site plan, internal zoning, and foundation of the Elinor North Dam. It is a general understanding that the typical cross section of the North Dam is similar to South Dam.

3. Dam Safety Review Methodology

This DSR is based on a review of available documentation, discussions with the RDOS staff and a site inspection to the Elinor Lake North (Saddle) Dam. The scope of the review includes the dam's physical condition, operation, maintenance, surveillance, emergency planning and response, dam performance and dam safety management process, as these pertain to overall dam safety management of the Elinor Lake North Dam.

The project commenced with document review that included the project performance expectations, including flood and earthquake criteria, based on the Canadian Dam Association – Dam Safety Guidelines published in 2007 (revised 2013) [CDA, 2013a], and the B.C. Water Sustainability Act and the B.C. Dam Safety Regulation (Reg. 44/2016). These were reviewed and discussed with RDOS staff. Prior dam safety reports and other reports pertaining to the dam safety of Elinor North Dam were made available to Hatch. A full listing of documents reviewed is provided in Section 4.1.

The Hatch team performed a site inspection as discussed in Section 5.

The DSR focuses on the history of the dam with attention to issues and work that had been performed since the last DSR [EBA, 2010] and encompassed the BC Dam Safety Regulation [B.C. Reg. 44/2016] and the CDA Guidelines [CDA, 2013a]. Where the aspects of the Dam Safety Management Program were found not to conform, the issue was identified as a deficiency or as a non-conformance and a recommendation for follow-up action was made. The identified deficiencies were categorized as being physical deficiencies (inadequate dam performance condition); or deficiencies of the physical infrastructure of the dam (such as the system for the collection of data and observations necessary to verify the physical performance of the dam); or procedural non-conformances. The priority rating of the various risks were defined as either high, medium and low based on the potential of the issue leading to a critical failure of the structure, in order to provide the RDOS recommended priorities to resolve these deficiencies.

Based on an understanding of hazards and associated failure modes, a "Hazards and Failure Modes Matrix" was created (see Section 7.1) that lists potential hazards and failure scenarios for the Elinor Lake North Dam.

The findings of the DSR were documented in this Report.

4. Data Collection and Review

4.1 Existing Information

RDOS provided available information on the dam to Hatch for this DSR. Historical data was provided as electronically scanned documents and was contained in various folders.

Table 4-1 summarizes each document that was reviewed.

Table 4-1: Existing Information Summary

File Name	Data	Description
Drawings		
Chute Lake Diversion – Existing Structure	October 1993	Spillway drawings
Naramata Lake Historical Drawings	1967 – 1978	Design drawings, area maps, topography, storage capacity, cross-section drawings, borrow areas (Drawing No.226-02-1 to 226-02-8 and Kelowna No. 1203)
Naramata Lake Dam – Remedial Filter Blanket	1969	Details of drains downstream of dam (Drawing No. 226-02-100)
Naramata Lake Dam – Piezometer Location Plan	Unknown	Shows the location of test well
Eleanor Lake Dam – Details of Culvert Gate Repairs	December 1966	Culvert gate repair plans for Elinor Lake Dam (Drawing No. 1316)
Eleanor & Naramata Lakes – Plan of Storage	17 April 1964	Storage plans for Elinor and Naramata Lakes (Drawing No. Kelowna-1203)
Improvements – South and North Intakes	6 December 1979	Improvements to South and North intakes of Elinor Lake Dam
Big Meadow Reservoir Plan of Storage	8 April 1963	Storage plans for Big Meadow Dam (Drawing No. Kelowna 1114)
Big Meadow Lake Storage Dam	November 1952	Spillway cross-sections (in sketch format)
Big Meadow Lake Reservoir – Plan of Reservoir	September 1979	Plan of Reservoir (Drawing No. 4567-5)
Big Meadow Dam – Details of Repairs to Culvert Gate & Outlet	19 September 1966	Repair plans to culvert gate and outlet (Drawing No. 1315)
Big Meadow Lake Reservoir – Plan of Reservoir	March 1982	Storage tables, rating curves for Big Meadow Reservoir
Big Meadow Dam – Grill at Gates	August 31, 1920	
Topographical Survey and Mapping		
Big Meadow Dam Site Topography	17 July 2012	Topographical survey from Okanagan Survey & Design
Elinor Lake – North Dam Site Topography	24 July 2012	Topographical survey from Okanagan Survey & Design

File Name	Data	Description
Elinor Lake – South Dam Site Topography	24 July 2012	Topographical survey from Okanagan Survey & Design
Naramata Lake Dam – Site Topography	24 July 2012	Topographical survey from Okanagan Survey & Design
Naramata Creek Watershed Area – Map 5: Groundwater Sensitivity Zones	21 December 1998	Groundwater sensitivity zones, recharge and discharge zones, flow and surface hydrology sensitivity zones for the Naramata watershed
Photos		
Big Meadow Lake Dam Site Photos	2010	
Elinor Lake Dams Site Photos	2010	
Naramata Lake Dam Site Photos	2010	
Naramata Water System North and South Creek Intake Photos	12 March 2020	
Inspection Reports (by RDOS staff)		
Naramata Dams Status Reports FLNRO	2002 to 2019	Dam Status report forms
Correspondence		
Naramata Dams FLNRO Dam Audit Program	Emails to 21 November 2019	Email correspondence on Audits between 2004-2019
Big Meadow Dam	2 November 2004.	Correspondence from Golder regarding insitu density testing along a repaired section of the south east abutment of the Big Meadow Dam.
Reports		
Risk Control Survey	2019	Review of RDOS facilities to identify exposures to liability and to assist staff in managing these exposures.
Big Meadow Reservoir and Dam Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan	May 2017	OMS and EPP Plan from RDOS
Elinor Lake Reservoir and Dams Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan	May 2017	OMS and EPP Plan from RDOS
Naramata Lake Reservoir and Dams Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan	May 2017	OMS and EPP Plan from RDOS
Naramata Uplands Waterworks (Diversion, Divide, Flume, Highline & Intakes - Maintenance and Surveillance Plan	April 2013	Maintenance and Surveillance Plan from RDOS
Big Meadow Lake Dam Geotechnical Assessment	11 January 2013	EBA Consultants 2013 Geotechnical Assessment Report

File Name	Data	Description
Topographical Survey of Naramata Dams	10 January 2013	EBA Consultants memo accompanying topographical survey. EBA File: 13103018
Dam Safety Review – Big Meadow Lake Dam	17 December 2010	EBA Consultants 2010 Dam Safety Review – No. K13101459.001
Dam Safety Review – Naramata Lake Dam	17 December 2010	EBA Consultants 2010 Dam Safety Review– No. K13101459.001
Dam Safety Review Summary Report – Naramata Dams	21 December 2010	EBA Consultants 2010 Dam Safety Review– No. K13101459.001
Dam Safety Reviews for Elinor Lake North (Saddle) Dam and Elinor Lake South Dam	17 December 2010	EBA Consultants 2010 Dam Safety Review– No. K13101459.001
Hydrotechnical Assessment of the Naramata Dams	20 December 2010	EBA Consultants 2010 Hydrotechnical Assessment Report
Naramata Fan Study (with Robinson and Chute Creeks)	December 1994	BC MoE Naramata Fan Study
Naramata Lake Operation and Maintenance Manual	April 1993	Naramata Irrigation District Operation and Maintenance Manual.
Big Meadow Reservoir – Storage Capacity Table	26 April 1979	Storage capacity table using survey data from Kelowna Regional Office Water Rights Branch
Eleanor Lake Reservoir – Storage Capacity Table	17 August 1979	Storage capacity table using survey data from Kelowna Regional Office Water Rights Branch
Naramata Lake Reservoir – Storage Capacity Table	29 June 1979	Storage capacity table using survey data from Kelowna Regional Office Water Rights Branch

4.2 Data Gaps

RDOS provided information available for Elinor North Dam including a dam safety study (EBA, 2010) that has been completed for the Elinor North Dam during the life of the structure. This documentation included previous dam analyses conducted by EBA (2010) as well as reports from inspections completed by RDOS personnel and RDOS Operations, Maintenance and Surveillance (OMS) information.

The project consists of structures that were constructed from 1946-to 1959 and have largely gone unchanged throughout the intervening years. No record of information on the design and construction of the North Dam could be provided. For the analysis in this review, it has been assumed that the general information contained in the data files received from RDOS reflects the current condition of the structures.

The data gaps that were identified during this review include:

- No drawings showing the dam’s internal zoning and geometry
- No construction specifications.

- A lack of geotechnical information including:
    - Internal zoning.
    - Gradation and in-situ compaction of fill materials.
    - Gradation and density of the foundation materials and depth to bedrock.
    - Shear strength information of the impervious fill, shell, and foundation materials.
    - Piezometric elevations in the dam and foundation.

Recommendations to fill some of these gaps are presented in the conclusions and recommendations sections of the report but none of these prevented the completion of the DSR.

5. Site Inspection and Staff Interviews

Hatch conducted a one (1) day site inspection to Elinor Lake North Dam for this Dam Safety Review (DSR). The site inspection was conducted on July 9, 2020 and attended by Hatch's Structural Engineer/Project Manager (Amit Pashan, P.Eng.), Geotechnical Engineer (Parham Ashayer, P.Eng.) and Hydrotechnical Engineer (Shayla Murphy, P.Eng.). The following personnel from RDOS also attended the site inspection: Shane Fenske (RDOS – Engineering Technologist and Naramata Dams Dam Safety Review Project Manager), and Jon Hillman (RDOS Dam Inspector).

The purpose of this site inspection was for the Hatch DSR Team to:

- Gain familiarity with the site.
- Inspect the various structures and equipment and document any observed deficiencies.
- Discuss aspects of RDOS's dam safety inspection and monitoring program.
- Discuss operational and dam safety aspects of the Elinor Lake North Dam site and RDOS's operations and maintenance staff.

Photos referred to in the following sections can be found in Appendix A.

5.1 General

A general walkover and inspection of the Dam structures was performed as part of the 2020 Hatch dam safety review. The Dam is within a remote area, yet clear indicators of public access were present. The reservoir rim was found to be generally next to natural high ground and dense trees surrounding the entire lake. In general, the reservoir rim in the vicinity of the dam was found in fair condition with no sign of failure or distress. Minor vegetation growth was observed on the upstream slopes of the dam, which was above the water level (see Photos A1 and A3 in Appendix A). Historical photos (EBA, 2010) show sand and gravel on the upstream slope of the dam. No riprap was found on the upstream face of the dam, notably, no sign of erosion or distress due to wave and surge actions were identified on the upstream face.

5.1.1 Freeboard

The dam crest elevation varies along its entire length and ranges between 1277.31 m to 1277.93 m.

Flood routing and freeboard analyses were completed, demonstrating that the existing freeboard will provide adequate protection due to wind generated waves. Given that there is currently no riprap or erosion protection layer on the upstream slope, it is recommended that RDOS inspect the dam after large wind storms to confirm if any damage has occurred and repair as necessary. This requirement has been added to the OMS. Provision of appropriately sized armor protection along the upstream face of the dam from the crest to 1 m below the low water level should be considered and is described in further detail in Section 7.2.6.

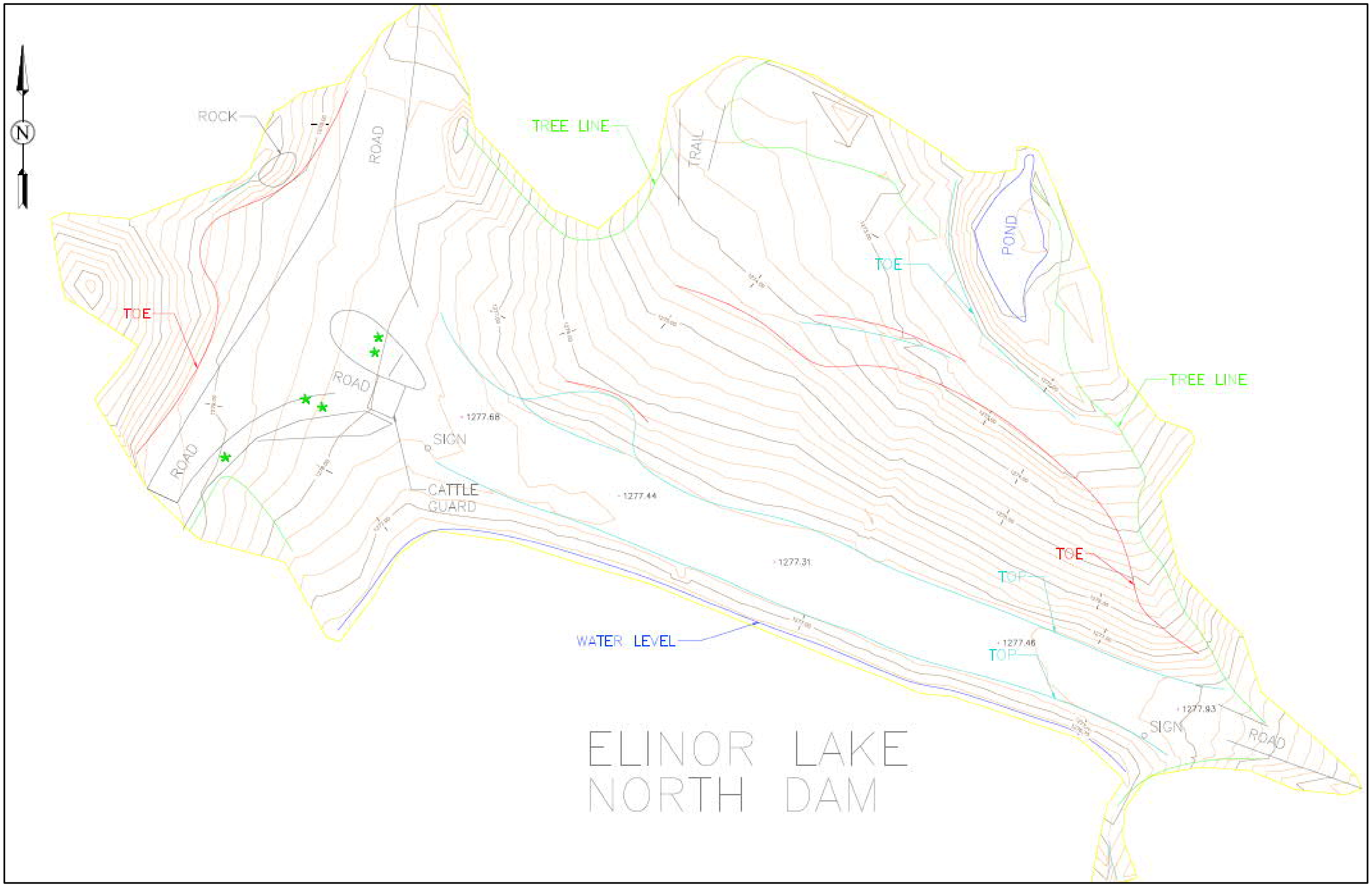


Figure 5-1: Elinor Lake North Dam Site Plan and Topography (Okanagan Survey, 2012)

The crest itself is frequented by recreational ATV traffic. Significant rutting of the crest was observed due to this traffic.

5.2 Elinor Lake North Earthfill Dam

Similar to the Elinor South embankment dam, it is expected that the North Dam consists of an upstream and downstream granular shell with an impervious central core which acts as the water barrier. No drawing or report exists showing the North Dam internal zoning, however, the internal zoning of the North Dam is inferred to be similar to the South Dam.

The upstream face of the dam is comprised of sand and gravel with no riprap. Minor vegetation growth was observed on the upstream slope which was comprised of grass and short bushes (see Photos A1 and A2).

The reservoir level was high at the time of Hatch's inspection, with water flowing over the spillway at the Elinor South Dam. A review of dam photos during the previous EBA (2010) inspection shows the presence of granular materials on the upstream face of the dam. The downstream slope of the North Dam was found to be comprised of granular materials covered by grass and vegetation (see Photos A3 to A6). Vegetation became denser close to the toe area, potentially due to seepage (see Photo A8). The downstream slope was found to be relatively shallow and the existing drawing of South Dam suggests a typical slope of 3.5H:1V on the downstream side (see Photos A8 and A9). A typical cross section evaluated the downstream slope at 3.75H:1V as described in Section 5 (Okanagan Survey, 2012). Since the survey was carried out during high water table, the upstream slope could not be surveyed. Vegetation growth appeared not to be an issue at the downstream slope of the North Dam where grass growth is favorable against erosion. The short vegetation and grass on the downstream slope, near the toe of the North Dam, was found to be scrubby which requires continuous effort to maintain. No erosion of this slope was observed.

The downstream face of the embankment was found to be used commonly by ATVs with some signs of rutting and erosion. Large boulders were observed laying on the downstream slope, possibly intended to prevent ATV access to the site.

Seepage was noticed at the toe of the Elinor North Dam (see Photo A4 to A6). The ponding at the toe of the dam suggested that seepage could be significant. However, no seepage monitoring weir was present at the site to enable measurement of seepage flow quantity. The absence of weir(s) at the toe of the dam combined with the absence of piezometer(s) in the embankment are not considered suitable for long term monitoring of the embankment dam.

A small wet area was found at the toe of the embankment which was covered with dense vegetation and trees (see Photos A7 to A9). The downstream toe area should be cleared of trees and shrubs for continuous inspection for seepage, piping, boiling, and turbidity. This is also prudent to keep downstream vegetation small in order to avoid the potential for root growth to cause a preferential seepage paths to develop.

The 2012 survey conducted by Okanagan Survey (2012) shows that the dam abuts to relatively high ground on the left and right abutments. An inspection of the dam abutments reveled no sign of distress, failure, or instability (see Photo A10 and A11). EBA (2010) noted bedrock on the right abutment, on the upstream side of the dam. Bedrock could be found on the right side as in existing site photos or site inspection.

The crest of the Elinor North Dam is a publicly accessible road and was observed to be in fair condition. No sign of distress, crack, or significant erosion could be found in the road. The crest of the dam appeared to be relatively lower in elevation in areas in the middle of the dam as indicated by 2012 topographical survey. The dam crest is at El. 1277.31 m close to the middle of the dam and gradually rises to higher elevations towards the abutments.

5.3 Spillway

No spillway or LLO structure exists at the Elinor North Dam. All ancillary structures are located at the Elinor South Dam.

6. Consequences of Dam Failure and Dam Classification

A full dam breach analysis and consequence classification and inundation mapping study was conducted as part of this project. The results of this analysis can be found under separate cover in Naramata Dam Breach Assessment and Inundation Mapping (2021). The following subsections summarize the results of this study.

6.1 Background Information

Dam classifications are used for the purpose of general dam safety management oversight, as well as for inspection, maintenance, and surveillance programs. Dam classifications provide guidance in the selection of specific design criteria such as, in the case of this study, IDF, freeboard, and stability criteria. B.C. Dam Safety Regulations present a classification scheme, presented in Table 6-1 and Table 6-2, which are used to provide guidance on the standard of care expected of dam owners. Estimates of potential consequences of dam failure are categorized to distinguish dams where the risk is much higher than others. The dam class is determined by the highest potential consequence, whether loss of life, environmental, cultural, or economic losses.

Table 6-1: Consequence Classification Guide (B.C. Dam Safety Regulation Under the Water Sustainability Act Dam Safety Regulation 40/2016)

Dam Failure Consequence Classification	Population at Risk	Consequences of Failure		
		Loss of Life	Environment and Cultural Values	Infrastructure and Economics
Low	None[1]	No possibility of loss of life other than through unforeseeable misadventure.	Minimal short-term loss or deterioration and no long-term loss or deterioration of: a) Fisheries habitat or wildlife habitat b) Rare or endangered species c) Unique landscapes, or d) Sites having significant cultural value.	Minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone.
Significant	Temporary Only[2]	Low potential for multiple loss of life.	No significant loss or deterioration of: a) Important fisheries habitat or important wildlife habitat b) Rare or endangered species c) Unique landscapes, or d) Sites having significant cultural value, and restoration or compensation in kind is highly possible.	Low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and irregular for temporary purpose.
High	Permanent[3]	10 or fewer.	Significant loss or deterioration of: a) Important fisheries habitat or important wildlife habitat b) Rare or endangered species c) Unique landscapes or d) Sites having significant cultural value, and restoration or compensation in kind is highly possible.	High economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings.

Dam Failure Consequence Classification	Population at Risk	Consequences of Failure		
		Loss of Life	Environment and Cultural Values	Infrastructure and Economics
Very high	Permanent[3]	100 or fewer.	Significant loss or deterioration of: a) Critical fisheries habitat or critical wildlife habitat b) Rare or endangered species c) Unique landscapes, or d) Sites having significant cultural value, and restoration or compensation in kind is possible but impractical	Very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of some severe damage to residential areas.
Extreme	Permanent[3]	more than 100.	Major loss or deterioration of: a) Critical fisheries habitat or critical wildlife habitat b) Rare or endangered species c) Unique landscapes, or d) Sites having significant cultural value, and restoration or compensation in kind is impossible.	Extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas.

[1] There is no identifiable population at risk.

[2] People are only occasionally and irregularly in the dam-breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.

[3] The population at risk is ordinarily or regularly located in the dam breach inundation zone, whether to live, work or recreate.

Table 6-2: B.C. Dam Safety Regulation Downstream Dam Failure Consequence Classification (DFCC) Guide

DFCC	Inflow Design Flood
Extreme	PMF
Very High	2/3 between AEP 1/1,000 and PMF
High	1/3 between AEP 1/1,000 and PMF
Significant	AEP between 1/100 and 1/1,000
Low	AEP 1/100

6.2 Previous Work by Others

The Elinor Lake North Dam is currently classified as Very High. The report, “Hydrotechnical Assessment of the Naramata Dams” (2010) was produced in tandem with the previous most recent Dam Safety Reviews by EBA Engineering Consultants, which classified Elinor North Dam as High.

However, a complete incremental damage and loss of life assessment and full dam breach and inundation study had not previously been performed for this dam. Previous classification assessments were conducted prior to the publication of the current CDA Dam Safety Guidelines [CDA, 2013a).

6.3 Recommended Classification

To determine the appropriate consequence classification, it was necessary to first assess the effect of a breach on the downstream area and inhabitants during “fair weather” and flood scenarios. This was carried out by Hatch as part of this study and is documented in a separate report entitled Naramata Dam Breach Assessment and Inundation Mapping (2020).

The CDA Technical Bulletin on Inundation, Consequences and Classification for Dam Safety (2007) and the BC Dam Safety Program “Downstream Consequence of Failure Classification Interpretation Guideline” provides guidance on the application of consequence assessments to aspects of dam design and dam safety:

- Incremental consequences of dam failure in flood conditions define the minimum requirements for the IDF.
- Consequences of dam failure in fair weather conditions define the minimum requirements for seismic loading.
- The higher of the two dictates the overall level of care in management oversight, inspection, maintenance, and safety assessment.

Elinor North Dam has been classified according to the current B.C. Water Sustainability Act Dam Safety Regulation [B.C. Reg 44/2016] dam classification system. The consequence assessment found that the classification for flood conditions was the same as for fair weather conditions. Results demonstrate that the overall classification for Elinor North Dam is “Very High”, and that the incremental damages due to a potential IDF are in line with a “High” classification (i.e. this defines the minimum requirements for IDF).

The classifications provided in this report apply to the existing dam in its present configuration. Alterations to the dam could change parameters such as the volume and/or height of impounded water, the flood routing capacity of the dam, or potential breach characteristics. This in turn could impact the nature and magnitude of consequences of failure and therefore the appropriate classification and design criteria. In the event of substantial alterations, flood routing calculations need to be updated and the potential consequences of failure reassessed by means of additional or revised dam breach analyses as needed.

7. Dam Safety Analyses

One of the basic requirements of a DSR is the engineering analysis and assessment of the structure. The CDA Guidelines state “Safety analysis of the dam system should include the internal and external hazards, failure modes and effects, operating reliability, dam response, and emergency scenarios.”

Also as stated in the CDA Bulletin on Analysis and Assessment “The purpose of dam safety analysis 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.”

The following subsections detail the dam safety analysis that were performed as part this DSR.

7.1 Failure Modes and Effects Analysis

A hazard and failure mode matrix was developed for the Elinor North Dam and is presented in Table 7-1. In this type of assessment, the interactions between hazards and failure modes are related using a matrix representation. The hazards and failure modes matrix (H&FMM) provides a simple means of summarising the considerations that, in principle must be embodied in every dam safety program. It provides a framework in which the various hazards and failure modes can interact and act in combination to lead to dam failure. Although the site consists of the dam, the failure modes listed are generally applicable to the site as a whole.

In a risk based evaluation of failure modes, risk can be described as the combination likelihood of a failure mode occurring (probability of the failure mode) with the consequence of what would happen should a failure mode occur (loss of containment of the reservoir). This is calculated in a quantitative assessment as Risk = Likelihood X Consequences. The intent of a Dam Safety Review is to ensure that the dam is constructed and operated in a manner to ensure the risk to the public is within the “broadly acceptable” range or where this is not possible, to reduce the risks to as low as is reasonably practicable (ALARP).

Based upon the configuration and conditions at the dam, a number of the hazard-failure mode combinations can be ruled out. These are illustrated in Table 7-1 with cells that are hatched. There are a number of failure modes that are possible, however, can be further ruled as improbable because the dam design and operation meet the requirements laid out in the BC Dam Safety Regulation, CDA Guidelines or general industry standards for a structure with the “Very High” DFCC and risks are considered ALARP. These are presented in black text in Table 7-1.

The remaining hazard failure mode combinations are identified as being possible and either reflect deficiencies in meeting the BC Dam Safety Regulation, CDA Guidelines or general industry standards or there is insufficient information to confirm that they meet these requirements. These are illustrated in Table 7-1 with red text.

Table 7-1: Hazard and Failure Modes Matrix for Elinor North Dam

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
Inadequate installed discharge capacity	**Meteorological inflow > buffer + outflow capacity**								
Inadequate available discharge capacity	**Inadequate reservoir operation (rules not followed)**								
	Random functional failure on demand								
	Discharge capability not maintained or retained								
Inadequate freeboard	**Excessive elevation due to landslide or U/S dam**	Improbable –The potential for the wave created by a landslide has not been specifically studied but likely not credible. Possible – Big Meadow Dam is upstream. It is connected by a Diversion only, but an upstream dam should always be considered a hazard if it fails during a metrological event.	Improbable –The potential for the wave created by a landslide has not been specifically studied but likely not credible based on topographic information. Possible – Big Meadow Dam is upstream. An upstream dam should always be considered a hazard if it fails under a seismic event.	Improbable – Potential for landslide into reservoir is unlikely based on topographic information.	Possible – although freeboard requirements are met, any additional loss of freeboard would result in a deficiency. Rutting from ATV activity has already reduced freeboard on this dam and could result in additional loss.	Improbable - Dam could be overtopped and fail if upstream Big Meadow Dam were to fail. However, Big Meadow Dam can pass the PMF therefore risk of failure is low. No landslide hazard identified.			
	Wind-wave dissipation inadequate	Improbable - meets CDA requirements for freeboard for wind wave events for normal and IDF conditions. No riprap layer on upstream face of dam, but this is mitigated by the small size of lake. This failure mode would take time to form and would require repeated events. Review for benching on upper slope, could inspect full slope while empty annually.	Improbable - meets freeboard for wind wave events. Settlement is not expected to be greater than the normal freeboard already available.	Improbable – Freeboard analysis completed. Based on the shape of the reservoir and topography around the reservoir and the fairly short fetch distance, high winds are unlikely to produce waves that overtops the dam.	Possible – although freeboard requirements are met, any additional loss of freeboard would result in a deficiency. Rutting from ATV activity has already reduced freeboard on this dam and could result in additional loss.	Improbable – Freeboard analysis completed. Based on the shape of the reservoir and topography around the reservoir and the fairly short fetch distance, high winds cannot produce a wave that overtops the dam.			Improbable - If wind and wave damage is not repaired freeboard could be compromised over time.
Safeguards fail to provide timely detection and correction	**Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy**	Improbable - due to weekly inspections and lack of mechanical operation. However, meteorological event could make dam inaccessible and therefore prevent the Dam Safety Engineers activities. Helicopter access should be considered in an emergency	Improbable - Likely no road access to the site following a seismic event due to loss of road. However, there are likely locations suitable for helicopter landing.	Improbable - Good OMS procedures and little expected influence from reservoir environment.		Improbable - due to weekly inspections, and lack of mechanical operation.			Improbable - due to weekly inspections and lack of mechanical operation.
	Operation, maintenance and surveillance fail to detect poor dam performance	Possible - No instrumentation or seepage monitoring. Mitigated by weekly inspections. Seepage is occurring during normal water level which may worsen during a high water table. This should be detected and responded appropriately and in a timely fashion. However, meteorological event could	Improbable – Saddle Dam has no LLO to operate; however, if the dam could be damaged due to overtopping due to malfunction or problems at the South Dam.	Improbable - Good OMS procedures and little expected influence from reservoir environment.		Possible - Lack of instrumentation or seepage monitoring. Mitigated by weekly inspections. Additional instrumentation is recommended.			Possible - insufficient instrumentation or seepage monitoring. Mitigated by weekly inspections. Additional instrumentation is recommended

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
		make dam inaccessible and therefore prevent the Dam Safety Engineers activities. Helicopter access should be considered in an emergency							
Stability under applied loads	Mass movement (external stability:- displacement, tilting, seismic resistance)	Improbable - Dam meets stability requirements.	Improbable - Dam meets seismic stability requirements.	Improbable - A landslide induced or seiche wave large enough to overtop the dam is not considered to be a highlighted hazard.		Improbable - Dam meets seismic stability requirements. Geotechnical investigation and assessment are needed to confirm the assumptions.			Improbable - regular inspections. Geotechnical investigation and assessment are needed to confirm the assumptions.
	Loss of support (foundation or abutment failure)	Improbable - Dam meets stability requirements.	Improbable - Dam meets seismic stability requirements.			Improbable - Dam meets stability requirements.			Possible - Insufficient instrumentation or seepage monitoring. Mitigated by weekly inspections. Additional instrumentation is recommended.
Watertightness	Seepage around interfaces (abutments, foundation, water stops)	Possible - Deteriorated foundation and boiling may happen in the future during IDF	Possible - Seepage and internal piping analyses not completed to date following an investigation.			Possible – Seepage is occurring. Materials internal stability and filter compatibility are not known which require investigation and assessment. Historic issue of internal piping during high water elevation.			Possible - Seepage/turbidity quantity monitoring and pore water pressure by piezometers not currently being conducted.
	Through dam seepage control failure (filters, drains, pumps)	Possible - Seepage analysis not completed to date. Deteriorated foundation and boiling happened in the past during IDF	Possible - Seepage and internal piping analyses not completed to date following an investigation.			Possible – Considerable seepage is occurring. Materials internal stability, filter compatibility are not known which require investigation and assessment. Historic issue of internal piping during high water elevation.			Possible – Insufficient seepage/turbidity quantity monitoring and pore water pressure measurement by piezometers not currently being conducted
Durability/cracking	Structural weakening (internal erosion, AAR, crushing, gradual strength loss)	Possible – But likely not credible under IDF. Requires future investigation and instrumentation.	Possible - Dam foundation susceptible to liquefaction. Investigation and assessment needed.			Possible - Dam foundation, upstream core and shell materials might be susceptible. Investigation and assessment needed.			Improbable - Regular and post-event inspections.
	Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)	Improbable	Possible - Dam foundation susceptible to liquefaction. Investigation and assessment needed.			Possible - Dam foundation susceptible to liquefaction. Investigation and assessment needed.			Improbable - Regular and post-event inspections.

Table 7-1 can then be used as a visual reference of the state of safety of the dam. The cells with black text illustrate the items that need to be guarded against through the OMS of the dams and planned for the in the Dam Emergency Plan (DEP). The cells with red text illustrate the major items that are current deficiencies that should be addressed to ensure the safety of the dam going forward.

7.2 Hydrotechnical Assessment

7.2.1 Review of Hydrological Studies

The flood hydrology associated with the Naramata Dams basin was developed during the 2010 Hydrotechnical Assessment of the Naramata Dams [EBA Engineering Consultants, 2010], and updated as part of this study, as detailed under separate cover in Naramata Dam Breach Assessment and Inundation Mapping (2021).

Additional data collected at the active gauges since the 2010 assessment was included in Hatch's assessment. Although results of the 2010 analysis were not presented in the previous report, results of the updated flood frequency analysis are found in Table 7-2.

Table 7-2: Flood Frequency Analysis

Return Period (years)	Current Flood Frequency Analysis: Peak Flow (m^3/s)
2	1.0
3	1.2
5	1.3
10	1.5
20	1.6
50	1.8
100	1.9
200	2.0
1000	2.3

A PMF analysis was completed for the Elinor reservoir. The procedures used to assess the IDF for the past studies are generally acceptable for such a small catchment without available local gauge information. Given the lack of available data it is unlikely that a more rigorous analysis could be performed that would yield more accurate results than those obtained. Therefore, the same analysis was completed, including gauge data collected since the previous assessment.

The PMF Estimator for British Columbia provides the following equation for the Okanagan region within Zone 12B for watershed areas less than 8320 km^2 [Abrahamson & Pentland, 2010]:

$Q = 2.1086A^{0.9240}$

Where Q is the probable maximum flood in m^3/s and A is the area of the watershed in km^2. The results are presented in Table 7-3.

Table 7-3: PMF Peak Flows

Dam	Watershed Area (km^2)	Peak PMF (m^3/s)
Elinor Lake North Dam	1.3	2.7

7.2.2 *Flood Operating Rules*

The Naramata Dams watershed operating system is detailed in the companion report: Naramata Dam Breach Assessment and Inundation Mapping (2021). There is no operable portion of the Elinor North Dam. Flood operation for the Elinor reservoir is carried out at the Elinor South Dam.

7.2.3 *Discharge Capacity*

The Elinor North Dam does not provide discharge capacity for the Elinor reservoir. Discharge capacity is provided at the Elinor South Dam.

7.2.4 *Flood Passage Capability*

The Elinor North Dam does not provide flood passage capacity for the Elinor reservoir. Discharge capacity is provided at the Elinor South Dam.

7.2.5 *Freeboard*

The B.C. Dam Safety Regulation [B.C. Reg 44/2016] under the Water Sustainability Act does not speak directly to freeboard requirements for dams. However, according to the CDA Guidelines [CDA, 2007a], embankment structures are required to meet the following wind/wave criteria.

No overtopping by 95% of the waves caused by the most critical wind with a frequency of 1:1,000 year when the reservoir is at its maximum normal elevation.

No overtopping by 95% of the waves caused by the most critical wind with a frequency of 1:2 year when the reservoir is at its maximum extreme level during the passage of the IDF.

In BC, the document that speaks to freeboard requirements specifically is the FLNRO, Plan Submission Requirements for the Construction and Rehabilitation of Small Dams, 2018. This document provides the following requirements:

> *"Two types of freeboard are discussed below; normal and minimum. Regardless of which freeboard is used in the dam design, both require the spillway be able pass the IDF (see section on Spillway above).*
>
> *(a) Normal Freeboard (or Gross Freeboard) is the difference of elevation between the lowest elevation of the top of the dam (or top of impervious core) and the maximum reservoir operating level (full supply level, often the spillway sill elevation).*

(b) Minimum Freeboard (or Net Freeboard) is the difference of elevation between the lowest elevation of the top of the dam (or top of impervious core) and the maximum water level of the reservoir should the Inflow Design Flood (IDF) occur.

To prevent overtopping and provide redundancies in the dam design, the following freeboard standards shall be applied:

- *The normal freeboard shall be at least 1.0 m in combination with a spillway width of at least 4.0 m.*
- *If the design engineer wants to present a case for a spillway width of less than 4.0 m wide, the minimum freeboard shall be at least 1.0 m. A spillway width of less than 4.0 m wide is not recommended for High and Very High dam failure consequence classification dams.*

In addition, the Canadian Dam Association's Dam Safety Guideline's Technical Bulletin, Section 6.0 - Hydrotechnical Considerations for Dam Safety, should be consulted."

Calculations for these conditions were carried out on Elinor Lake to determine if adequate freeboard exists.

During the site inspection, observations were made that indicated that the 1 m requirement may in fact be overly conservative for this specific dam. It was noted that the maximum effective fetch in which wind waves can be developed in the lake is less than 470 m (very short) and the lake is located in a valley with less exposure to wind. It is also understood that the 1 m requirement is largely a 'rule of thumb' based upon guidance provided by the United States Bureau of Reclamation as well as other jurisdictions. This or a similar rule are applied in many jurisdictions across Canada where more sophisticated analysis is not performed. For these reasons, it was deemed reasonable to perform a standard wind/wave assessment following the CDA Guidelines to determine the level of conservatism in the 1 m requirements and whether a lower standard may be acceptable.

First, fetch lengths for each cardinal and intercardinal wind direction for the most exposed location of Elinor Lake North Dam was determined using the methodology specified in the USACE Coastal Engineering Manual (CEM) 2011. Calculated critical fetches for each cardinal and intercardinal direction are shown in Table 7-4.

Table 7-4: Elinor North Dam Effective Fetch Calculations

Direction	Length (m)
N	6
NE	8
E	58
SE	87
S	465
SW	285
W	40
NW	24

Wind speed and direction data was taken from the Environment Canada climate gauge located at Summerland CS. This gauge is located approximately 14 km from Naramata Dam and has data from 1994 - 2020. This gauge was chosen over others in the area because it had the longest period of record within the vicinity of Elinor Lake.

A frequency analysis was conducted on the wind data to determine wind speeds for several annual exceedance probabilities and for each intercardinal direction. Annual maximum one-hour wind speed values were fitted to a Gumbel statistical distribution to determine the wind speeds associated with various return periods. The results of the frequency analysis are summarized in Table 7-5.

Table 7-5: Wind Velocities (km/h)

Return Period	Direction							
	N	NE	E	SE	S	SW	W	NW
2	25	17	17	36	46	21	24	29
10	32	23	22	43	55	27	30	35
20	35	26	23	45	58	29	33	37
30	36	27	24	47	60	30	35	38
50	38	29	25	49	62	31	36	39
100	41	31	27	51	66	33	39	41
1,000	50	39	32	60	76	40	47	48

Over-land wind speeds are converted to over-water wind speeds using correction factors based on empirical relationships found in the CEM [USACE, 2011]. These factors include corrections for non-standard anemometer elevation, minimum time required to form fetch limited waves, air-water temperature difference and surface roughness relationships.

To calculate wave characteristics the water depth was assumed to be 4.1 m.

Wave characteristics were calculated for an IDF fetch combined with a 1:2-year wind event and the FSL fetch combined with a 1:1,000-year wind for all intercardinal directions to determine the critical wave condition. It was found that the largest fetch length and critical wave conditions were in the S direction in all cases.

In addition, the wave characteristics were calculated for the 1:100-year wind event combined with the FSL shoreline fetch lengths to assess riprap requirements.

Wave height, wave period, wind setup and wave runup which are exceeded by 5% of the incoming waves were calculated using the equations found in the CEM.

To calculate wave runup, the dam slope was taken to be 2.75H:1V. For wind setup (wind tide), , the maximum length of the reservoir that was considered was determined to be 0.42 km. The impact of wind setup was negligible (approximately 1 cm during a 1000 year wind).

The still water level for the extreme wind condition at FSL was assumed to be the same as the spillway crest elevation of 1276.55 m. For freeboard calculations, the still water level for the IDF was taken as 1277.08 m based on reservoir routing results shown in Section 7.2.4.

Table 7-6 shows the wind setup and wave runup results obtained using the CEM method.

As shown, freeboard requirements are governed by the IDF case. The analysis shows that the minimum required crest elevation to account for wind/wave effect is 1277.31 m. Based on the 2010 Topographic Survey [EBA], the minimum crest elevation of the dams is 1277.31 m, meaning that there is 0 m of additional freeboard available after wind and wave effects are taken into consideration. Therefore, by the CDA guidelines the freeboard to the lowest portion of the dam crest is adequate. The only issue remains that this does not meet the 1 m minimum recommended by the Plan Submission Requirements for the Construction and Rehabilitation of Small Dams [FLNRO, 2018].

Given the results of this analysis it is our recommendation that RDOS open a dialogue with BC Dam Safety to discuss whether the freeboard analysis performed would be acceptable in lieu of meeting the minimum 1 m requirement (see Issue No. EN-7 in Table 13-1). It is recommended that the dam crest be restored to its design elevation regardless, given the unknown material and erodibility, and the presence of ATV traffic causing rutting. Any additional loss of freeboard would result in a deficiency. However, given the fact that the freeboard is technically adequate, the priority may be lowered.

Table 7-6: Elinor North Dam Freeboard Assessment Results (CEM)

Case	Dir	Wind Event Return Period	Fetch (km)	Over Water Wind Speed (km/hr)	Still Water Level (m)	5% Wave Runup (m)	Fetch for Setup (km)	Wind Setup (m)	Total Wind Effects (m)	Maximum Water Level Including Wind Effects (m)	Structure Design Crest Elevation (m)	Freeboard Remaining (m)
Extreme Wind	S	1:1,000	0.46	50.12	1276.55	0.41	0.42	0.01	0.42	1276.97	1277.31	0.34
1/3 between 1000-year and PMF Flood Passage	S	1:2	0.46	24.72	1277.08	0.23	0.42	0.00	0.23	1277.31	1277.31	0

7.2.6 Riprap

Based on the wind and wave analysis that was carried out for the freeboard portion of this review, Hatch also completed an assessment of the required riprap protection based on the CEM method and Hudson equation for the Elinor Lake North Dam and compared the results to what was observed during the site visit.

Key assumptions that were used for the calculation of required riprap sizing included:

- A riprap density of 2,700 kg/m^3.
- A Kd value of 2.2 was used to size the riprap.
- The maximum mass of rock was defined as four times M_{50} (mass of the median rock) and the minimum mass of rock was defined as 0.125 M_{50}.

Based on these values, required riprap rock sizes and thicknesses were calculated for a number of return periods. The resulting minimum, maximum, and D_{50} (median rock diameter) values are shown in Table 7-7.

Table 7-7: CEM Riprap Requirements

Return Period	Diameter of Riprap (m)			Thickness of Riprap (m)
	Minimum	Maximum	D_{50}	
2	0.0	0.1	0.1	0.3
10	0.0	0.2	0.1	0.3
20	0.1	0.2	0.1	0.3
30	0.1	0.2	0.1	0.3
50	0.1	0.2	0.1	0.3
100	0.1	0.2	0.1	0.3
1,000	0.1	0.3	0.2	0.3

The CDA is not prescriptive on a specific return period required for riprap protection. Within the industry generally the return period of wind events used varies between a 1:10 (USACE) to 1:100 (USBR, USACE, SEBJ) to 1:1000 (SEBJ for tolerable damage). Generally speaking, most guidelines agree that a 1 in 100-year wind is appropriate for riprap protection. Based on the review in Table 7-7, the riprap layer should be 0.3 m thick with a D_{50} of 0.1 m (if using the assumptions provided in the above analysis) to resist wind generated waves up to a 100-year event. Since there does not appear to be existing riprap, the condition of the upstream face of the dam should continue to be monitored as part of RDOS's regular surveillance and maintenance program and any erosion problems identified and repaired in a timely fashion. In addition, the size of the riprap protection needed is very small, this is a good indicator that riprap protection is not a large concern for this structure and erosion due to wind wave action can be adequately addressed through regular inspection and repair as needed. (see Issue No. EN-13 in Table 13-1).

7.2.7 *Ice and Debris*

No records of debris problems at the structure have been found in the documentation. It has been noted that peat islands can be found in Elinor Lake, but that campers and hunters typically remove them for their own use.

7.3 Structural Assessment

All ancillary concrete structures are located at the Elinor South Dam. No spillway or LLO structure exists at the Elinor North Dam. Therefore, no structural assessment was required on this dam.

7.4 Geotechnical Assessment

As part of the 2020 DSR, Hatch reviewed the geotechnical conditions of Elinor North Dam. This was limited to a review of the available information on the site geology, since no original construction drawings, as-built records, or construction reports exist. Hatch used the Elinor South drawings as a representative section of the internal zoning of the North Dam. The profile of the slopes was generated from the 2012 topographic survey data. The background review and site visit observations made on July 9, 2020 (photos provided in Appendix A) were used to determine appropriate ground properties for the assessments including seepage and stability analyses. In the absence of information, Hatch has made acceptable assumptions and provided recommendations for further investigation.

7.4.1 *Geology*

As described by EBA (2010), the Geological Survey of Canada Map Surficial Geology Kootenay Lake (1984) indicates that surficial soil at the Elinor North Dam site is anticipated to be comprised of Sandy Till overlying crystalline metamorphic bedrock. The Sandy Till is described as a olive grey, grey to pale grey, weakly calcareous to non-calcareous loamy sand, sandy loam and loam, generally gravelly, cobbly or bouldery. It is mainly massive but may contain lenses of stratified sediments. It occurs as a blanket deposit with surface relief due to the shape of the underlying surface. The thickness of the soil unit varies from up to 30 m in the valley bottoms to no more than 5 m thick.

Clast lithologies reflect local bedrock which comprises mainly crystalline metamorphic and granitic rock. The surficial geology in the area of the Naramata dams is shown on EBA (2010), Figure 1.

7.4.2 *Seismicity*

The Elinor Lake North Dam has been classified as a “Very High” consequence dam based on incremental consequences of failure. Under this consequence classification, the seismic stability of the dam should be evaluated considering an earthquake with a return period of 1/2 between 1/2,475 years and 1/10,000 years or Maximum Credible Earthquake (MCE) as described in the CDA Dam Safety Guidelines (CDA, 2013 revision).

The foundation at the dam site is expected to be comprised of glacial till not deeper than 5 m. Therefore, site Class C conditions (foundations on Very Dense Soil and Soft Rock) are considered appropriate for the Naramata dam sites.

A 2015 National Building Code of Canada (NBCC) Seismic Hazard Calculation provides an estimated Peak Ground Acceleration (PGA) for the events up to 2,475 year events. In order to determine the PGA for an earthquake event with a 1:10,000 year return period, a site-specific hazard assessment is required. Here, an estimate for the 1:10,000 year return event has been made by extrapolating from the 1:1,000 year and 1:2,475 year return period events on a log-log scale. Appendix B contains the 2015 NBCC seismic hazard assessment for the Naramata Lake Dam, which is also used for the Elinor Lake Dams, and an estimate of the 1:10,000 year PGA. It is noted that the validity of these extrapolated PGAs cannot be assured even though the straight-line extrapolation to the 1:10,000-year return period often provides values that are conservative.

An average of 2,475 year and 10,000 year, 0.110 g event was selected in this work. Correspondingly, a PGA of 0.110 g was used in the stability analyses of the Elinor Lake North Dam, equivalent to full PGA value. It should be noted that this value is smaller than the PGA of 0.138 g, as was estimated and selected during 2010 DSR (EBA, 2010), which is due to refinements to the seismic model used in subsequent editions of the NBCC.

Table 7-8: National Building Code of Canada (NBCC) Seismic Hazard

Annual Exceedance Probability	NBCC 2005	NBCC 2010	NBCC 2015
1/100	0.034g	0.035g	0.010g
1/475	0.073g	0.073g	0.029g
1/1000	0.098g	0.098g	0.044g
1/2,475	0.138g	0.061g	0.070g
Selected PGA value – ½ between 1/2475 and 1/10,000	**-**	**-**	**0.110g**
Extrapolated 1/10,000	-	-	0.148g

7.4.3 *Preliminary and Supplementary Field Investigations*

No geotechnical investigation has been completed at the location of the Elinor North Dam. Conducting a detailed geotechnical investigation is recommended for future assessment of the embankment during normal and extreme load combinations. Such investigation should include a combination of drilling intrusive test holes (with Standard Penetration Testing (SPT)) and pushing Cone Penetration Testing (CPT) probes. Test holes should be advanced into foundation materials to enable ground characterization of the foundation. Laboratory testing should also be carried out for detailed classification of the embankment and foundation materials. A few piezometers should be installed upon completion of the test holes for long-term monitoring of the pore water pressure inside the embankment.

7.4.3.1 Embankment Dam

The Elinor North Dam is considered as a saddle dam providing water containment for Elinor Lake. No design or as-built drawings exist describing the details or internal zoning of the North Dam. The general configuration of the dam has been considered to be similar to the South Dam as described by EBA (2010) and OMS Manual (2017).

The North Dam is expected to be constructed of embankment shells with a central impervious clay zone. Based on the 2012 topographic survey data, the downstream slope is approximately 3.75H:1V. The full upstream slope was not surveyed, however the exposed upper portion above the water level was also sloped at approximately 3.75H:1V.

The available construction drawings for Elinor Lake South Dam indicate that the central core of the dam is constructed with clay core materials with vertical side slopes as is illustrated in Figure 7-1. This geometry is considered non-conventional which could be due to the lack of considerable quantity of clay materials at the site. Embankment dam cores are generally constructed with inclined slopes to ensure that no core/shell separation and sliding take place and the core materials experience vertical positive stress from the shell materials.

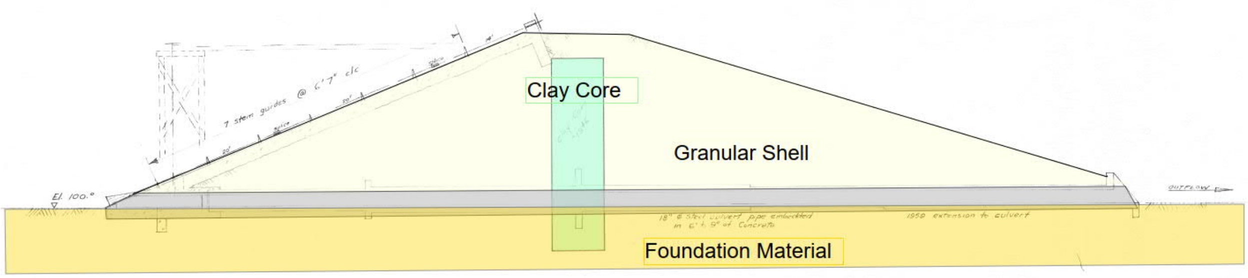


Figure 7-1: Typical Cross Section of the Elinor South Embankment Dam used for North Dam Assessment

7.4.3.2 Spillway

No spillway or other ancillary structure exists at the North Elinor (Saddle) Dam.

7.4.3.3 Foundation

No information exists of foundation material type or bedrock depth. As noted in Section 7.4.1, the foundation is anticipated to be comprised of Sandy Till overlying crystalline metamorphic bedrock. As noted by EBA (2010), the North Dam abuts to bedrock on the right abutment.

7.4.4 Geotechnical Seepage and Stability Assessment

A geotechnical assessment of seepage and slope stability of the dam were undertaken as part of this DSR. A review of available information pertaining to the material properties, cross section and construction history of the dam were carried out prior to the analyses. The following drawings and data provided by RDOS were used to develop the cross-sectional geometries, and material properties for the sections analyzed:

- Water Rights Branch. Naramata Irrigation District – Eleanor Lake Dam – Details of Culvert Gate Repairs. December 1966.
- Note: Drawing above depicts Elinor Lake South Dam. The internal zoning of Elinor Lake North Dam was assumed to be similar to Elinor Lake South.
- Okanagan Survey and Design Ltd. Elinor Lake – North Dam – Site Topography (EN-01). July 2012.

7.4.4.1 Material Properties

There is very little information available regarding properties of the embankment and foundation materials at Elinor Lake North Dam. Due to the limited background data, a preliminary analysis was conducted using assumed values. The values were selected with reference to typical published values for each type of material, and from results of historical and more recent geotechnical investigations conducted at Big Meadow Lake Dam and Naramata Lake Dam. The embankment was considered to consist of two zones, as described in Section 0:

- Central impervious zone (silty clay)
- Granular shell fill.

Additionally, the foundation material was assumed as sandy till.

The saturated permeability for each material was assumed for use in the seepage assessment. The selected permeability values for each material are listed in Table 7-9

Table 7-9: Material Permeabilities

Material Name	Saturated Permeability (m/sec)
Silty Clay	$2.5 * 10^{-8}$
Shell Fill	$5.0 * 10^{-5}$
Foundation – Sandy Till	$5.0 * 10^{-6}$

The unit weights and material strength parameters selected for each material are shown in Table 7-10.

Table 7-10: Material Properties – Mohr-Coulomb Strength Parameters

Materials	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Clay Core	18	28	0
Shell Fill	20	33	0
Foundation – Sandy Till	21	32	0

7.4.4.2 Model Geometry

The geometries of the embankment were determined from available drawings, reports and survey data. The critical section used for the seepage and slope stability analyses was selected at the tallest dam section. A plan view sketch of the section chosen for analysis is presented in Figure 7-2, and the cross-section as used in the analysis is presented in Figure 7-3.

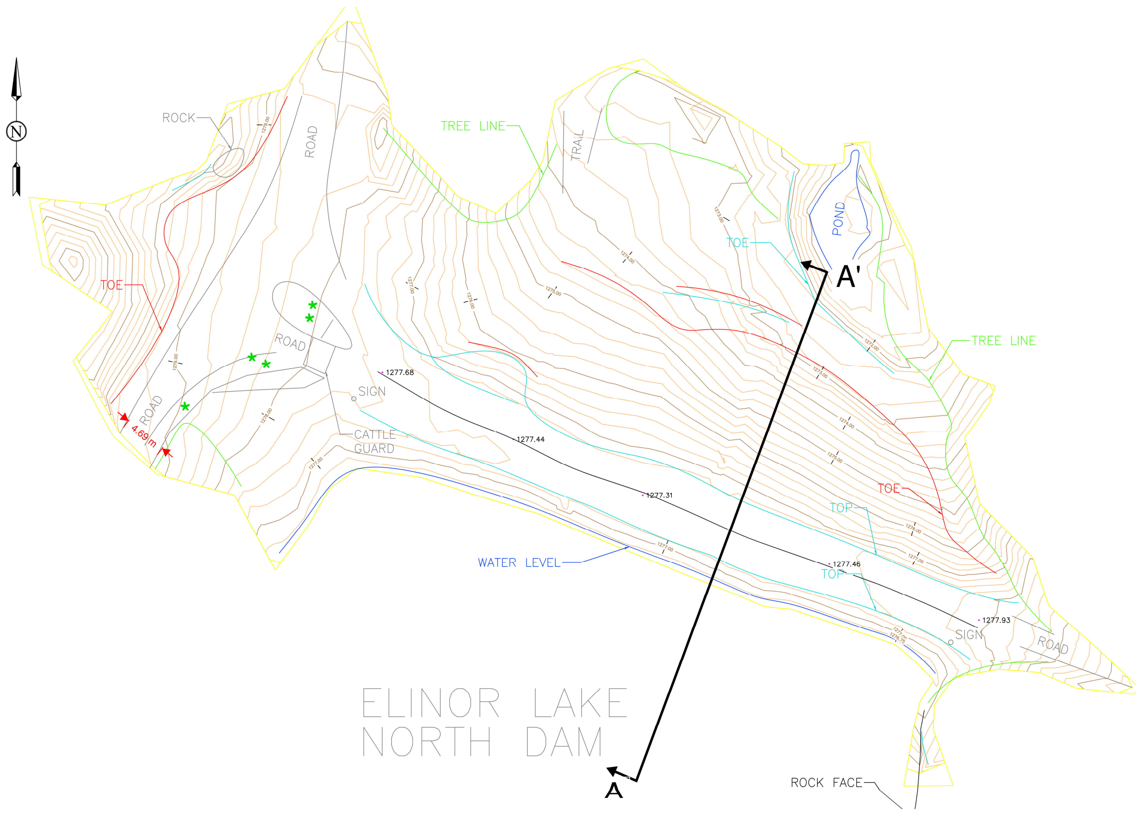


Figure 7-2: Location of Seepage/Stability Cross-Section (Okanagan Survey, 2012)

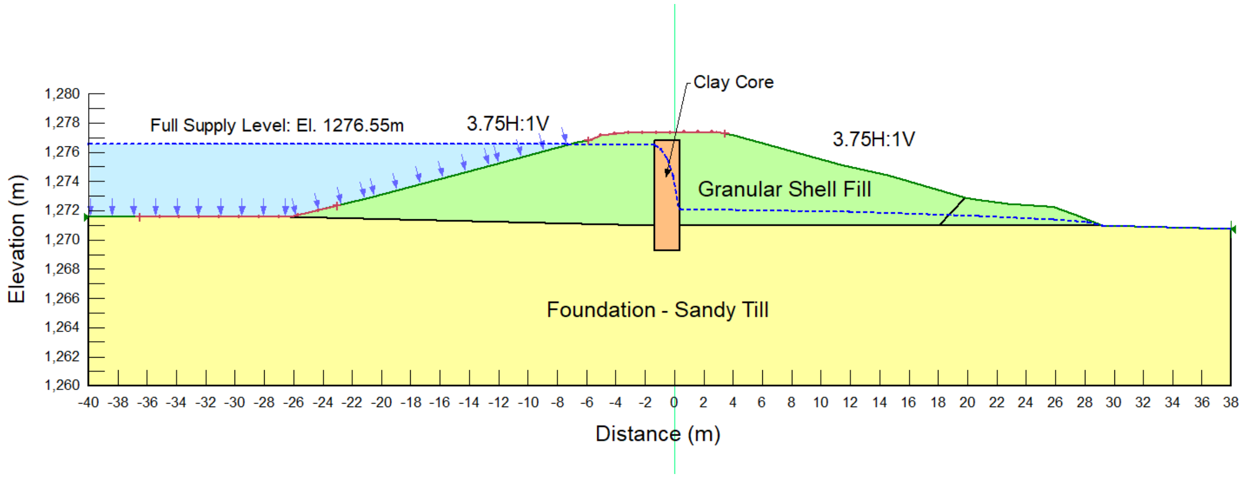


Figure 7-3: Modelled Critical Cross Section

The critical geometries used in the stability analyses for Elinor Lake North Dam are presented in Table 7-11.

Table 7-11: Elinor Lake North Dam Selected Section Properties

Structure	Embankment Section
Height	Overall: 6.4 m
Crest Width	6.8 m
Upstream Slope	Overall: 3.75H:1V
Downstream Slope	Overall: 3.75H:1V
Dam Crest Elevation	1277.5 m

7.4.4.3 *Seepage Analysis*

The seepage analyses were performed using SEEP/W software developed by GEO-SLOPE International Ltd. Version 10.1.1.18972. The program was used to generate the pore pressure distribution used for evaluating the exit gradients of the embankment. For evaluating the slope stability of the embankment, the porewater pressures developed in the SEEP/W program were interpreted to create a phreatic surface line in the SLOPE/W program.

The seepage analysis was performed for steady-state conditions under the following reservoir supply levels:

- Full supply level (FSL): 1276.55 m.

The Inflow Design Flood (IDF) condition was not analyzed since the IDF is a transient condition, and the pore water pressure conditions in the core and downstream are not expected to change significantly in the length of time corresponding to a flood event.

There is currently no instrumentation installed at the Elinor Lake North dam. Data from instruments such as piezometers and seepage weirs would allow for more accurate calibration of seepage modeling results. A minimum of one piezometer and a seepage weir should be installed as part of a geotechnical investigation program at the Elinor Lake North Dam.

A summary of the results of the seepage analyses are shown in Table 7-12. The complete results of each of the simulations completed for the seepage analyses of Elinor Lake North Dam are presented in detail in Appendix B.

Table 7-12: Results for Seepage Analyses

Load Case	Flow Rate per meter (m^3/day/m)	Maximum Exit Gradient	Factor of Safety Against Piping
FSL	1.19	0.343	2.92

Piping potential for the foundation has been assessed based on exit hydraulic gradients at the toe of the dam. Water that percolates through earth dams and their foundations can carry soil particles that are free to migrate. The seepage forces tend to cause the erodible soil or soft rock to move towards the downstream face of the dam.

The preceding exit gradient estimates represent the total head loss per unit length of the seepage path. High exit gradients may contribute to boiling or piping near the downstream toe. The critical hydraulic gradient (i_c) is defined as the hydraulic gradient at which boiling or piping (loss of soil strength initiating erosion) occurs and generally ranges between 0.85 to 1.1 (for most soils). The factor of safety against piping is therefore calculated as the ratio between the critical and estimated exit hydraulic gradients, as follows:

$$FoS_{piping} = \frac{i_c}{i}$$

Allowable factors of safety against piping typically range between 2 and 4 as outlined in Table 7-13.

Table 7-13: Summary of Allowable Exit Gradients and Factors of Safety

Reference	Minimum Required FoS	Approximate Maximum Gradient	Remarks
USACE (2005)	2	0.5	Sand boils generally occurred at gradients between 0.5 and 0.8 based on historical observations.
USBR (2011)	3 – 4	0.25 – 0.33	Factor of safety of 4 recommended for remediation of dams where high exit gradients exist.

The results of the seepage analysis indicate that the exit gradients at the downstream toe are elevated. The factor of safety against piping is approximately 2.9. This result is consistent with the observations of seepage downstream of the dam. It should be noted that this analysis is based on assumed material parameters due to the lack of information available regarding the embankment and foundation materials. As such, consideration should also be given to other methods of evaluating piping, such as the risk assessment in Section 7.4.5.5.

A geotechnical investigation and assessment should be completed to confirm the seepage characteristics of the dam and foundation. Due to the dam's seepage history, it is anticipated that the results of such an assessment would provide recommendations for remedial works such as a toe berm or drain.

7.4.4.4 Stability Modelling

The stability analyses were performed using SLOPE/W software developed by GEO-SLOPE International Ltd. Version 10.1.1.18972. The program uses the limit state equilibrium technique to model heterogeneous soil types, complex stratigraphic and slip surface geometry, and variable porewater pressure conditions using a large selection of soil strength models. Stability analyses for the Elinor Lake North Dam were performed based on effective stress analysis. The Morgenstern-Price method of slices with a half-sine function was selected for the inter-slice force function since this method satisfies both moment and force equilibrium.

The Entry and Exit method was used to generate slip surfaces, which calculates circular slip surfaces extending between a series of points on the upper and lower portions of a slope, and with a series of increasing radii.

As noted above, the embankment section utilized interpreted pore water pressure conditions from the results of the SEEP/W analysis. As there is no information available regarding the material properties, the phreatic surface was modified from the raw SEEP/W outputs to account for observed conditions of seepage at the downstream toe.

Load cases for the stability analyses were selected based on CDA Dam Safety Guidelines (CDA, 2013a). The design loads for the flood and seismic conditions were determined based on the methodologies discussed in Section 0 and 7.4.2, respectively. The slope stability load cases are summarized in Table 7-14.

Table 7-14: Loading Conditions Elinor Lake North Dam Section

Load Case	Operating Conditions	Remarks
LC-1	Normal Load Condition - Full Supply Level (FSL)	Reservoir Elevation = 1276.45
LC-2	Flood Condition - Inflow Design Flood (IDF)	N/A
LC-3	Rapid Drawdown (RDD)	Reservoir Elevation = 1273.25 m*
LC-4	Seismic	Horizontal seismic coefficient (kh) of 0.11g corresponding to the full PGA of the EDGM**.

* Corresponds to elevation of low level outlet at Elinor Lake South Dam.

** EDGM defined as average of 1:2,475 year and 1:10,000 year seismic events (CDA, 2013a)

The Elinor Lake North Dam does not have any facilities for rapidly drawing down the reservoir. However, the reservoir for this dam is also impounded by the Elinor Lake South Dam. There is a low level outlet at Elinor Lake South, at approximately El. 1273.25 m. The rapid drawdown case therefore considers a drawdown to this elevation.

A summary of the results of the stability analyses are shown in Table 7-15. The complete results of the slope stability analyses are presented in Appendix D.

Table 7-15: Results of Stability Analyses

Load Condition	Required Minimum Factor of Safety	Factor of Safety Normal Loading Conditions	
		Upstream	Downstream
LC-1 (FSL)	1.50	2.45	2.35
LC-2 (IDF)	N/A		
LC-3 (RDD)	1.20	1.77	N/A
LC-4 (Seismic)	1.00	1.32	1.53

Overall, the calculated factors of safety for upstream and downstream for each load case exceed the minimum recommended values as indicated by 2007 CDA Guidelines (2013 Revision).

7.4.5 Geotechnical Considerations

Geotechnical considerations related to the dam safety of the Elinor Lake North Dam are discussed in the following sections.

7.4.5.1 Liquefaction Potential

Available information regarding subsurface conditions was not available at the time of writing this report. Accordingly, no quantitative liquefaction assessments were undertaken for Elinor Lake South dam. A seismic assessment of the dam is recommended due to its “High” consequence classification and limited embankment and foundation information.

A geotechnical subsurface investigation is recommended to characterize the embankment and foundation materials, and provide relevant information for a liquefaction triggering assessment.

7.4.5.2 *Post-seismic*

The expected performance of the dam following the design seismic event is currently unknown due to the lack of in-situ geotechnical information. The post-seismic stability will also depend on the extent of liquefaction, particularly within the dam's granular shell. Post-seismic stability considering residual strength parameters should be assessed using results from a future geotechnical investigation and liquefaction assessment (see Issues EN-2c and EN-5 in Table 13-1).

7.4.5.3 *Internal Stability and Material Compatibility*

Seepage flows through granular materials in an embankment dam can cause fine particles in the material to be eroded away, leaving only coarser grained particles and higher proportion of voids. The susceptibility of a material to this phenomenon is referred to as internal stability.

Internal stability is assessed by analysis of the grain size distribution curves obtained from a laboratory sieve test of embankment materials. No such grain size distribution curves are available for the Elinor Lake North dam. This testing should be conducted in a future geotechnical investigation and an internal stability analysis subsequently completed (see Issues EN-2c and EN-5 in Table 13-1).

An additional factor affecting risk of piping is the compatibility between different zones of the embankment. This is defined by the ratios between certain index grain sizes of materials in adjacent embankment zones, such as the clay core and granular shell. This should also be assessed for the Elinor Lake North Dam upon completion of a geotechnical investigation and laboratory testing.

7.4.5.4 *Instrumentation*

There is currently limited instrumentation installed at the Elinor Lake South Dam. Considering the consequence classification of the dam, instrumentation should be installed and monitored regularly, consisting of at least two piezometers and seepage weirs (see Issues EN-2d and EN-12 in Table 13-1).

7.4.5.5 *Piping Potential*

EBA [2010] carried out an assessment of piping Failure Risk Assessment at the Elinor Lake North Dam. Past inspections have not specifically identified the presence of turbid seepage downstream of each dam, particularly the most recent inspections. However, this may not have been apparent due to the way seepage is currently monitored especially downstream of the Elinor North Dam and in the past inspectors may not have been aware that they should be looking for seepage turbidity. Even though the history doesn't indicate an issue, there is never a guarantee that turbid seepage may not start in the future.

As part of this DSR, Hatch repeated the piping risk assessment for Elinor North Dam as carried out by EBA [2010], given the new condition and relating the risks presented by the Elinor North Dam considering the “Very High” DFCC. In addition, EBA [2010] considered one piping risk assessment for both dams, however, the seepage, conduit presence, and dam classification make the piping risk and its consequence different at the North and South Dams.

The piping failure risk assessment method used is based on Foster and Fell [2000] assessment method. This method quantifies the probability of dam failure due to potential of seepage and piping events. The Foster and Fell [2000] approach estimates the relative likelihood of dam failure by piping, P_p, by quantifying the influence of several factors that affect the likelihood of piping. The approach calculates the relative probability of several piping modes, namely:

- Piping through the embankment (E).
- Piping through the foundation (F).
- Piping of embankment into foundation (EF).

Relative probabilities are determined by assessing historical failure frequencies due to piping and seepage phenomena. The method accounts for general factors influencing the likelihood of failure. The annual likelihood of failure by piping is then calculated using the following formula:

$$P_p = w_E P_e + w_F P_f + w_{EF} P_{ef}$$

Where w_x and P_x represent the weighting factor and relative annual likelihood of failure by piping, respectively. Note that the subscript ‘x’ denotes a mode of failure, where ‘E’ represents a failure of the embankment, ‘F’ represents a failure of the foundation, and ‘EF’ represents a failure from piping of the embankment into the foundation. Refer to the paper published by Foster et al., 2000 for a more detailed explanation of the methodology.

Considering the level of information related to design and construction, despite the fact that the two (North and South) dams are different in height, the assessment performed for the North and South Elinor Lake Dams was the same. Furthermore, the piping risk of both dams should be addressed together due to similarities (and differences, e.g., no culvert in the North Dam) in their current consequence classifications, design concept, and construction scheme. The various assumptions utilized in the Foster and Fell [2000] analysis at the dams for the three (3) discussed failure types are presented in Table 7-16 through Table 7-18. References for the weighting factors are provided in Figure 7-4 to Figure 7-6. Annual failure probabilities applicable to both dams are presented in Figure 7-7.

Table 7-16: Foster and Fell [2000] Coefficients for Piping through the Elinor North Embankment Dam

Factor	Factor Description	Score	Commentary
Embankment Filters	No embankment filter (for dams that usually have filters;	2	Filter criteria and compatibility unknown between upstream blanket and shell. Filter blanket existent.
Core Geological Orogin	Glacial	0.5	Source not known.
Core Soil	low placicity silt (ML)	2.5	Source is not known. Silt type is selected conservatively.
Compaction	Rolled, modest control	1.2	Average level of compaction was assumed
Conduits	No Conduit	0.5	Average construction scheme assumed; no arresting filter detail on D/S side.
Foundation Treatment - Bedrock	Irregularities in foundation or abutment, steep abutments	1.2	No detail of core foundation treatment is available.
Observations of seepage	Leakage steady, clear, or not observed	1	Seepage is observed; clean however.
Monitoring and surveillance	Irregular seepage observations, inspections weekly	1	Weekly inspection, but no leakage being measured.
Type of Embankment	Cenrtal core earth and rockfill		
Age in years	50		
Embankment type factor	34		
	W_E =	1.800	Embankment Weighting Factor
	P_E =	3.40E-05	Cenrtal core earth and rockfill
	Overall Embankment Probablilty	6.12E-05	

Note: USBR refers to US Bureau of Reclamation

Table 7-17: Foster and Fell [2000] Coefficients for Piping through Foundation of the Elinor North Embankment Dam

Factor	Factor Description	Score	Commentary
Foundation Filters	No foundation filter present	1	Foundation filter blanket present; however, not effective.
Foundation below cutoff	Soil	5	Not used. Foundation is granular glacial till.
Cut-off (soil foundation)	Shallow or no core trench	1.2	No core trench exists
Cut-off (rock foundation)	Not applicable	1	No cutoff constructed
Soil Geology below condut	Glacial	0.5	not applicable
Rock Geology (below cut-off)	Not applicable	1	no cutoff
Observations of seepage	Leakage gradually increasing, clear, sinkholes, sand boils	2	Seepage is observed; clean however.
Observations of pore pressure	High pressures in foundation	1	No abnormal pore pressure occurences in foundation; but pressure distributes in foundation.
Monitoring and surveillance	Irregular seepage observations, inspections weekly	1	Weekly inspection.
Embankment type factor	19		
	W_F =	6.000	
			Foundation Weighting Factor
	P_F =	1.90E-05	Cenrtal core earth and rockfill
	Foundation piping probability =	1.14E-04	

Note: General foundation properties of both dams were considered as a unit for this piping probability approximation.

Table 7-18: Foster and Fell [2000] Coefficients for Piping of Embankment into Foundation of the Elinor Lake North Dam

Factor	Factor Description	Score	Commentary
Filters	Appears to be independent of presence–absence of embankment or foundation filters	1	no seepage from dam to foundation is expected.
Foundation cutoff trench	Shallow or no trench	0.8	No cutoff trench.
Foundation	On or partly on soil	0.5	Fully on overburden.
Erosion control measures of core foundation	None, average foundation conditions	1.2	No filter exists
Foundation Grouting	Soil foundation - not applicable	1	None.
Soil Geology Types	Glacial	2	Granular glacial till.
Rock Geology	Not applicable	1	Central core.
Core geological orogin	Glacial	0.5	Galical sources were used.
Core soil type	Low placticity silt (ML)	2.5	Not much information. Assumed classification according to existing info.
Core compaction	Appears to be idependent of compaction	1	Little info.
Foundation Treatment (rock)	Irregularities in foundation or abutment, steep abutments	1.1	Foundation prep under the dam or abutments not known.
Observations of seepage	Leakage steady, clear or not monitored	1	Seepage is observed; clean however.
Monitoring and surveillance	Irregular seepage observations, inspections weekly	1	Weekly inspection happens.
Embankment type factor	4		
	W_{EF} =	1.320	Embankment Weighting Factor
	P_{EF} =	4.00E-06	Cenrtal core earth and rockfill
	Embankment piping into Foundation Probabiity =	5.28E-06	

	General factors influencing likelihood of failure				
Factor*	Much more likely	More likely	Neutral	Less likely	Much less likely
Embankment filters $w_{E(filt)}$		No embankment filter (for dams that usually have filters; refer to text) (2)	Other dam types (1)	Embankment filter present, poor quality (0.2)	Embankment filter present, well designed, and well constructed (0.02)
Core geological origin $w_{E(cgo)}$	Alluvial (1.5)	Aeolian, colluvial (1.25)	Residual, lacustrine, marine, volcanic (1.0)		Glacial (0.5)
Core soil $w_{E(cst)}$	Dispersive clays (5); low-plasticity silts (ML) (2.5); poorly graded and well-graded sands (SP, SW) (2)	Clayey and silty sands (SC, SM) (1.2)	Well-graded and poorly graded gravels (GW, GP) (1.0); high-plasticity silts (MH) (1.0)	Clayey and silty gravels (GC, GM) (0.8); low-plasticity clays (0.8)	High-plasticity clays (CH) (0.3)
Compaction $w_{E(cc)}$	No formal compaction (5)	Rolled, modest control (1.2)	Puddle, hydraulic fill (1.0)		Rolled, good control (0.5)
Conduits $w_{E(con)}$	Conduit through the embankment, many poor details (5)	Conduit through the embankment, some poor details (2)	Conduit through embankment, typical USBR practice (1.0)	Conduit through embankment, including downstream filters (0.8)	No conduit through the embankment (0.5)
Foundation treatment $w_{E(ft)}$	Untreated vertical faces or overhangs in core foundation (2)	Irregularities in foundation or abutment, steep abutments (1.2)		Careful slope modification by cutting, filling with concrete (0.9)	Careful slope modification by cutting, filling with concrete (0.9)
Observations of seepage $w_{E(obs)}$	Muddy leakage, sudden increases in leakage (up to 10)	Leakage gradually increasing, clear, sinkholes, seepage emerging on downstream slope (2)	Leakage steady, clear, or not observed (1.0)	Minor leakage (0.7)	Leakage measured none or very small (0.5)
Monitoring and surveillance $w_{E(mon)}$	Inspections annually (2)	Inspections monthly (1.2)	Irregular seepage observations, inspections weekly (1.0)	Weekly–monthly seepage monitoring, weekly inspections (0.8)	Daily monitoring of seepage, daily inspections (0.5)

Figure 7-4: Weighting Factors (Values in Parentheses) for Piping through the Embankment Mode of Failure

	General factors influencing likelihood of failure				
Factor*	Much more likely	More likely	Neutral	Less likely	Much less likely
Filters $w_{F(filt)}$		No foundation filter present when required (1.2)	No foundation filter (1.0)	Foundation filter(s) present (0.8)	
Foundation (below cutoff) $w_{F(fnd)}$	Soil foundation (5)		Rock, clay-infilled or open fractures and (or) erodible rock substance (1.0)	Better rock quality ⟶	Rock, closed fractures and non-erodible substance (0.05)
Cutoff (soil foundation) $w_{F(cts)}$		Shallow or no cutoff trench (1.2)	Partially penetrating sheetpile wall or poorly constructed slurry trench wall (1.0)	Upstream blanket, partially penetrating, well-constructed slurry trench wall (0.8)	Partially penetrating deep cutoff trench (0.7)
Cutoff (rock foundation) $w_{F(ctr)}$	Sheetpile wall, poorly constructed diaphragm wall (3)	Well-constructed diaphragm wall (1.5)	Average cutoff trench (1.0)	Well-constructed cutoff trench (0.9)	
Soil geology (below cutoff) $w_{F(sg)}$	Dispersive soils (5); volcanic ash (5)	Residual (1.2)	Aeolian, colluvial, lacustrine, marine (1.0)	Alluvial (0.9)	Glacial (0.5)
Rock geology (below cutoff) $w_{F(rg)}$	Limestone (5); dolomite (3); saline (gypsum) (5); basalt (3)	Tuff (1.5); rhyolite (2); marble (2); quartzite (2)		Sandstone, shale, siltstone, claystone, mudstone, hornfels (0.7); agglomerate, volcanic breccia (0.8)	Conglomerate (0.5); andesite, gabbro (0.5); granite, gneiss (0.2); schist, phyllite, slate (0.5)
Observations of seepage $w_{F(obs)}$	Muddy leakage, sudden increases in leakage (up to 10)	Leakage gradually increasing, clear, sinkholes, sand boils (2)	Leakage steady, clear, or not observed (1.0)	Minor leakage (0.7)	Leakage measured none or very small (0.5)
Observations of pore pressures $w_{F(obp)}$	Sudden increases in pressures (up to 10)	Gradually increasing pressures in foundation (2)	High pressures measured in foundation (1.0)		Low pore pressures in foundation (0.8)
Monitoring and surveillance $w_{F(mon)}$	Inspections annually (2)	Inspections monthly (1.2)	Irregular seepage observations, inspections weekly (1.0)	Weekly–monthly seepage monitoring, weekly inspections (0.8)	Daily monitoring of seepage, daily inspections (0.5)

Figure 7-5: Weighting Factors (Values in Parentheses) for Piping through the Foundation Mode of Failure

Factor*	General factors influencing likelihood of initiation of piping: Much more likely	More likely	Neutral	Less likely	Much less likely
Filters $w_{EF(filt)}$	Appears to be independent of presence–absence of embankment or foundation filters (1.0)	Appears to be independent of presence–absence of embankment or foundation filters (1.0)	Appears to be independent of presence–absence of embankment or foundation filters (1.0)	Appears to be independent of presence–absence of embankment or foundation filters (1.0)	Appears to be independent of presence–absence of embankment or foundation filters (1.0)
Foundation cutoff trench $w_{EF(cot)}$	Deep and narrow cutoff trench (1.5)		Average cutoff trench width and depth (1.0)	Shallow or no cutoff trench (0.8)	
Foundation $w_{EF(fnd)}$		Founding on or partly on rock foundations (1.5)			Founding on or partly on soil foundations (0.5)
Erosion-control measures of core foundation $w_{EF(ecm)}$	No erosion-control measures, open-jointed bedrock, or open-work gravels (up to 5)	No erosion-control measures, average foundation conditions (1.2)	No erosion-control measures, good foundation conditions (1.0)	Erosion-control measures present, poor foundations (0.5)	Good to very good erosion-control measures present and good foundation (0.3–0.1)
Grouting of foundations $w_{EF(gr)}$		No grouting on rock foundations (1.3)	Soil foundation only, not applicable (1.0)	Rock foundations grouted (0.8)	
Soil geology types $w_{EF(sg)}$	Colluvial (5)	Glacial (2)		Residual (0.8)	Alluvial, aeolian, lacustrine, marine, volcanic (0.5)
Rock geology types $w_{EF(rg)}$	Sandstone interbedded with shale or limestone (3); limestone, gypsum (2.5)	Dolomite, tuff, quartzite (1.5); rhyolite, basalt, marble (1.2)	Agglomerate, volcanic breccia (1.0); granite, andesite, gabbro, gneiss (1.0)	Sandstone, conglomerate (0.8); schist, phyllite, slate, hornfels (0.6)	Shale, siltstone, mudstone, claystone, (0.2)
Core geological origin $w_{EF(cgo)}$	Alluvial (1.5)	Aeolian, colluvial (1.25)	Residual, lacustrine, marine, volcanic (1.0)		Glacial (0.5)
Core soil type $w_{EF(cst)}$	Dispersive clays (5); low-plasticity silts (ML) (2.5); poorly graded and well-graded sands (SP, SW) (2)	Clayey and silty sands (SC, SM) (1.2)	Well-graded and poorly graded gravels (GW, GP) (1.0); high-plasticity silts (MH) (1.0)	Clayey and silty gravels (GC, GM) (0.8); low-plasticity clays (CL) (0.8)	High-plasticity clays (CH) (0.3)
Core compaction $w_{EF(cc)}$	Appears to be independent of compaction, all compaction types (1.0)	Appears to be independent of compaction, all compaction types (1.0)	Appears to be independent of compaction, all compaction types (1.0)	Appears to be independent of compaction, all compaction types (1.0)	Appears to be independent of compaction, all compaction types (1.0)
Foundation treatment $w_{EF(ft)}$	Untreated vertical faces or overhangs in core foundation (1.5)	Irregularities in foundation or abutment, steep abutments (1.1)		Careful slope modification by cutting, filling with concrete (0.9)	Careful slope modification by cutting, filling with concrete (0.9)
Observations of seepage $w_{EF(obs)}$	Muddy leakage, sudden increases in leakage (up to 10)	Leakage gradually increasing, clear, sinkholes (2)	Leakage steady, clear, or not monitored (1.0)	Minor leakage (0.7)	No or very small leakage measured (0.5)
Monitoring and surveillance $w_{EF(mon)}$	Inspections annually (2)	Inspections monthly (1.2)	Irregular seepage observations, inspections weekly (1.0)	Weekly–monthly seepage monitoring, weekly inspections (0.8)	Daily monitoring of seepage, daily inspections (0.5)

Figure 7-6: Weighting Factors (Values in Parentheses) for Accidents and Failures as a Result of Piping from the Embankment into the Foundation

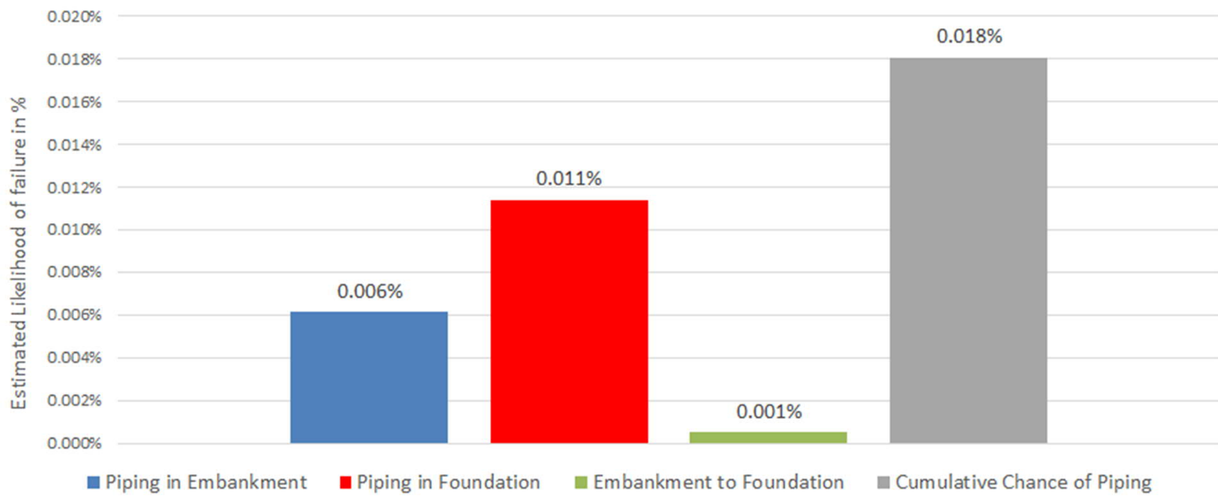


Figure 7-7: Estimated Annual Probability of Failure of the Elinor Lake North Dam Using Foster and Fell [2000]

According to CDA Guidelines [CDA, 2013a], life safety risk should be consistent with values used in other hazardous industries and with the principle that risks should be made as low as reasonably practicable (ALARP). Using this principal, a better understanding of the piping risks can be obtained by plotting annual exceedance probability against the expected number of persons subjected to a Life Safety Risk. Figure 7-8 outlines the piping risk with regards to life safety risk using the DFCC of “High” an assuming a potential for Loss of Life.

The red, yellow, and green bands represent unacceptable, tolerable (as long as the risk is ALARP), and acceptable risk ranges, respectively. ALARP refers to an operating condition where all prudent measures to reduce risk have been undertaken and continuous surveillance is implemented.

In its existing condition, the total probability of piping failure at the Elinor Lake North Earthfill Dam appears to be close to unacceptable ranges. However, this potential can be reduced in a number of ways. First, as can be observed in Figure 7-8 the broadly acceptable band is highly influenced by the potential number of people.

The following activities may be undertaken to reduce the piping failure risk at the Elinor Lake North Dam:

- Provide additional training and instruction to Dam Operators to property identify, sample and respond to seepage turbidity would reduce the piping risk a. Seasonal turbidity laboratory tests could then be conducted on any water samples taken (see Issues All-7 and All-8 in Table 13-1).

- Structural mitigation in terms of installing piping control measures such as a reverse filter blanket at the toe of dam is an alternative measure which might be considered for the Elinor North Dam. (see Issue EN-5 in Table 13-1).
- Conduct geotechnical investigation and assessments to further assess the internal zoning, internal stability, and filter criteria.
- Install additional instrument at dams to measure internal pore water pressure and total seepage quantity, by the installation of piezometers and weirs, respectively.

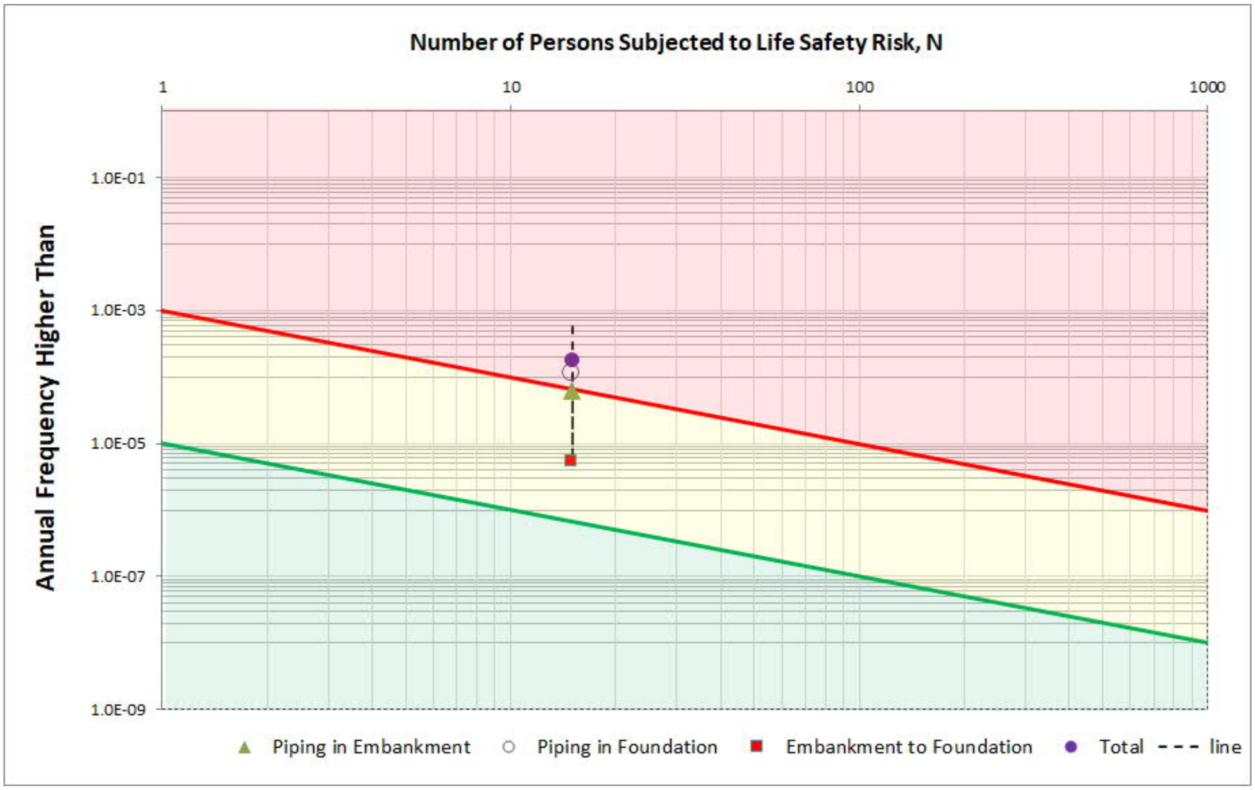


Figure 7-8: Existing Risk Acceptability for Elinor North Earthfill Dam Considering DFCC of 15

7.4.6 Geotechnical Assessment Conclusions

The following recommendations have been developed from the results of the geotechnical assessment:

- There is insufficient geotechnical data available to fully evaluate the current geotechnical condition of the Elinor Lake North Dam. A geotechnical investigation should be undertaken to characterize the embankment and foundation materials. A geotechnical investigation should at minimum include boreholes advanced through the embankment and extended into the foundation. Samples of the core and shell materials should be collected and tested for geotechnical parameters.

- Upon completion of the Geotechnical investigation, seepage, stability and exit piping risk assessments should be updated and a liquefaction and post-seismic stability assessments should be performed.
- Additional assessments such as internal stability of various shell and core materials and filter criteria should be conducted upon completion of laboratory testing.
- There is currently no instrumentation installed at the Elinor Lake North Dam. A minimum of one piezometer should be installed as part of any future geotechnical investigation. A downstream weir should also be installed to capture and quantify seepage flows through the embankment.

7.5 Mechanical Assessment

The is no mechanical control equipment at this site.

8. Public Safety and Security

In 2011, the CDA published guidelines for Public Safety Around Dams [CDA, 2011] and the 2013 revision of the CDA Dam Safety Guidelines [CDA, 2013a] outlines the requirements to address Public Safety and Security in Section 5.4.8. However, public safety and security are not explicitly addressed under the BC Dam Safety Regulation [B.C. Reg 44/2016]. In general, managing public safety and security around dams are important for the dam owner in order to ensure that the presence and normal operation of their structure does not pose an unacceptable risk to the public and to mitigate potential liability should a member of the public become injured at their structure.

8.1 Site Observations

Elinor North Dam is accessible by either 4x4 vehicles, hiking, snowmobile, motorbikes or off-road recreational vehicles (ATV), and vehicle access is made available via the Elinor Lake Forestry Service Road. ATV trails were present around the dam with rutting on the dam crest, indicating the presence of the public on this structure. As shown in the freeboard analysis, there is no excess freeboard available and so any additional loss of freeboard in the dam would result in a deficiency. In addition, campfire remnants were observed on the crest of the dam, and near the Chute Creek Diversion channel. These observations indicate the type of access the public has to the site and the potential for safety incidents to occur. Currently, there is a sign including contact information for dam safety concerns, including contacts for an emergency, and large boulders along the downstream side of the dam crest to discourage ATV traffic.

8.2 Public Safety Management Plan Audit

RDOS does not currently have a comprehensive public safety management plan in place for Elinor North Dam, however, a “Risk Control Survey” has recently been completed by Precise Services in 2019 with the intent of identifying exposures to liability and to assist the risk management and public works staff in managing those exposures. As such, some of the types of control measures recommended within this document are similar to those expected as part of a formal public safety around dams management plan. These include fencing, signage, barriers at the low flow outlet structure, informative signage, warning signage and gates.

A summary of the findings and recommendations of the report is provided below for each component along with additional comments as applicable. All outstanding recommendations in the Risk Control Survey should be implemented.

8.2.1 General

The Risk Control Survey recommends the addition of more large boulders that cannot be moved by truck winches or off-road vehicles to discourage off-road vehicles from driving around on the dam face, as well as signage to provide information about the dams, water flow, the use of the water in the event of emergency, off-road vehicle restrictions and why, a requirement to pack out what you pack in, ask the public to observe, record and report if they see others vandalizing any aspect of the dam infrastructure. It also recommends the homemade bridge structure used to cross the Chute Creek Diversion be removed. During the site inspection, Hatch observed remnants of a campfire on the other side of this bridge. The risk survey also recommends the addition of a latched gate along the fence at the access point to the dam, along with signage.

No signage was present on the dam itself to warn of steep slopes and fall hazards.

8.3 Recommendations

We recommend that all outstanding recommendations in the Risk Control Survey be implemented with a high priority. A supplemental public safety risk analysis and assessment should be considered in the future to align with CDA Guidelines [CDA, 2011]. This exercise would ensure that all hazards have been considered and covered off and serve as formal documentation of public safety improvement and reduction of liability for RDOS.

9. Dam Safety Management

The CDA Dam Safety Guidelines state that "The owner is responsible for the safe management of a dam. Dam safety management takes place within the context of public safety reassuring the public and stakeholders that risks to people, property, and the environment are being properly addressed." The Guidelines also state that "A dam safety management system, incorporating policies, responsibilities, plans and procedures, documentation, training, and review and correction of deficiencies and non-conformances, shall be in place." Dam owners can demonstrate a commitment to diligent safety management through the implementation of a formal Dam Safety Management System.

The CDA Dam Safety Guidelines note that the effectiveness of the dam safety management system should be assessed during the course of a DSR. Key elements of the management system are policy development, planning, implementation of procedures, checking, corrective action, and reporting. Indications of effectiveness include the following:

- Roles, responsibilities, and authorities are clearly assigned.
- Key activities are clearly assigned.
- Personnel understand their roles and responsibilities and training is administered.
- Operation, maintenance, and surveillance activities are carried out and documented.
- Safety measures recommended in previous Dam Safety Review reports have been carried out.
- Other supporting documentation (as-built drawings, design calculations, engineering studies, monitoring data, licenses) are readily available.

The RDOS has a dam safety strategy that is in compliance with the B.C. Dam Safety Regulation [B.C. Reg 44/2016] under the Water Sustainability Act, but no formal Dam Safety Management policy document was provided. RDOS has an OMS Manual with documented OMS procedures or activities, and a DEP specific to the dam. Regular surveillance and maintenance activities are conducted. Dam safety training is understood to be completed on the job; although documentation of such is not available.

Recommendations from the previous Dam Safety Review by EBA in 2010 have been partially implemented to date. A number of Dam Safety Concerns are being acted on, as is the case with the boil scenario at Naramata Dam that emerged just prior to this DSR inspection.

Pertinent records including drawings, consultant reports and some monitoring records are readily available.

Based on the above, it is evident that RDOS has implemented a number of the elements of an effective Dam Safety Management System with the main shortfalls found in proper documentation of their activities rather than performance of the requirements. RDOS should continue to improve operation, maintenance, and surveillance protocols, improve DEPs as required, and conduct independent dam safety reviews and audits.

RDOS should ensure that its existing dam safety activities are continued in the context of a Dam Safety Management System which provides an overall framework for safety activities, decisions, and supporting processes. This is particularly important to maintain continuity in the event of internal reorganization or changing responsibilities for dam safety. The system should include implementation of the following.

- Dam Safety Policy, defining ultimate accountability and authority for implementation.
- Documented annual reports to management on the state of dam safety activities.
- Keeping of employee training records, inspection records, and DEP testing and training records.
- Public Safety Management Plan.

An overview of the elements of an owner's Dam Safety Management System as described in the CDA Dam Safety Guidelines is shown in Figure 9-1. Additional detail is provided in the following sections.

9.1 Policy Development

The owner should have a Dam Safety Policy that clearly demonstrates commitment to safety management throughout the complete life cycle of the dam. The Policy should define the following:

- The level of safety that is to be provided, and the safety criteria to be used. Applicable regulations must be met, and industry practice and due diligence must be taken into account.
- Ultimate accountability and authority in the organization for ensuring that the policy is implemented. To ensure that safety objectives are not considered secondary to other objectives, accountability for dam safety should be placed at the highest level of management.
- The delegation of responsibility and authority for all dam safety activities. Key individual positions accountable for dam safety, operation, surveillance and maintenance should be identified, along with their responsibilities for internal and external reporting.
- The process for making decisions related to dam safety. Critical safety decisions with significant societal or financial implications should be made or approved at the highest level.

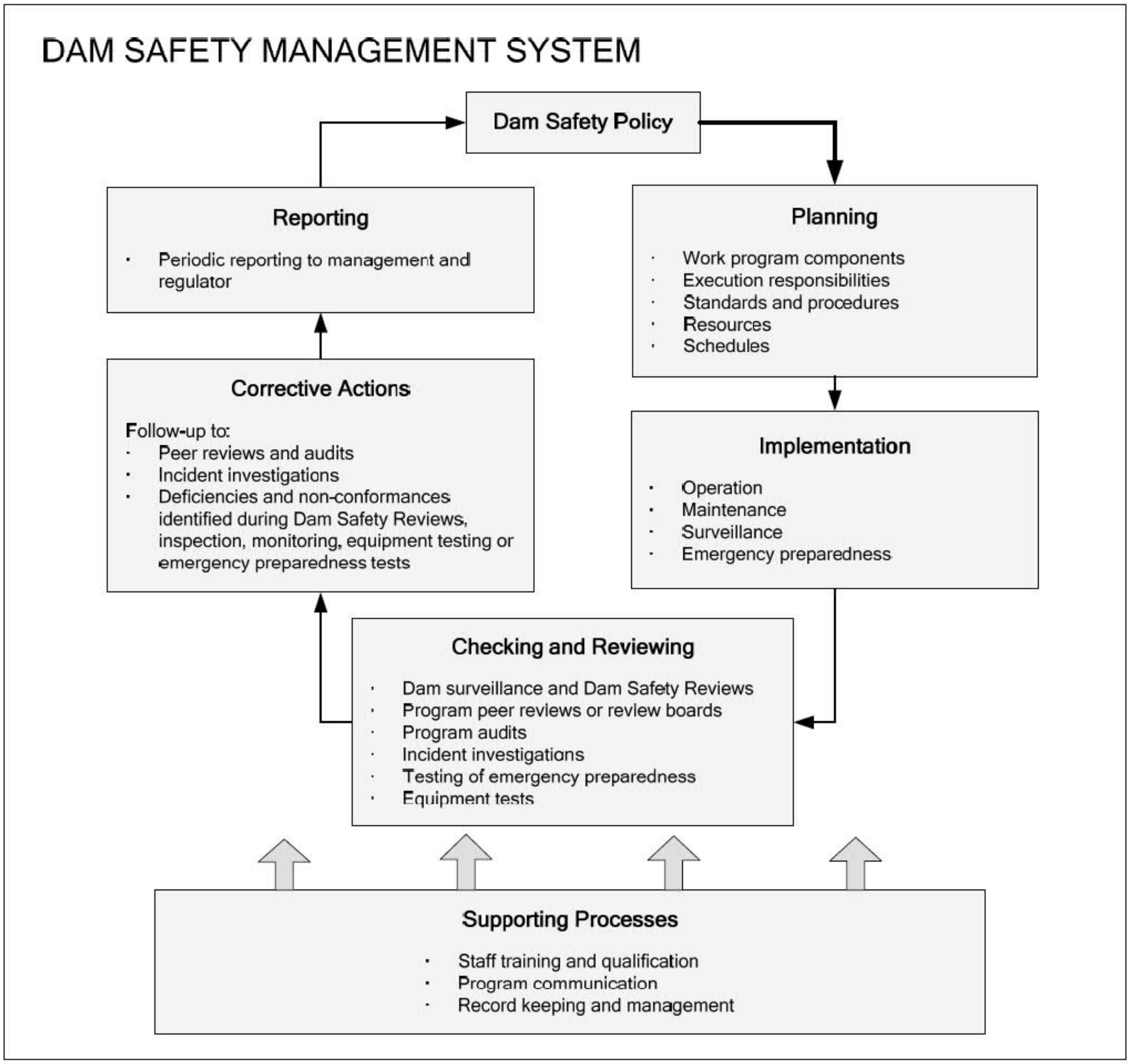


Figure 9-1: Overview of a Dam Safety Management System

We recommend that every dam owner develop a comprehensive policy regarding dam safety so that in an emergency situation the dam managers and operators are empowered to make critical decisions and have clear guidance in making these decisions. This type of policy has been shown to be instrumental in preventing dam safety emergencies from progressing into disasters in numerous situations.

9.2 Planning

Planning involves identifying the items in a dam safety work program, assigning responsibilities for carrying out each item, and ensuring resources are adequate to carry out the work. It is often useful to consider three levels of planning: the strategic or long-range plan (5 to 10 years); the management plan (annual); and operational plans specific to an individual project or task. RDOS currently has a planning process in place that should be more formally documented within their dam safety program.

9.3 Implementation

Ongoing activities associated with dam safety management include operation, maintenance and surveillance, and emergency preparedness. RDOS's regular operations, maintenance and surveillance activities are generally carried out in a structured manner. The results of the current project formalize their DEP and OMS manuals. These should continue to be improved and updated to provide better records of what is planned and what is completed.

9.4 Checking and Reviewing

The Dam Safety Management System should include processes for checking and reviewing dam performance and the management system itself.

Inspections, monitoring and assessment of data, testing of equipment, and emergency exercises are processes to check and review the condition and performance of the dams and their components. Dam Safety Reviews should be performed periodically to provide independent assurance that current safety requirements are met and to make recommendations for improvement.

After any significant dam safety incident, the owner should carry out an investigation to determine root causes, minimize potential for such incidents to happen again, and ensure that lessons learned are incorporated into the system and communicated to staff.

RDOS undertakes periodic reviews of their monitoring and surveillance data. These should be further formalized and documenting as part of their dam safety management program. DSRs are being conducted on a regular basis and should continue to be performed on the required schedule.

9.5 Corrective Actions

The Dam Safety Management System should include a process for timely follow-up and correction whenever safety deficiencies or non-conformance with standards, policies or procedures are identified. This includes prioritizing corrective actions. Prioritizing should take into account the consequences of potential dam failure, the magnitude and significance of the deficiency or issue in question, a risk assessment of the deficiency, applicable regulations and laws, and financial resources.

A strategy for implementing corrective actions and improvements should be implemented and should include priority (the order in which actions should be taken), urgency (how soon the actions should be taken), and progressive improvement (whether the actions can be implemented in stages).

The results of this DSR provide a starting point for dam safety issues tracking and mitigation. This should continue to be formalized and documented in the future.

9.6 Reporting

As a minimum, senior management should be updated annually on the status of the dam safety program. The update should cover:

- Results of the various reviews
- Outstanding issues and deficiencies
- Incidents
- Corrective actions
- Adequacy of policies and procedures (or need for change)
- Program objectives
- Adequacy of resources.

This is one area where RDOS can improve to better document their activities and issues tracking, providing better clarity and understanding for themselves, the BC Dam Safety office and for future DSRs.

9.7 Supporting Processes

9.7.1 Training and Qualification

Supporting processes include adequate training of all individuals with responsibilities for dam safety activities. Training records should be maintained. Training can take the form of internal training, formal courses (held online by bodies such as CDA, USSD, ASDSO, USBR etc.), participation in the BC Dam Safety Office’s seminars and self-study of dam safety publications and journals.

9.7.2 Program Communication

It is of utmost importance that the dam safety policy and management commitment be clearly communicated to staff involved in dam safety activities. Dam safety awareness and a culture of continuous improvement should be supported.

Contact with stakeholders (including emergency responders and civic authorities) is necessary during the development, maintenance and testing of plans involving public safety and emergency preparedness.

Once the DEPs are reviewed and accepted a program of regular updates and testing should be implemented to assure the currency of the documents into the future.

9.7.3 *Record Keeping and Management*

Documentation should be kept up to date so there is a permanent record of (i) the design, construction, operation and performance of the dam; and (ii) the management of its safety. Such documents typically include, but are not limited to:

- An inventory of dams and appurtenant structures in the system
- Permits and licenses
- Design records
- Geotechnical investigation records
- As-built drawings
- Construction completion reports
- Photo and video records of construction activities at various stages
- Instrumentation readings and other technical data
- Inspection and test reports
- Dam Safety Review reports
- Operation and maintenance records
- Closure plans, if any
- Records of dam safety incidents, lessons learned, and follow-up actions
- Records of staff training
- Records of flow control equipment tests
- Records of emergency preparedness tests and follow up actions.

9.8 Recommendations

Based on the above, it is evident that RDOS has implemented a number of the elements of an effective Dam Safety Management System. RDOS should continue to improve operation, maintenance, and surveillance protocols, improve DEPs as required, and conduct independent dam safety reviews and audits. Hatch recommends the following Dam Safety Management actions:

- The RDOS should adopt a formal policy statement on Dam Safety for their program to satisfy the CDA Dam Safety Guidelines. This will demonstrate a commitment to the regulation and provides a reason to perform necessary works. (See Issue No. All-4 in Table 13-1).

- RDOS staff responsible for the DEP should regularly attend BC Dam Safety Dam Management seminars on dam safety and inspections (understood to be provided annually in most areas of BC, including Penticton). Records of attendance at these inspection workshops should be documented along with information on any additional training completed. This could include review of material provided on BC Dam Safety website. (See Issue No. All-7 in Table 13-1).
- Provide documented training to staff in emergency procedures, and carry out and document regular exercises to test the emergency procedures. Follow additional recommendations in proposed new Dam Emergency Plan (DEP) procedure. (See Issue No. All-8 in Table 13-1).

10. Operations, Maintenance and Surveillance

Elinor North Dam has a DFCC of “Very High”. Under the B.C. Dam Safety Regulation [B.C. Reg 44/2016] and the Water Sustainability Act, a dam under such DFCC requires additional general safety requirements. This includes the preparation of an Operation, Maintenance and Surveillance (OMS) manual and a Dam Emergency Plan (DEP) (see Section 1). The OMS manual must be accepted by the Dam Safety Officer. The CDA Dam Safety Guidelines [CDA, 2013a] recommend that an OMS manual be prepared for each dam project. It should include operating procedures for normal, unusual and emergency conditions. Maintenance procedures should ensure that the dam remains in a safe and operational condition. The surveillance portion of the manual should allow for early identification of issues and allow for timely mitigation of conditions that could affect dam safety.

Hatch has reviewed the combined Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan (OMS EPP) manual prepared by RDOS dated May 2017 [RDOS, 2017], which includes Elinor North Lake Reservoir and Dam. As part of this project Hatch undertook the separation and update of the OMS and DEP into standalone documents as required by the Dam Safety Regulation. These documents provided some areas that RDOS is required to update and submit to the Dam Safety Office. Into the future, once approved, both of these documents should be reviewed and updated at least annually. Formally, they should be reviewed, revised if necessary, and the revision should be submitted to the DSO every 7 years.

Findings relating to the operation, maintenance, and surveillance of Elinor North Dam are outlined in the following sections.

10.1 Operation

10.1.1 Normal Operations

Although there is no discharge operations at the Elinor North Dam, the OMS manual produced as part of this project provides adequate information of monitoring and operation of Elinor Lake, contained at its north end by Elinor North Dam during normal flow conditions. This includes inflow forecasting, the filling schedule and release procedures. RDOS may compare the documented Snow Survey Sites with previous years’ records on file to predict the potential runoff to the storage reservoirs or at the diversion intake. As part of the reservoir filling schedule, the upstream Chute Creek Diversion can be operated to allow inflows to Elinor Lake followed by Naramata Lake. Once Elinor Dam is filled to 3 ft below its full pool elevation and Naramata Dam is filled to 2 ft below its full pool elevation, the Chute Creek Diversion gate is manually closed. The full supply level/ full pool level of the reservoir is managed by inflow into the spillway channel once water levels exceed the FSL of 1271.95 m which is the crest elevation of the spillway weir. Big Meadow Dam, located upstream of the Chute Creek Diversion, is opened by the end of July. If the water level at Naramata Dam has been drawn down by outlet operations, water can again be diverted through the system to

Elinor Lake and Naramata Lake. During the summer months the goal is to have a stable drawdown of all of the dams through closely monitored levels and adjustments.

10.1.2 Flood Operations

There are no flood operations associated with the Elinor North Dam.

As part of the reservoir filling schedule, the upstream Chute Creek Diversion gate would be closed prior to reaching the FSL. Documentation on how and when this system should be operated is included in the OMS manual.

During times of extreme reservoir inflows, the process for issuing inflow forecasts by comparing the documented Snow Survey Sites with previous years' records on file to predict the potential runoff to the storage reservoirs or at the diversion intake should be outlined. The OMS manual should provide a table with these comparisons, as well as the rating curves for the structures to facilitate calculation of outflows. Any recommended drawdown in anticipation of large spring runoff events should also be documented.

10.1.3 Emergency Operations

The manual should indicate the policy to be followed should an unusual condition develop at Elinor North Dam. The OMS has been updated to refer to the Dam Emergency Plan (DEP) in this scenario. The DEP has been updated using the BC Dam Safety "Guide & Template for Preparing a Dam Emergency Plan (DEP) in British Columbia", which fully defines the processes and responsibilities related to emergency management.

The DEP indicates the operating rules to be followed if an unusual condition develops at Elinor North Dam. The CDA Guidelines [2013a], recommend having flood operating rules that are specific enough that Dam Operators can easily understand and follow them. Additional detail in the Dam Emergency Plan directing Dam Operators on how to identify an emergency condition would be helpful to be included (see Issue No. All-5 in Table 13-1).

Given the steepness of the drainage basin and speed of a runoff even it is unlikely that additional pumping, syphon or drawdown capacity would be useful in managing a single event. However, in the case of a series of rainfall events it may be useful to have the capacity available to help drawdown between events. In addition, emergency drawdown may be required in the case of a potential failure event (i.e., rapid increase in turbid seepage, structural movement of either of the dams or after an earthquake event).

For the Naramata Dam, it has been recommended that RDOS have on hand one (1) or more high volume pumps or a portable syphon in the case that high water levels are observed and assistance in drawdown is required. This has been specifically called out as the reservoir has recently required rapid drawdown due to the boil issue. These units could be used at Elinor Lake North Dam if a need for emergency drawdown ever presents itself (as in a seismic event). It is recommended that an understanding of the rate of drawdown that can be achieved through this method should be evaluated for operations planning (see Issue No. All-5 in Table 13-1).

10.2 Maintenance

As stated in the CDA Guidelines [CDA, 2013a], the maintenance of equipment and systems is pertinent to ensure safe operations and to upkeep the integrity of the dam. In the BC Dam Safety Regulation [B.C. Reg 44/2016], a “Very High” DFCC dam is expected to have site surveillance conducted on a weekly basis and a formal inspection on an annual basis. Ongoing maintenance checks have been conducted by RDOS staff on a regular basis with annual dam safety inspections and weekly site inspections. The frequency of inspections held since the previous Dam Safety Review is currently adequate and should be continued.

The OMS Manual includes a general discussion on maintenance, followed by maintenance instructions and required frequency for the earthfill dam and signage.

10.3 Surveillance

Under Section 3.4.4 of the CDA Guidelines [CDA, 2013a], information related to flow control system operations should be identified and documented. In the BC Dam Safety Regulation, it states that a dam owner must install necessary instruments and maintain or replace the instrumentation to adequately monitor the dam and the surrounding area.

The OMS Manual including Surveillance and Inspection, includes sections and discussion on: Inspection equipment to bring to the inspection and procedure for recordings, Inspection frequencies for components, Routine Surveillance procedures including a Dam Inspection Checklist to be used in conjunction with the provincial Inspection and Maintenance of Dams Manual Appendix F, though a list of key points from this manual are included in the OMS as well; Important Site Specific surveillance conditions; deficiencies; instrumentation; and instruction on when to notify higher authorities.

A review of the annual dam inspection reports shows that in general they conform to the requirements of the BC Dam Safety Regulation. The most recent Formal Annual Inspection forms follow the form provided by the BC Dam Safety Office in their Annual Formal Inspection Form. However, the Routine Dam Inspection Report could be improved by more closely following the form provided by BC Dam Safety Office in their Site Surveillance Form, used for weekly inspections (included in the updated OMS manual). This form can be tailored to the dam itself to include items that are currently documented on the RDOS form and the basic information reused from year to year but in general it provides a more detailed assessment of the dam condition and may reduce the potential of missing an emerging issue.

In addition, when a new geotechnical investigation is undertaken (as described in Section 7.4.6 and Issue EN-2c in Table 13-1), additional piezometers should be installed and monitored on a regular basis to detect changes and trends.

10.4 Recommendations

Hatch recommends the following OMS actions:

- The Routine Dam Inspection report format should be improved by incorporating aspects of the BC Dam Safety Office's Site Surveillance Form (included in the updated OMS manual appendices). (See Issue No. All-3 in Table 13-1).
- Install new instrumentation including piezometers and install weirs downstream of the dam along the toe. Piezometer installation will be carried out as part of geotechnical investigation. The instrumentation monitoring shall include continuous records, plotting, and interpretation of piezometer data and seepage flow quantities against reservoir elevation. (See Issue No. EN-2d, EN-3 and EN-12 in Table 13-1).
- Logs should be kept to show that a review of the OMS is being completed annually, including the documentation of annual training refresher on the OMS Manual and DEP.

11. Dam Emergency Plan

In British Columbia as per Sections 9 and 33 of the Dam Safety Regulation, Water Sustainability Act [B.C. Reg 40/2016], an owner of a dam that has a consequence of failure classification of SIGNIFICANT, HIGH, VERY HIGH or EXTREME must prepare a Dam Emergency Plan (DEP) that includes

- A record describing actions to be taken by the owner if there is an emergency at the dam
- A record containing information for the use of the local emergency authorities for the dam for the purpose of preparing local emergency plans under the Emergency Program Act.

The new regulation still requires dam owners to prepare an emergency plan, but it is now called a Dam Emergency Plan (DEP) and includes some differences including what they contain, what must be done with them, and the date by which they must be prepared and submitted for acceptance by the Dam Safety Officer (DSO). The OMS EPP manual [RDOS, 2017] contains an EPP (Emergency Preparedness Plan) section that generally complies with both the BC Dam Safety Regulation and the CDA guidelines. However, it has previously been noted that some improvements can be made to more fully define the processes and responsibilities related to emergency management. A Guide & Template for Preparing a Dam Emergency Plan (DEP) in British Columbia has been developed to assist dam owners in preparing their DEP. Information in the existing EPP has been brought into this template as part of this study, and any additional relevant information that has come to light during this DSR has been added. This standalone document should be submitted to the DSO for acceptance.

The EPP component of the OMS EPP manual [RDOS, 2017] contains the following sections, which have been brought into the DEP template as appropriate:

- Introduction
- Responsibility
- Emergency Reporting
- Assessment and Categorization of the Emergency
- Emergency Response
- Emergency Materials.

Appendices of information include RDOS Emergency Contacts with a list of contractors and material location, a map of possible affected areas (which can be updated following the “Naramata Dam Breach Assessment and Inundation Mapping” 2020 report), Inundation Properties and Infrastructure Data.

The inundation maps included in the DEP have been updated as part of this study.

11.1 Recommendations

Hatch recommends the following DEP actions:

- Provide documented training to staff in emergency procedures and carry out and document regular exercises to test the emergency procedures. Follow additional recommendations in proposed new Dam Emergency Plan (DEP) procedure.
- Increase frequency of review of DEP including any necessary revisions and submission to the DSO to every 7 years instead of every 10 years.
- It is recommended that an understanding of the rate of drawdown that can be achieved should be evaluated for operations planning and documented in the DEP. Under the CDA Guidelines [2013a], it is recommended to provide information on staffing requirements and the time required to complete system operations so that an appropriate response can be initiated during an emergency (see Issue No. All-5 in Table 13-1).
- It is recommended that the RDOS emergency call alert system, CivicReady be setup to allow for public signup in order to receive external text message notifications during an emergency, if possible. The current Emergency Response and Notification does meet the recommendations in the BC Dam Safety Regulation [B.C. Reg 44/2016] CDA Guidelines [CDA, 2013a].
- Use results of the Dam Break analysis to form the Emergency Evacuation Plan.
- Consider using results of Dam Break analysis to prioritize contact list of downstream population to notify in an emergency.

12. Dam Safety Expectations and Deficiencies

12.1 Dam Safety Review Assurance Statement

A Dam Safety Review Assurance Statement was completed by Hatch Ltd. to verify that the DSR was completed in accordance with the APEGBC Guidelines and is included in **Appendix E**.

The definitions of Deficiencies and Non-Conformances used during this DSR are listed in Table 12-1.

Table 12-1: Definition of Deficiencies and Non- Conformances [FLNRO, 2015]

Deficiencies	
An	Actual performance deficiencies under normal loading conditions.
Au	Actual performance deficiencies under unusual loading conditions.
Pn	Potential performance deficiencies under normal loading conditions, expected to be confirmed as actual deficiencies by means of analysis in a dam performance investigation.
Pu	Potential performance deficiencies under unusual loading conditions, expected to be confirmed as actual deficiencies by means of analysis in a dam performance investigation.
Pq	Potential deficiencies under normal or unusual loading conditions, that would lead to dam safety improvements if it could not be readily (quickly) demonstrated that such procedures for activities required for normal or unusual load conditions.
Pd	Potential performance deficiencies under normal or unusual loading conditions, in the following senses: The “Dam” meets minimum performance goals, but additional safety benefits are desirable, practicable and affordable, or, the uncertainties around the concern are such that it is extremely difficult if not impossible to demonstrate that safety improvements are neither required nor desirable.
Non-Conformances	
NCo	Non-Conformance Operational: Established operational procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.
NCm	Non-Conformance Maintenance: Established maintenance procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.
NCs	Non-Conformance Surveillance: Established surveillance procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.
NCi	Non-Conformance Information: There is a deficiency in information required to determine if an actual or potential performance deficiency exists. There is not enough information to determine if an Actual or Potential Deficiency exists.
NCp	Non-Conformance Procedures: Other established procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.

Identified issues have been categorized as non-conformance, actual deficiency or potential deficiency, as outlined in the Dam Safety Expectations table, Table 12-2.

Table 12-2: Dam Safety Expectations

	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			NCi	There is insufficient official as-built information, and limited construction records and drawings of the dam were available during this review. Official topographic survey of the dam was carried out in 2012. Likely no further information will be found through document search. No past post-construction geotechnical investigation and instrument installation were carried out at the dam. Additional geotechnical investigations are needed to fill in knowledge gaps.
1.2	Hazards external and internal to the dam have been defined	X						Yes, as part of the current DSR.
1.3	The potential failure modes for the dam and the initial conditions downstream from the dam have been identified	X						Potential failure modes for the dam have been identified as part of this study. A full inundation study and downstream consequence classification has been undertaken as part of this study.
1.4	Inundation study adequate to determine consequence classification. Flood and “sunny day” scenarios assessed.	X						A full inundation study and downstream consequence classification has been undertaken as part of this study including the assessment of 5 potential inflow design floods and sunny day scenarios.
1.5	The Dam is classified appropriately in terms of the consequences of failure including life, environmental, cultural and third-party economic losses.	X						Has been assessed as part of this study.
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						Yes, all water barrier system components were considered including the dam and its foundations.
1.7	The EDGM selected reflects current seismic understanding	X						Yes, this was assessed as part of the current study. No site specific seismic hazard assessment is deemed necessary.
1.8	The IDF is based on appropriate hydrological analyses	X						Yes, this has been assessed as part of this study.
1.9	The dam is safely capable of passing flows as required for all applicable loading conditions (normal, winter, earthquake, flood)		X					This dam has no flood passage capabilities. See Elinor (South) Main Dam.
1.10	The dam has adequate freeboard for all applicable operating conditions (normal, winter, earthquake, flood)			X			NCi	Topographical survey of embankment demonstrates some loss of design freeboard. Freeboard analysis including wind/wave effects for normal and IDF conditions has been analyzed as part of this DSR and is adequate as per CDA guidelines. Dam resistance to liquefaction and post-seismic stability is not known and requires investigation and assessment.
1.11	The dam safety analyses (stability & hydrological) use current information and standards of practice			X			NCi	Yes, as presented in the DSR report. Stability assessments are done based on best practice. Information related to the embankment and its foundation shear strength parameters, compaction, pore water pressure, and internal stability is limited. A geotechnical investigation and subsequent assessment are needed for the dam assessment. Filter and internal stability assessment of embankment is also needed.
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					N/A
1.13	The dams, abutments and foundations are not subject to unacceptable deformation or overstressing	X						The dam, abutments, and foundation are performing well corresponding to loads, deformation and stress. Slopes are relatively shallow and no sign of distress was observed and expected.

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
1.14	Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion			X		Pn, Pu	NCi	The dam was designed without a filter blanket or toe. Seepage at the toe of the embankment has been observed in the past. Exit gradients are high. The design of a toe berm incorporating a filter should be investigated after conducting a geotechnical investigation, testing, assessment, and piezometer installation.
1.15	Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability			X		Pn, Pu	NCi	Hydraulic exit gradients at the toe of the dam are high. Conduct a geotechnical investigation and install instrumentation. Analysis should be re-conducted based on parameters derived from an intrusive investigation at the site so that the nature and dam zones engineering parameters can be better defined. Should the re-analysis concluded that the toe is of marginal stability, the design of a toe berm incorporating a filter should be investigated.
1.16	Slopes of the embankments have adequate protection against erosion, seepage, traffic, frost and burrowing animals			X			NCm	Dam exhibits erosion from vehicle traffic. No upstream riprap exists on the dam slope. No significant erosion was reported in the past due to wave and surge effects. Seepage on the downstream slope has been observed and reported in the past.
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						Reservoir sides slopes are considered suitable therefore present no perceived risk. No sign of distress or concern were raised in the past as well.
1.18	The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure has been assessed.			X			NCo	Need for emergency drawdown should be assessed.
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						Assumed. The OMS EPP was last reviewed in 2017 where updates were made to the filling and release procedures, among others. OMS and DEP have been updated as part of the current study.
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.							
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					
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						
b.	Reservoir levels and rates of drawdown	X						
c.	Reservoir control and discharge during an emergency	X						

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
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						
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			NCm	Clear evidence that maintenance activities are being carried out in the records. Low dam crest should be compensated to restore crest.
	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				Currently there is not much instrumentation or procedures for flow monitoring to flag the seepage quantity increase downstream of the dam.
2.11	The surveillance program provides regular monitoring of dam performance, as follows:							
a.	Actual and expected performance are compared to identify deviations			X			NCs	No instrumentation installed in dam to monitor performance. Installation of piezometers in the embankment and abutment are recommended, and instrumentation to monitor toe seepage if identified.
b.	Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions			X			NCs	No instrumentation installed in dam to monitor performance. Installation of piezometers in the embankment and abutment are recommended, and monitoring of toe seepage if identified.
c.	Reservoir operations are confirmed to be in compliance with dam safety requirements	X						The dam does not require operation. The dam spillway is a free overflow crest.
d.	Confirmation that adequate maintenance is being carried out			X			NCs	Maintenance requirements documented in weekly inspections and some maintenance documentation was provided within these forms as well. Regular recording of maintenance completion would further support that this is being completed.
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			NCp	Weekly inspections are adequate. Recommend using the BC Dam Safety “Site Surveillance” checklist customized to this dam for weekly inspections to make sure nothing is missed.
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						Dams inspected weekly, weather permitting and documented.
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						
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			NCs	No available documentation provided to show if regular dam safety training is provided to the inspector(s). As a minimum RDOS staff responsible for the DEP should regularly attend BC Dam Safety Dam Management seminars on dam safety and inspections (understood to be provided annually in most areas of BC, including Penticton). Records of attendance at these inspection workshops should be documented along with information on any additional training completed. This could include review of material provided on BC Dam Safety website.

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
2.16	Qualifications and training records of all individuals with responsibilities for dam safety activities are available and maintained			X			NCs	No available documentation provided to show if regular dam safety training is provided to the inspector(s).
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	No instrumentation installed in dam to monitor performance. Installation of piezometers in the embankment and abutment are recommended, and instrumentation (weirs) to monitor toe seepage.
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						The existing EPP has been incorporated into the BC Dam Safety DEP template. Dam Breach inundation maps and emergency contact information from downstream landowners has been updated in 2017.
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						There is an Appendix with an Emergency Contact List for both RDOS and for those located in the potential inundation zone (updated 2017). This information has not been made available to review for privacy purposes, but it has been stated that it exists. With new information on inundation zone, the contact list for downstream inundation could be prioritized.
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						DEP has been prepared. Consider using results of Dam Break analysis to form the Emergency evacuation Plan.
3.6	Roles and responsibilities of the dam owner and response agencies are defined.	X						DEP has been prepared.
3.7	Inundation maps and critical flood information are appropriate and are available to downstream response agencies.	X						Inundation study has been undertaken and inundation maps are to be included in the DEP.
3.8	Exercises are carried out regularly to test the emergency procedures.			X			NCp	No documentation that exercises have been undertaken was provided.
3.9	Staff are adequately trained in the emergency procedures.			X			NCi	No documentation that staff have been undertaken training was provided.
3.10	Emergency plans are updated regularly and updated pages are distributed to all plan holders in a controlled manner.	X						The EPP was prepared in 2010, and updated in 2016 and 2017. DEP has been updated as part of this study.
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						RDOS commissioned a DSR in 2010 and this dam safety review in 2020. Another Dam Safety Review should be conducted in ten years (2030), however RDOS should endeavor to implement the recommendations of this review before that time.
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			NCp	Public safety and security plans not in place. 2019 “Risk Control Survey” has been completed but no evidence of implementation of recommended measures yet.
d.	documentation,	X						
e.	training and review,			X			NCp	No available documentation provided to show if regular dam safety training is provided to the inspector(s).

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-conformances	Comments
					Actual	Potential		
f.	prioritization and correction of deficiencies and non-conformances,	X						Prioritization and corrections of deficiencies and non-conformances are documented in this Dam Safety Review.
g.	supporting infrastructure			X			NCs	No instrumentation installed in dam and seepage monitoring.
5.2	Deficiencies are documented, reviewed and resolved in a timely manner. Decisions are justified and documented	X						Deficiencies are documented in this Dam Safety Review. Recommendations from the previous Dam Safety Review by EBA in 2010 have been partially implemented to date.
5.3	Applicable regulations are met	X						

A listing of existing and new deficiencies and non-conformances with priority ratings assigned is provided in Table 13-1.

13. Conclusions and Recommendations

A systematic Dam Safety Review has been performed for Naramata Dam in accordance with the current B.C. Water Sustainability Act and the B.C. Dam Safety Regulation [Reg. 44/2016] and the current Canadian Dam Association Dam Safety Guidelines. This DSR confirms that the reservoir and its water retaining structures are being operated and maintained in a generally safe condition; however, there are some notable dam safety deficiencies that require further investigation and action.

Deficiencies have been identified throughout the document and are tabulated along with their prioritization. The tables of issues and recommendations are provided in Table 13-1.

Recommended actions in the table for each issue are outlined; these represent the controls that can be implemented to mitigate the hazards. The actual and potential deficiencies were given an overall priority rating of the risks, defined as high, medium and low, based upon the potential of the issue leading to a critical failure of the structure. The actual or potential deficiencies are summarized in Table 13-1. The non-conformances were assigned a ranking of low, medium or high based on how they impact dam safety. Priority definitions are as follows:

High: Potential failure mode(s) are judged to present serious risks, either due to a high probability of failure or due to very high potential incremental damages, which justify an urgency in actions to reduce risk.

Medium: Potential failure mode(s) appear to be dam safety deficiencies that appear to indicate a potential concern, and actions are needed to better define risks or to reduce risks. Ensure routine risk management activities are in place. For those actions for which the case has been built to proceed before the next comprehensive review, take appropriate interim measures and schedule other actions as appropriate. Prioritize investigations to support justification for remediation and remediation design, as appropriate.

Low: Potential failure mode(s) at the facility do not appear to present significant risks. Determine whether action can wait until after the next comprehensive review of the dam and appurtenant structures. Continue routine dam safety risk management activities, normal operation, and maintenance.

The various action items are categorized based on areas of responsibility as Minor Improvements (Operations), Minor Capital Works (Engineering), or Major Capital Works (Capital). A budgetary level Class D cost estimate is included with notes on inclusions.

Table 13-1: Summary of Recommendations and Estimated Costs of Implementing New and Existing Deficiencies and Non-Conformances

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating	Cost Estimate - Type	Estimated Cost	Notes
EN-1	Dam classification – dam is currently classified as High consequence. Recommended dam classification is Very High.	2020 DSR FLNRO, 2019		New	Classify the Elinor North Dam as a Very High consequence dam. This should be reviewed annually in accordance with the BC Dam Safety Regulation, noting changes downstream of the dam.	Low	N/A		
EN-2	Poor documentation currently exists of the dam construction and performance history, site-specific geotechnical information, embankment materials, among other details. The Elinor North dam is assumed to use the same construction methodology and materials as the Elinor South Dam. This includes the presence of an impervious core, however this could not be confirmed. The 2010 DSR recommended a topographic survey of the dam (EBA, 2010).	2010 DSR, FLNRO, 2019 2020 DSR	NCi	Outstanding	If not already completed, a thorough review should be conducted for records related to design, construction and performance of the dam. In the absence of geotechnical data, detailed analyses of the dam's stability, and resilience against risks such as seepage and seismic events cannot be evaluated in detail.	Medium	N/A	-	Noted as an outstanding item but recommendations are discussed below.
EN-2b	There is no topographic survey to confirm elevations.	2010 DSR		Resolved					
EN-2c	Lack of as-built information. Geotechnical information not available.	2020 DSR	Nci	Outstanding	A geotechnical investigation should be conducted to provide necessary input for further engineering analyses. The investigation should consist of test pits and boreholes at the dam crest to attempt to locate and characterize the material zones of the dam, if present. Laboratory and in-situ testing should be conducted to determine the material properties.	High	Minor Capital Works	$41,000	Split with ES-2c
EN-2d	Lack of instrumentation.		NCi,s	Outstanding	Piezometer(s) should be installed with the borehole drilling to enable continued monitoring of the pore water pressure conditions within the dam.	N/A	Minor Capital Works		Included in cost estimate for EN-2c
EN-3	There is currently no ability to measure quantity of seepage in areas where seepage has been observed historically.	2010 DSR 2020 DSR	NCi,s	Outstanding	If possible, install new weir at the downstream toe of the dam to allow for quantitative measurement of seepage flows. A seepage monitoring program should be developed and maintained.	Medium	Minor Capital Works	$ 6,000	1 weir
EN-4	Evidence of seepage was observed at the downstream toe. However, heavy vegetation limited access to the area where seepage was observed.	2010 DSR FLNRO, 2019 2020 DSR	NCs	Outstanding	Extend limits of vegetation clearing downstream of the dam to allow for inspection of the toe and regular seepage observations.	Medium	N/A		
EN-5	A detailed geotechnical assessment could not be completed due to the absence of construction documentation and site-specific geotechnical data. The dam is potentially susceptible to failure modes including slope instability, piping, and liquefaction.	2010 DSR 2020 DSR	NCi	Outstanding	Geotechnical assessments should be undertaken upon completion of the recommended geotechnical investigation. These should evaluate risks of common failure modes including seismic and normal slope stability, piping, and liquefaction. It is expected that the results of these assessments may lead to a recommendation for construction of a toe berm or similar improvements to limit seepage and increase the stability of the dam at the downstream toe. In addition, internal stability assessment of dam core and filter compatibility assessment should be conducted.	High	Minor Capital Works	$ 40,000	The design of potential improvements up to preliminary stage.
EN-6	The risk of piping failure was found to be in the unacceptable risk zone as outlined by the CDA Guidelines (EBA, 2010)	2010 DSR	NCi, An	Outstanding	The risk level remains similar to the previous assessment, however, due to an increase in dam classification the acceptable risk threshold decreases and this further emphasize on the unacceptable condition. The recommendations above to complete a geotechnical investigation and improve seepage monitoring and instrumentation can contribute to reducing the risk of piping failure.	Medium	N/A		Included in EN-2c and EN-5

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating	Cost Estimate - Type	Estimated Cost	Notes
EN-7	Topographic survey data from 2012 shows the dam crest elevation is lower than the assumed design elevation of El. 1278 m (EBA, 2013), assumed as there is no original design documentation is available for this dam. The topographic survey shows a minimum crest elevation of approximately 1277.31 m. Flood routing and freeboard analysis indicates that during the IDF, the reservoir surcharges to El. 1277.31 m when wind and wave effects are included, with no remaining additional freeboard to the lowest portion of the dam. This meets CDA requirements. However, overall risk should be taken into consideration, including unknown material and erodibility, and the presence of ATV traffic causing rutting. Any additional loss of freeboard in the dam would result in a deficiency.	2010 DSR FLNRO, 2019 2020 DSR	NCm	Outstanding	Place material to re-grade the crest to the design/typical elevation to provide additional freeboard.	High	Minor Capital Works	$ 15,000	
EN-8	Security/access issues leading to damage on dam crest and face from ATV traffic. Recent inspections also note damage by cattle and vehicles. Note that any additional loss of freeboard would result in a freeboard deficiency.	2010 DSR FLNRO, 2019 2019 Risk Survey 2020 DSR	NCp	Outstanding	Review security and access protocols and implement appropriate restrictions including those recommended in the 2019 Risk Control Study (Precise Services, 2019) to prevent damage or vandalism.	High	Minor Improvements	$ 10,000	
EN-9	No Operations, Maintenance and Surveillance (OMS) manual was prepared for the dam as of the previous Dam Safety Review.	2010 DSR		Resolved					
EN-10	Dam Safety Review schedule	2020 DSR		New	In accordance with the High consequence classification, the next Dam Safety Review should be conducted in 2030, and every 10 years thereafter.	N/A	N/A		
EN-11	Dam Emergency Plan – the Emergency Preparedness Plan (EPP) should be updated to comply with the updated requirements for a Dam Emergency Plan (DEP) in the Dam Safety Regulation.	FLNRO, 2019 2020 DSR		Resolved					
EN-12	Lack of sufficient instrumentation and data assessment for performance monitoring	2020 DSR		New	The instrumentation monitoring shall include continuous records, plotting, and interpretation of seepage flow quantities against reservoir elevation. The piezometer information should be closely monitored once available.	Medium	N/A		
EN-13	Currently no riprap or erosion protection layer on the dam crest or upstream slope.	2020 DSR	NCm	New	Provide appropriately sized armour protection along the upstream face of the dam from the crest to 1 m below the low water level.	Low	Minor Capital Works		
All-1	OMS could be improved by including supporting confirmation that highlighted maintenance activities are being completed.	2020 DSR	NCs	New	Regular verification of the completion of maintenance items recorded in the weekly site surveillance form would further support that maintenance items are being completed.	Low	Minor Improvements		
All-2	OMS does not have a table with positions and associated names describing roles and responsibilities.	2020 DSR	NCo	New	Update table in OMS to include positions and associated names describing roles and responsibilities.	Medium	Minor Improvements		
All-3	Routine Dam Inspection Report format does not contain all aspects of BC Dam Safety Office's Site Surveillance Form for weekly inspections.	2020 DSR	NCp	New	Routine Dam Inspection Report format should be improved to more closely follow the BC Dam Safety Site Surveillance Form for weekly inspections.	Low	Minor Improvements		

Issue No.	Deficiency/Non-Conformance	Originator	Type	Status	Recommendation	Priority Rating	Cost Estimate - Type	Estimated Cost	Notes
All-4	No formal Dam Safety Policy is in place for their dam safety program.	2020 DSR	NCp	New	The RDOS appears to be meeting the intent of a dam safety management system and should continue to improve and develop their system and adopt a formal policy statement on Dam Safety for their program to satisfy the CDA Dam Safety Guidelines. This will demonstrate a commitment to the regulation and provide a reason to perform necessary works.	Medium	Minor Improvements		
All-5	OMS could be improved by including more information to assist Dam Safety inspectors in detecting and responding to an emergency situation.	2020 DSR	NCp	New	In the OMS, inflow forecasting should include alarm limits on what scenario of Snow Survey combined with reservoir levels would create a need for action. Actions to be taken should be described. Any recommended drawdown in anticipation of large spring runoff events should also be documented.	Medium	Minor Improvements		
All-6	Emergency notification systems to alert the public should be expanded to include a text message template to facilitate public notification in the event of an emergency.	2020 DSR	NCp	New	It is recommended that the RDOS emergency call alert system, CivicReady be setup to allow for public signup in order to receive external text message notifications during an emergency.	Medium	Minor Improvements		
All-7	No available documentation provided to show if regular dam safety training is provided to the inspector(s).	2010 DSR, 2020 DSR	NCs	Outstanding	RDOS staff responsible for the DEP should regularly attend BC Dam Safety Dam Management seminars on dam safety and inspections (understood to be provided annually in most areas of BC, including Penticton). Records of attendance at these inspection workshops should be documented along with information on any additional training completed. This could include review of material provided on BC Dam Safety website.	Medium	Minor Improvements		
All-8	No available documentation to show that exercises are carried out regularly to test the emergency procedures.	2020 DSR	NCp	New	Provide documented training to staff in emergency procedures and carry out and document regular exercises to test the emergency procedures. Follow additional recommendations in proposed new Dam Emergency Plan (DEP) procedure.	Medium	Minor Improvements		

Note that Issues No's are categorized as either "EN" (Elinor North) or "All" (indicating similar OMS related issues that span all of the Naramata Dams).

14. References

Abrahamson BT and Pentland RS. 2010. Probable Maximum Flood Estimator for British Columbia. Agriculture and Agri-Food Canada (AAFC).

B.C. Reg 44/2000. 2000. Water Act - British Columbia Dam Safety Regulation.

B.C. Reg 40/2016, 2016, “Water Sustainability Act, Dam Safety Regulation”, 2016.

B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRO). 2018. Dam Safety Program. Plan Submission Requirements for the Construction and Rehabilitation of Small Dams.

Big Meadow Lake Dam Site Photos. 2010.

British Columbia Department of Lands, Forests and Water Resources – Water Rights Branch. Drawing: “Big Meadow Reservoir Plan of Storage”. 8 April 1963.

British Columbia Department of Lands, Forests and Water Resources – Water Rights Branch. Drawing: “Big Meadow Dam – Details of Repairs to Culvert Gate & Outlet”. 19 September 1966.

British Columbia Department of Lands, Forests and Water Resources – Water Rights Branch. Drawing: “Eleanor & Naramata Lakes – Plan of Storage”. 17 April 1964.

British Columbia Department of Lands, Forests and Water Resources – Water Rights Branch. Drawing: “Eleanor Lake Dam – Details of Culvert Gate Repairs”. December 1966.

British Columbia Department of Lands, Forests and Water Resources – Mapping Branch. Mapping: “Naramata Creek Watershed Area – Map 5: Groundwater Sensitivity Zones”. 21 December 1998.

British Columbia Ministry of Environment – Inventory and Engineering Branch. Drawing: “Big Meadow Lake Reservoir – Plan of Reservoir”. March 1982

British Columbia Ministry of Environment, Lands and Parks - Water Management Division. “Naramata Fan Study (with Robinson and Chute Creeks)”. December 1994

Canadian Dam Association (CDA). 2011. Guidelines for Public Safety Around Dams.

Canadian Dam Association (CDA). 2013a. Dam Safety Guidelines 2007 (2013 Revision).

Canadian Dam Association (CDA). 2013b. Seismic Hazard Considerations for Dam Safety 2007 Dam Safety Guidelines, Canadian Dam Association, 2013 Revision.

EBA Engineering Consultants. “Big Meadow Lake Dam Geotechnical Assessment”. 11 January 2013.

EBA Engineering Consultants. “Dam Safety Review – Big Meadow Lake Dam”. 17 December 2010.

EBA Engineering Consultants. "Dam Safety Review – Naramata Lake Dam". 17 December 2010.

EBA Engineering Consultants. "Dam Safety Review Summary Report – Naramata Dams". 21 December 2010.

EBA Engineering Consultants. "Dam Safety Reviews for Elinor Lake North (Saddle) Dam and Elinor Lake South Dam". 17 December 2010.

EBA Engineering Consultants. "Hydrotechnical Assessment of the Naramata Dams". 20 December 2010.

EBA Engineering Consultants. Memo: "Topographical Survey of Naramata Dams". 10 January 2013.

EGBC. 2016. Legislated Dam Safety Reviews in BC. Professional Practice Guidelines. V3.0.

Elinor Lake Dams Site Photos. 2010.

Foster M., Fell R., Spannagle M., 2000. A Method for Assessing the Relative Likelihood of Failure of Embankment Dams by Piping, Canadian Geotechnical Journal, 37: 1025-1061.

Garner SJ and Fannin RJ. 2010 Understanding Internal Erosion: A decade of research following a sinkhole event. International Journal on Hydropower and Dams 17(3):93-98 · January 2010.

ICOLD (International Commission On Large Dams). 2017. Internal Erosion of Existing Dams, Levees, and Dikes. Bulletin 164.

Kelowna Regional Office – Water Rights Branch. "Eleanor Lake Reservoir – Storage Capacity Table". 17 August 1979.

Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRO RD). 2018. Plan Submission Requirements for the Construction and Rehabilitation of Small Dams.

Naramata Irrigation District. Drawing: "Improvements – South and North Intakes". 6 December 1979.

Naramata Irrigation District. "Naramata Lake Operation and Maintenance Manual". April 1993.

Naramata Lake Dam Site Photos. 2010.

Okanagan Survey & Design Ltd. Mapping: "Elinor Lake – North Dam Site Topography". 24 July 2012.

Okanagan Survey & Design Ltd. Mapping: "Elinor Lake – South Dam Site Topography". 24 July 2012.

Okanagan Survey & Design Ltd. Mapping: “Naramata Lake Dam – Site Topography”. 24 July 2012.

Precise Services. “Risk Control Survey”. 2019

Regional District of Okanagan-Similkameen. “Elinor Lake Reservoir and Dams Operation, Maintenance and Surveillance Plan Emergency Preparedness Plan”. May 2017.

Regional District of Okanagan-Similkameen. “Naramata Uplands Waterworks (Diversion, Divide, Flume, Highline & Intakes - Maintenance and Surveillance Plan”. April 2013.

Regional District of Okanagan-Similkameen. “Naramata Water System North and South Creek Intake Photos”. 12 March 2020.

Stanley Associates Engineering Ltd. Drawing: “Chute Lake Diversion – Existing Structure”. October 1993.

Various. Drawing: “Naramata Lake Historical Drawings”. 1967 – 1978.

Canadian Dam Association, Technical Bulletin: Dam Safety Reviews, 2016.

OPTA Precise Services LP, “Risk Control Survey: Municipal Insurance Association of British Columbia”. July 2019.

USBR. 1989. Design standards no. 13 — embankment dams. United States Bureau of Reclamation, United States Department of the Interior, Denver, Colo.

Appendix A
Site Visit Photo Report

Photo A1: Elinor Lake North Dam Upstream Slope, Looking from Right Abutment

Photo A2: Elinor Lake North Dam, Crest, Right Abutment and Upstream Slope

Photo A3: Elinor Lake North Dam Crest, looking from Right Abutment

Photo A4: Elinor Lake North Dam Downstream Slope, looking from Right Abutment

Photo A5: Elinor Lake North Dam, Downstream Slope, looking at Right Abutment

Photo A6: Elinor Lake North Dam, Downstream Slope, Looking at Left Abutment

Photo A7: Elinor Lake North Dam, Downstream Toe Area Pond

Photo A8: Elinor Lake North Dam Pond, Downstream Toe Seepage

Photo A9: Elinor Lake North Dam, Downstream Toe Seepage

Photo A10: Elinor Lake North Dam, Left Abutment at the Downstream Side

Photo A11: Elinor Lake North Dam, Crest and Right Abutment Area

Appendix B
Geotechnical Stability Analysis Results

2015 National Building Code Seismic Hazard Calculation

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

Site: 49.667N 119.537W **User File Reference:** Naramata Dam Sites 2021-01-06 18:11 UT

Requested by: Tim Tuo, Hatch Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.081	0.049	0.032	0.011
Sa (0.1)	0.119	0.071	0.046	0.015
Sa (0.2)	0.151	0.095	0.064	0.025
Sa (0.3)	0.148	0.098	0.069	0.029
Sa (0.5)	0.130	0.089	0.064	0.028
Sa (1.0)	0.097	0.066	0.046	0.020
Sa (2.0)	0.067	0.043	0.030	0.012
Sa (5.0)	0.030	0.017	0.011	0.004
Sa (10.0)	0.010	0.006	0.004	0.002
PGA (g)	0.070	0.044	0.029	0.010
PGV (m/s)	0.124	0.078	0.051	0.020

Notes: Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

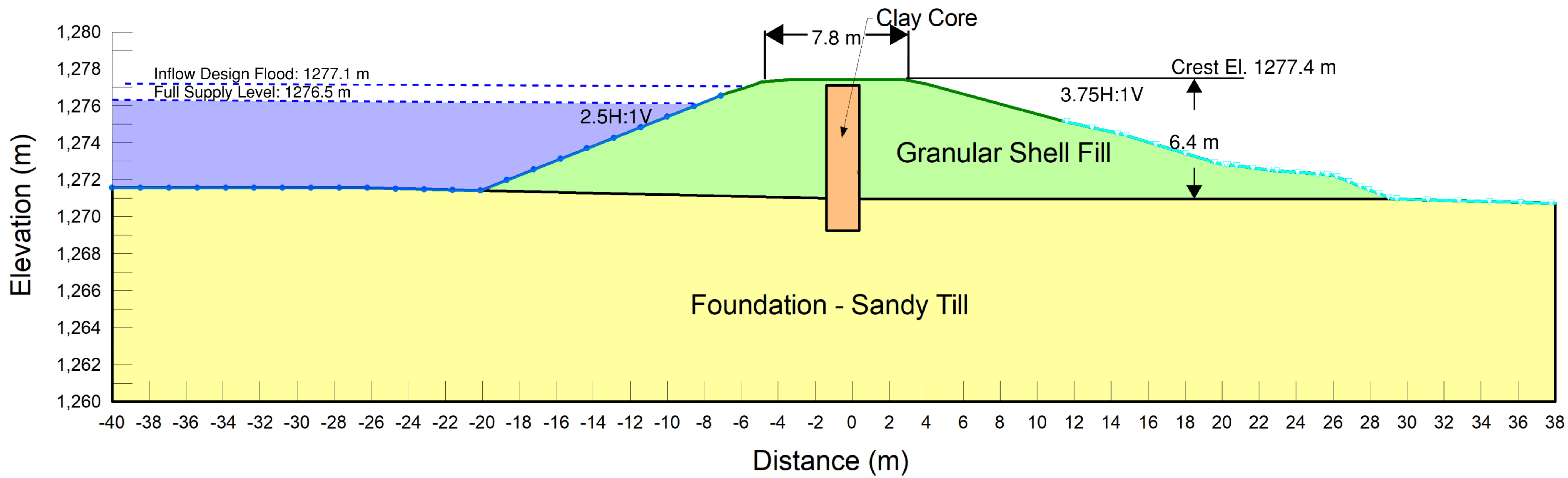
Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

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

Appendix C
Stability Analysis Sections Sketch

Color	Name	Category	Kind	Parameters
	1- US Head : FSL 1276.55 m	Hydraulic	Water Total Head	1,276.55 m
	3-Potential Seepage face	Hydraulic	Water Flux	0 m/sec

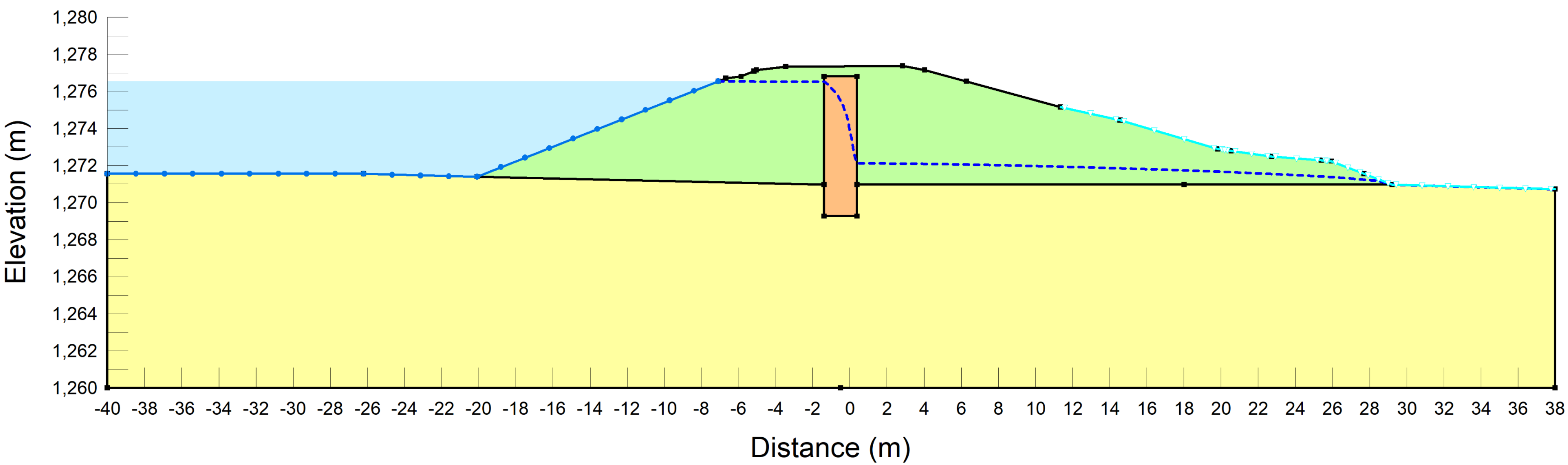
Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
	Clay Core	Saturated / Unsaturated	Generic	Clay/Silt, Ksat = 2.5e-08 m/s	1	0
	Foundation - Sandy Till	Saturated / Unsaturated	Generic	ND - Foundation Sandy Till	1	0
	Shell Fill	Saturated / Unsaturated	Generic	ND - Shell Fill	1	0



HATCH	Project	Elinor Lake North Dam – Dam Safety Review	
	Analysis Description	Seepage Analysis – Model Geometry	
	Analysis By T. Tuo	Output	Model Geometry
	Date 11/01/2021	Report No.	H362819

Color	Name	Category	Kind	Parameters
	1- US Head : FSL 1276.55 m	Hydraulic	Water Total Head	1,276.55 m
	3-Potential Seepage face	Hydraulic	Water Flux	0 m/sec

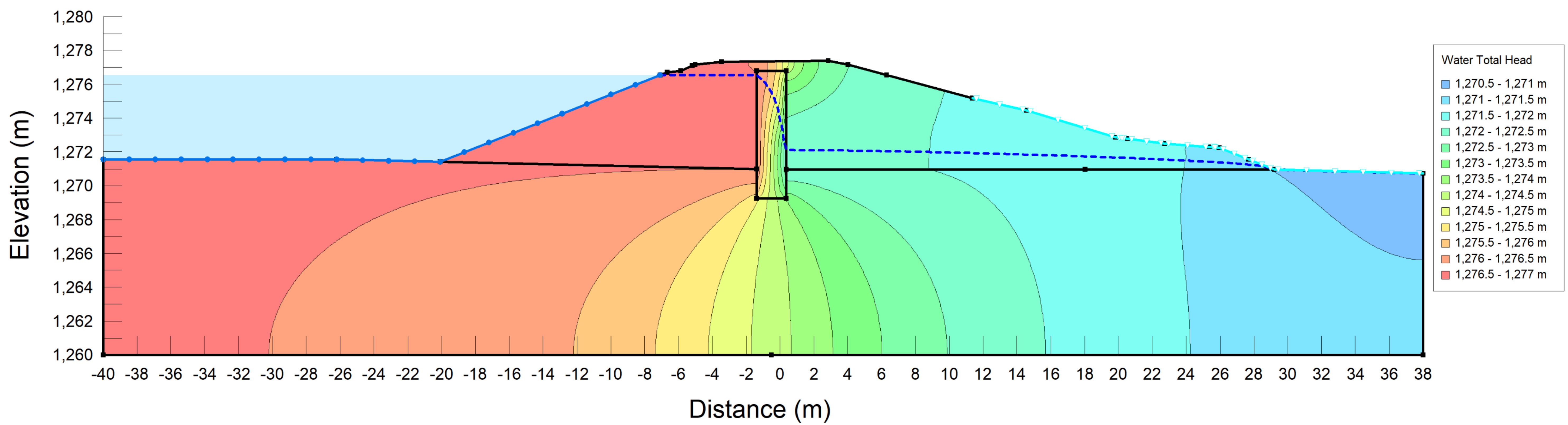
Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
	SU - Clay Core	Saturated / Unsaturated	Generic	Clay/Silt, Ksat = 2.5e-08 m/s	1	0
	SU - Foundation - Sandy Till	Saturated / Unsaturated	Generic	ND - Foundation Sandy Till	1	0
	SU - Shell Fill	Saturated / Unsaturated	Generic	ND - Shell Fill	1	0



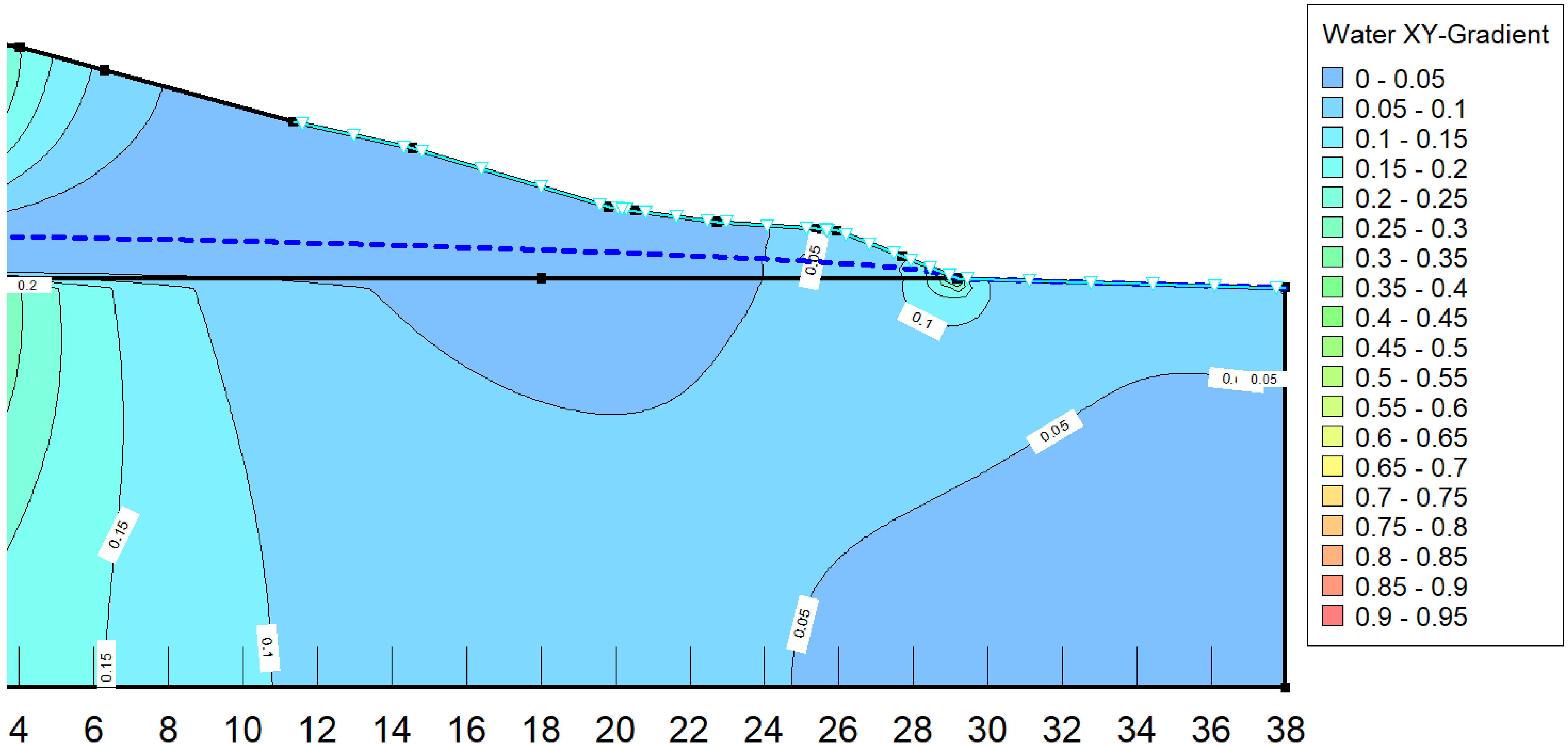
HATCH	Project	Elinor Lake North Dam – Dam Safety Review	
	Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level	
	Analysis By T. Tuo	Output	Steady State Phreatic Surface
	Date 11/01/2021	Report No.	H362819

Color	Name	Category	Kind	Parameters
	1- US Head : FSL 1276.55 m	Hydraulic	Water Total Head	1,276.55 m
	3-Potential Seepage face	Hydraulic	Water Flux	0 m/sec

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
	SU - Clay Core	Saturated / Unsaturated	Generic	Clay/Silt, Ksat = 2.5e-08 m/s	1	0
	SU - Foundation - Sandy Till	Saturated / Unsaturated	Generic	ND - Foundation Sandy Till	1	0
	SU - Shell Fill	Saturated / Unsaturated	Generic	ND - Shell Fill	1	0



HATCH	Project	Elinor Lake North Dam – Dam Safety Review	
	Analysis Description	Seepage Analysis: Steady State Condition – Full Supply Level	
	Analysis By T. Tuo	Output	Water Total Head (m)
	Date 11/01/2021	Report No.	H362819

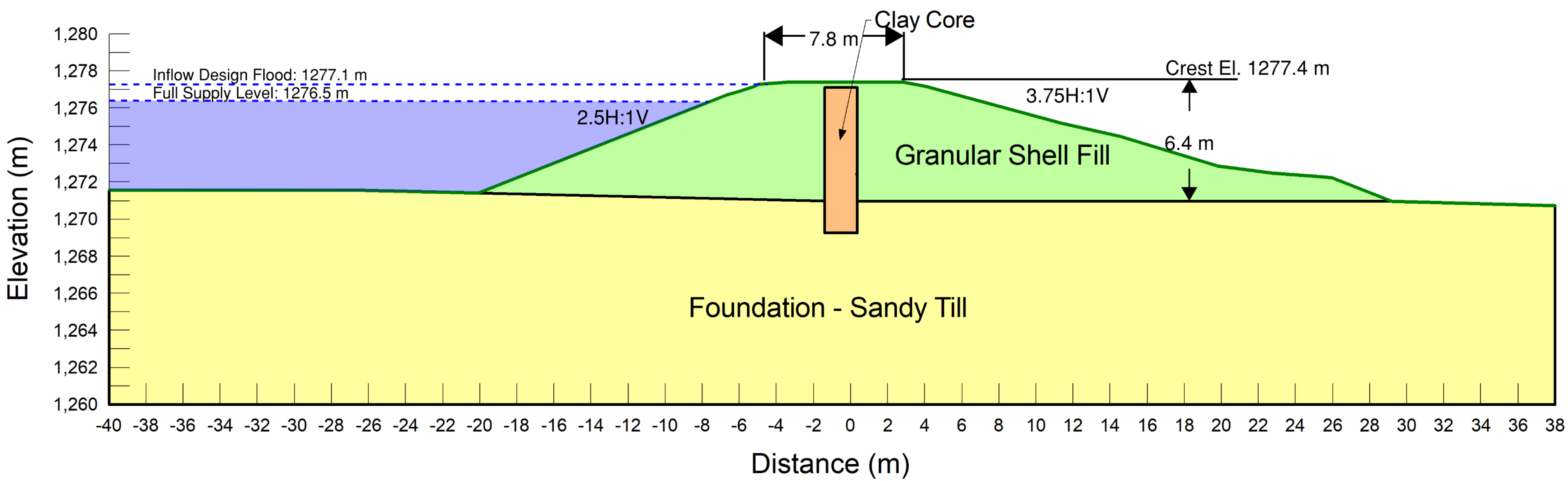


HATCH

Project	**Elinor Lake North Dam – Dam Safety Review**
Analysis Description	**Seepage Analysis: Steady State Condition – Full Supply Level**
Analysis By	T. Tuo
Output	Toe Exit Gradients
Date	11/01/2021
Report No.	H362819

Appendix D
Slope Stability Analysis Results

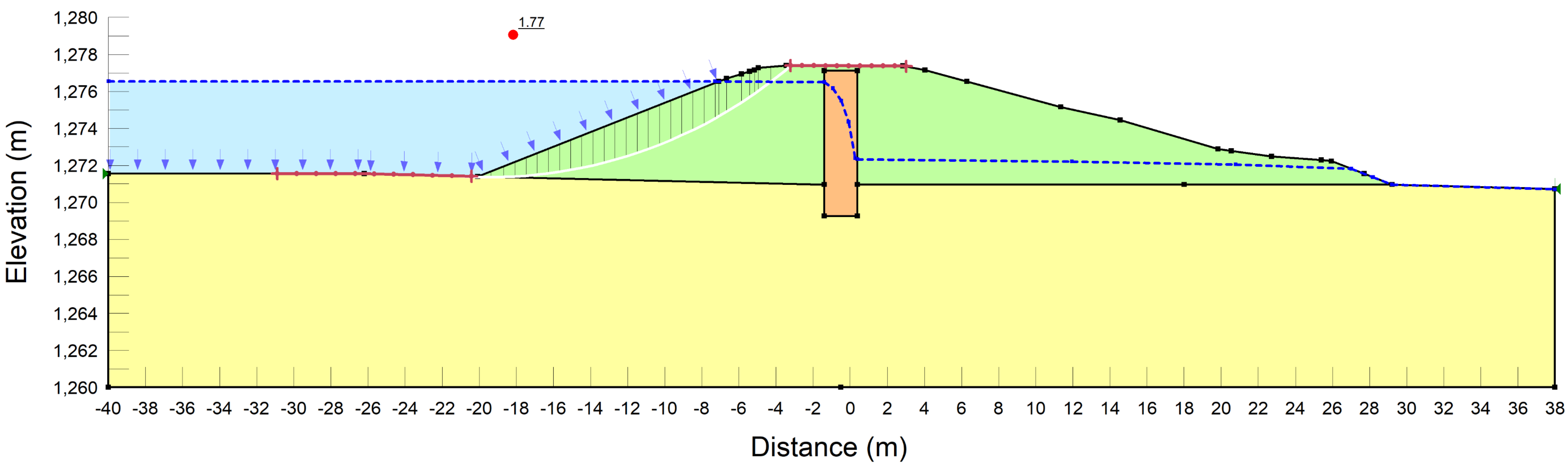
Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH

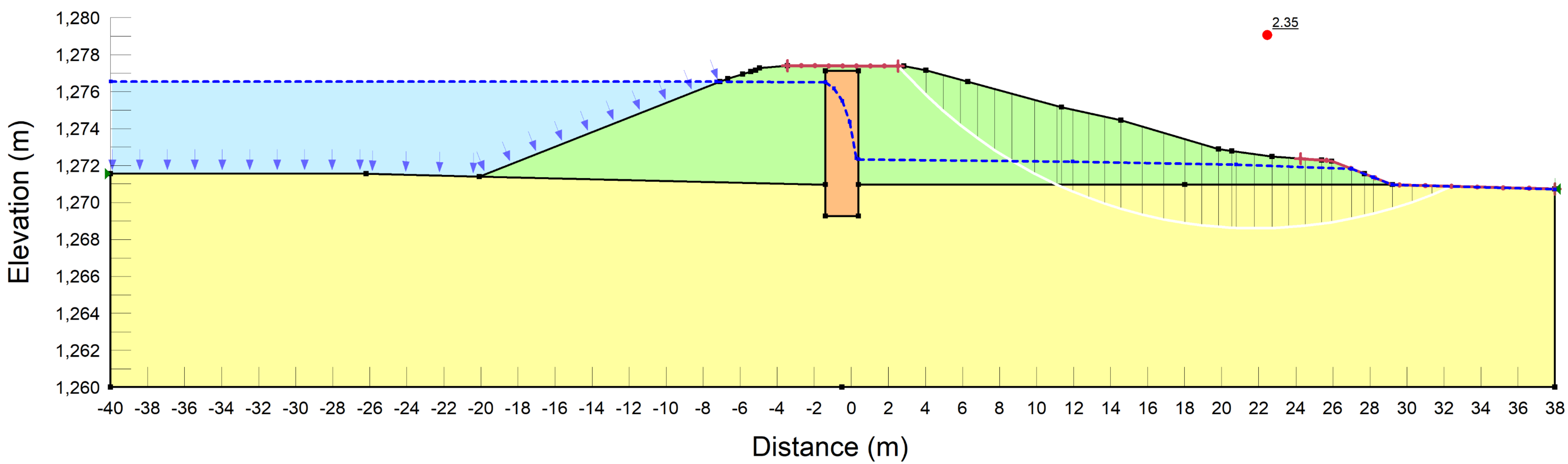
Project	Elinor Lake North Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis – Model Geometry		
Analysis By	T. Tuo	Output	Model Geometry
Date	11/01/2021	Report No.	H362819

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH	Project	Elinor Lake North Dam – Dam Safety Review	
	Analysis Description	Slope Stability Analysis: LC-1 – Normal Load Condition – Full Supply Level	
	Analysis By: T. Tuo	Slope	Upstream
	Date: 11/01/2021	Report No.	H362819

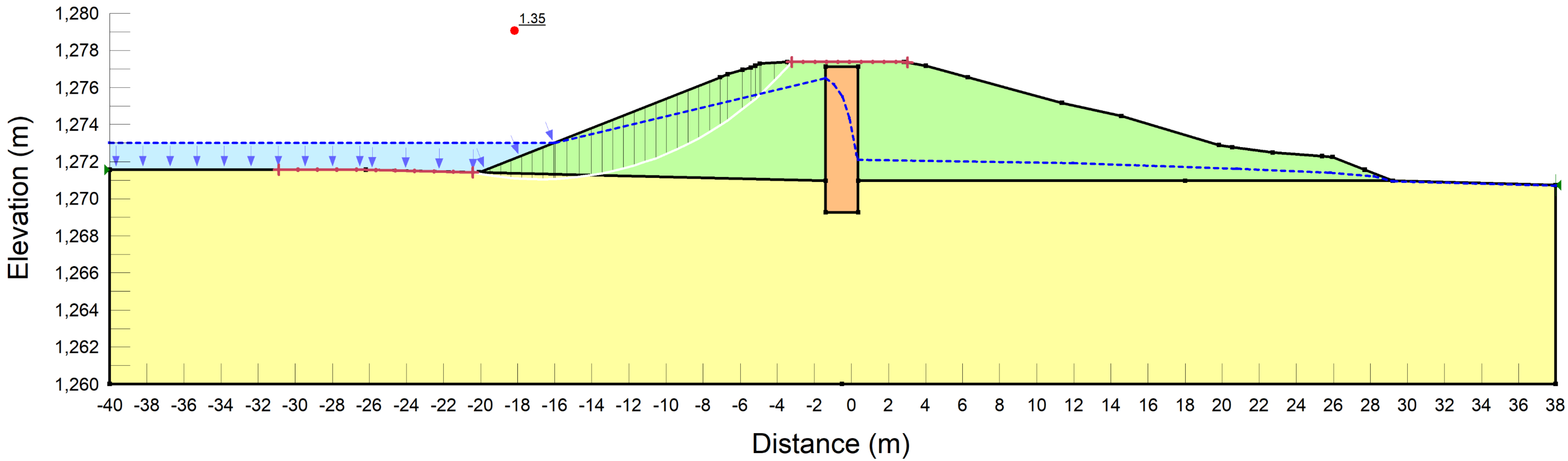
Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH

Project	Elinor Lake North Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis: LC-1 – Normal Load Condition – Full Supply Level		
Analysis By	T. Tuo	Slope	Downstream
Date	11/01/2021	Report No.	H362819

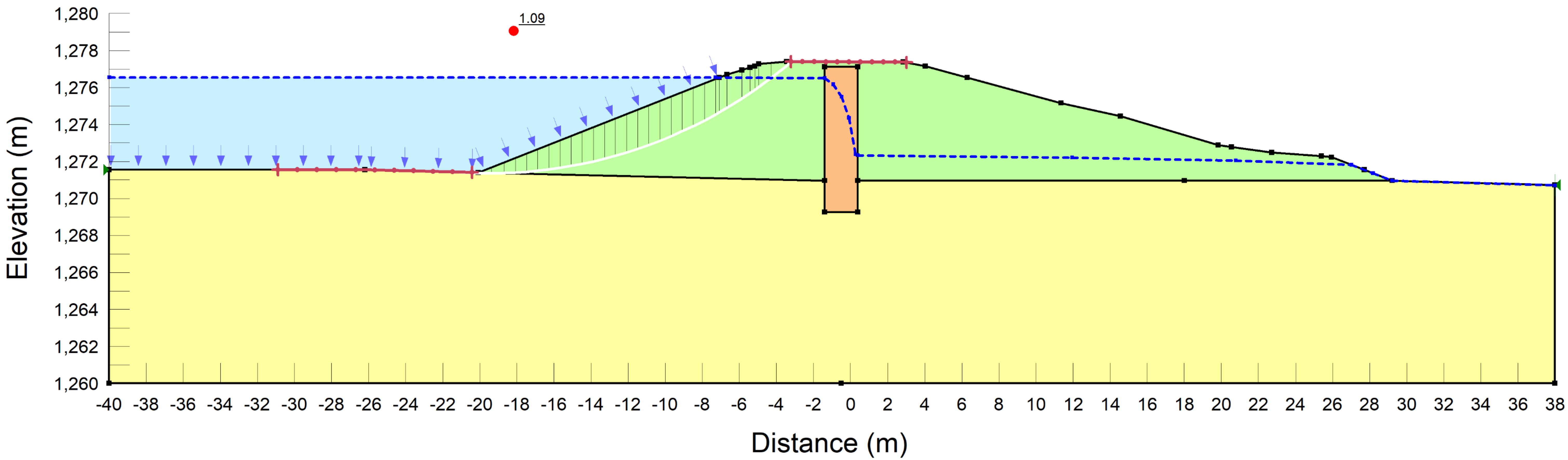
Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH

Project	Elinor Lake North Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis: LC-3 – Rapid Draw Down – From Full Supply Level		
Analysis By	T Singh	Slope	Upstream
Date	11/01/2021	Report No.	H362819

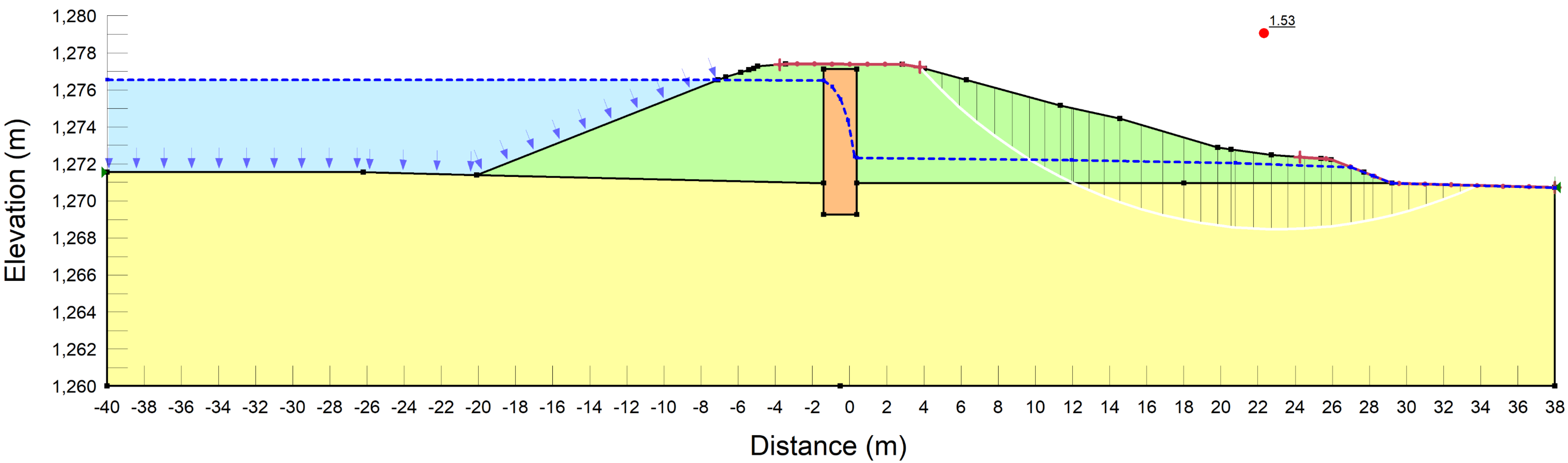
Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH

Project	Elinor Lake North Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis: LC-4 – Seismic Condition – Full Supply Level		
Analysis By	T Singh	Slope	Upstream
Date	11/01/2021	Report No.	H362819

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Clay Core	Mohr-Coulomb	18	0	28	0	1
	Foundation - Sandy Till	Mohr-Coulomb	21	0	32	0	1
	Shell Fill	Mohr-Coulomb	20	0	33	0	1



HATCH

Project	Elinor Lake North Dam – Dam Safety Review		
Analysis Description	Slope Stability Analysis: LC-4 – Seismic Condition – Full Supply Level		
Analysis By	T. Tuo	Slope	Downstream
Date	11/01/2021	Report No.	H362819

Appendix E
Dam Safety Review Assurance Statement

Dam Safety Review Assurance Statement

Note: This statement is to be read and completed in conjunction with the current APEGBC Professional Practice Guidelines – Legislated Dam Safety Reviews in British Columbia, ("APEGBC 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: February 25, 2021

Regional District of Okanagan-Similkameen

Name

101 Martin Street, Penticton, BC, V2A 5J9

Address

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

For the dam:

UTM (Location):	Elinor Lake North Dam:49.6710 North, 119.5345 West
Located at (Description):	North to south trending valley, approximately 9.2 km to the northeast of the Naramata Township.
Name of dam or description:	Elinor Lake North Dam
Provincial dam number:	Elinor Lake North Dam:
Dam function:	Maintaining essential creek flows, emergency backup supply of water and supplying irrigation water to agricultural lands
Owned by: (the "Dam")	Regional District of Okanagan-Similkameen

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.

I have signed, sealed and dated the attached dam safety review report on the Dam in accordance with the APEGBC 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 and the Dam Emergency Plan (DEP).
✓ 8. Confirmed proper functioning of flow control equipment.
✓ 9. After the above, reassess the consequence classification, including the identification of required dam safety criteria.
✓ 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

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 set out in section(s) __12__ 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.

Name: David Bonin P.Eng. (Dam Safety/Hydrotechnical)
Shayla Murphy P.Eng. (Hydrotechnical)
Parham Ashayer P.Eng. (Geotechnical)
Amit Pashan P.Eng. (Structural)

Date: February 25, 2021

Signatures: ____________________
Shayla Murphy
____
P. Ashayer
____
____

PROFESSIONAL PROVINCE OF D. V. BONIN # 42966 BRITISH COLUMBIA ENGINEER
2021-02-26

Shayla Murphy
Feb. 26, 2021
PROFESSIONAL PROVINCE OF S. J. MURPHY # 48322 BRITISH COLUMBIA ENGINEER

PROFESSIONAL PROVINCE OF A. PASHAN # 33146 BRITISH COLUMBIA ENGINEER
2021-02-26

PROFESSIONAL PROVINCE OF P. ASHAYER # 43014 BRITISH COLUMBIA ENGINEER
P. Ashayer
2021-02-26

Address: 1066 W Hastings St., Suite 400,
Vancouver, BC, V6E 3X2

Telephone: (604) 689-5767

(Affix Professional Seals here)

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

I am a member of the firm ______Hatch Ltd.______
and I sign this letter on behalf of the firm. (Print name of firm)